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EVALUATION OF PHYSIOLOGICAL PROCESSES IN SOME POTATO GENOTYPES CULTIVATED ON SANDY SOILS IN SOUTHERN OLTENIA

Alina-Nicoleta PARASCHIV[1], Aurelia DIACONU[1], Gheorghe COTEȚ[1], Ștefan NANU[1], Floriana Maria ȘTEFAN[2], Cristina BÎRSOGHE[1]

[1]Research Development Station for Plant Culture on Sands Dăbuleni, 217 Petre Baniţă Street, Călăraşi, Dolj County, Romania
[2]National Institute for Research and Development for Potato and Sugar Beet Braşov, 2 Fundăturii Street, Braşov, Romania

Corresponding author email: alina22paraschiv@yahoo.com

Abstract

This study presents the research conducted at the Dăbuleni Research and Development Station for Plant Culture on Sands, which aimed at monitoring the physiological reactions of 11 potato genotypes, in order to determine their tolerance to the thermo-hydric stress characteristic of the sandy soil area in southern Oltenia. At an air temperature between 33.4-35.07°C and a very strong solar radiation, between 1800-2090 µmol/m²/s, the photosynthesis rate ranged between 6.08 µmol CO²/m²/s for the TS 12-1489-1576 genotype and 15.46 µmol CO²/m²/s for the 22-1941/8 genotype. Calculating the water use efficiency, as the ratio between the photosynthesis rate and transpiration (µmol / mmol), in all experimental variants supraunitary values were obtained, which demonstrates that the plants efficiently used the water lost through transpiration. From this point of view, the genotypes TS 09-1441-1525, TS 12-1489-1576 and TS 16-1527-1867 were highlighted. Between stomatal conductance and the physiological processes of photosynthesis and foliar transpiration, statistically significant correlations were established.

***Key words**: photosynthesis, transpiration, climate, potato, sandy soils.*

INTRODUCTION

Potato, *Solanum tuberosum* (L.) is a plant species of the *Solanaceae* family and one of the top four widely cultivated crops in the world (Islam et al., 2024). The appeal of potatoes lies in their nutritional content and high production rate per unit time and area, making them particularly valuable in underdeveloped countries (Islam et al., 2022). In addition to being a staple food, potatoes are widely used in various industries to produce a diverse range of products. Furthermore, its wide range of applications, including food, alcohol, starch-based products, and raw materials, have made it quite popular in industrialized countries (Awasthi and Verma, 2017). Due to the vital importance of the potato, it is imperative to increase potato production. On the other hand, its production potential is often reduced due to its high susceptibility to numerous disease invasions, including various soil-borne pathogens and viruses (Awasthi and Verma, 2017; Chakrabarti et al., 2022). Such infestations increase the use of fungicides or insecticides for disease management, which reduces the profit margins of the growers (Islam et al., 2018). In addition to biotic pressures, abiotic factors such as drought, too low or too high temperatures, and salinity have caused challenges for producers during potato cultivation (Kikuchi et al., 2015). Therefore, both biotic and abiotic factors play a major role as stressors for potato cultivation. Potato tuber production is dramatically reduced under adverse environmental conditions. Due to abiotic stress, total production losses are expected to reach up to 32% by 2050. High temperatures and drought influence all biosynthetic processes in plants, but especially photosynthesis. In the case of plants exposed to moderate stress, which acclimatize, the synthesis of numerous proteins and enzymes occurs, allowing these plants to withstand the action of a more pronounced thermohydric stress. The optimal temperature for the photosynthesis process in potato plants is approximately 20°C according to Ku et al. (1977) and 30°C according to Hodson and Bryant (2012). The increase in temperature

determines the inhibition of the photosynthesis process and the stimulation of the respiration process, so that the intensity of the two processes can become equal, and the plants can no longer accumulate reserve substances (Burzo, 2014). Researchers and farmers alike are interested in measurements of photosynthesis intensity as a reaction of plants to applied technology, but also as a method of monitoring crop health or as a result of the effects of climate change.
At the Research Development Station for Plant Culture on Sands Dabuleni (RDSPCS) the research undertaken aimed at monitoring the physiological reactions of 11 potato genotypes, studied on different vegetation phenophases, in order to determine their tolerance to the thermo-hydric stress characteristic of the sandy soil area in southern Romania.

MATERIALS AND METHODS

Within the framework of the ADER 5.1.1 project Research on the impact of climate change on potato cultivation in traditional areas in order to reconfigure optimal cultivation areas in accordance with the EU "Green Deal" strategy and to identify and model the new potato ideotype with tolerance/resistance to climate change, an experimental field with biological material at different stages of the genetic improvement process, namely 11 potato genotypes (Figure 1), was established at RDSPCS Dabuleni in the spring of 2024.

Potato genotypes studied:
1. TS 09-1441-1525
2. TS 16-1515-1856
3. TS 16-1527-1867
4. TS 16-1526-1883
5. TS 12-1489-1576
6. Redsec (Control 1)
7. 1901/12
8. 1895/4
9. 1927/1
10. 22-1941/8
11. Ervant (Control 2)

Figure 1. Potato genotypes studied

In order to ensure early harvest, the tuber sprouting work was carried out one month before planting in the field. Thus, by planting the sprouted tubers, conditions were ensured for harvesting the tubers in June, thus avoiding the crop being subjected to the drought and heat periods in July-August characteristic of the southern area of Romania. Planting was carried out on February 22, 2024, semi-mechanized, consisting of opening the trenches mechanically, planting the sprouted tubers manually and then covering the trenches mechanically. The distance between the rows was 70 cm, and between the tubers in a row was 25 cm, achieving a planting density of about 57,000 plants/ha. The experiment was located in randomized blocks, in three repetitions. Since the natural fertility of the sandy soils in Oltenia is very low, before planting, it was fertilized with complex NPK fertilizer 15:15:15 at a dose of 100 kg a.s./ha, incorporated into the soil by a pass with a disc harrow, followed by a phased fertilization with ammonium nitrate 100 kg a.s./ha, approximately one week after the potatoes emerged.
From a physiological point of view, the processes of photosynthesis, transpiration and stomatal conductance were analyzed using the portable LC Pro SD system. With the help of this device, the gas exchange between plants and the environment was analyzed with the broad leaf chamber, during the period between the appearance of flower buds and the maximum flowering period of potato plants. LC Pro SD is an analysis system that can be easily used both in field and laboratory conditions, presenting the advantage that it has no negative effect on the analyzed plants, being non-destructive.

RESULTS AND DISCUSSIONS

Numerous specialists have followed the effects of thermal stress on horticultural plants. Thus, the limit temperature at which photosystem II in potato plants was irreversibly impaired is 38°C (Havaux, 1993). But plants that were exposed to a temperature of 40°C did not suffer obvious impairments in the activity of photosystem II, if they were acclimatized to temperatures between 30 and 35°C.
Tables 1-3 present the average results obtained at RDSPCS Dabuleni during the vegetation period between the appearance of the flower bud and the full flowering of the potato. The

intensity of the photosynthesis process of potato genotypes grown on sandy soils from Dabuleni (Table 1) varied depending on the genotype and their degree of adaptability to high thermal stress.

At an air temperature ranging between 33.4-35.07°C and a very strong solar radiation, ranging between 1800-2090 μmol/m²/s, the photosynthesis rate ranged between 6.08 μmol CO_2/m²/s for the *TS 12-1489-1576* genotype and 15.46 μmol CO_2/m²/s for the *22-1941/8* genotype.

As can be seen in Table 1, the results are presented in comparison with 2 controls, the *Redsec* and *Ervant* varieties. If we refer to the *Redsec* variety, a variety created at the Târgu Secuiesc Potato Research and Development Station, most of the genotypes analyzed recorded statistically significant negative differences, their photosynthetic capacity under heat stress conditions being much lower than that of the *Redsec* control variety. However, comparing the results obtained with the average values of the *Ervant* variety (control 2) created at the Research and Development National Institute for Potato and Sugar Beet Brașov, it was found that 8 of the genotypes differentiated positively, with values statistically assured as being distinctly significant and very significant. The genotypes *1927/1* and *22-1941/8* were noted to have increased tolerance to thermal stress.

Table 1. Photosynthesis rate in potatoes grown on sandy soils in Dăbuleni - 2024

Genotypes	Photosynthesis (μmol CO_2/m²/s)						
	Average value	Compared to *Redsec* (Control 1)			Compared to *Ervant* (Control 2)		
		Relative	Difference	Significance	Relative	Difference	Significance
TS 09-1441-1525	10.67	70.43	-4.48	ooo	140.95	3.10	**
TS 16-1515-1856	11.64	76.85	-3.51	oo	153.81	4.07	***
TS 16-1527-1867	10.96	72.34	-4.19	ooo	144.78	3.39	**
TS 16-1526-1883	12.08	79.76	-3.07	oo	159.62	4.51	***
TS 12-1489-1576	6.08	40.11	-9.07	ooo	80.27	-1.49	ns
Redsec (control 1)	15.15	100.00	0.00	Control 1	200.13	7.58	***
1901/12	9.34	61.65	-5.81	ooo	123.38	1.77	ns
1895/4	11.55	76.24	-3.60	oo	152.58	3.98	**
1927/1	15.19	100.26	0.04	ns	200.66	7.62	***
22-1941/8	15.46	102.02	0.31	ns	204.18	7.89	***
Ervant (control 2)	7.57	49.97	-7.58	ooo	100.00	0.00	Control 2
DL		5% = 2.21		1% = 3.00		0.01% = 4.07	

The transpiration process, dependent on both the temperature level and the water content of the soil and the plant, took place with an intensity directly proportional to the photosynthesis rate (Table 2). The average values of this physiological process ranged between 0.74 mmol H_2O/m²/s for the *TS 12-1489-1576* genotype and 3.96 mmol H_2O/m²/s for the *22-1941/8* genotype. The genotypes *1927/1* and *22-1941/8* transpired the most intensely, for which positive, statistically significant differences were recorded, both in comparison with the *Redsec* variety and the *Ervant* variety. Calculating water use efficiency, as the ratio between the rate of gross photosynthesis and transpiration (μmol / mmol), in all experimental variants supra-unitary values were obtained, which demonstrates that the plants efficiently used the water lost through transpiration. From this point of view, the genotypes TS 09-1441-1525, TS 12-1489-1576 and TS 16-1527-1867 were highlighted.

Table 2. Transpiration rate of potatoes grown on sandy soils in Dăbuleni - 2024

Genotypes	Transpiration (mmol $H_2O/m^2/s$)						
	Average value	Compared to *Redsec* (Control 1)			Compared to *Ervant* (Control 2)		
		Relative	Difference	Significance	Relative	Difference	Significance
TS 09-1441-1525	1.12	36.12	-1.99	ooo	68.92	-0.51	ooo
TS 16-1515-1856	1.67	53.80	-1.44	ooo	102.66	0.04	ns
TS 16-1527-1867	1.54	49.52	-1.57	ooo	94.48	-0.09	ns
TS 16-1526-1883	2.24	72.03	-0.87	ooo	137.42	0.61	***
TS 12-1489-1576	0.74	23.90	-2.37	ooo	45.60	-0.89	ooo
Redsec (control 1)	3.11	100.00	0.00	Control 1	190.80	1.48	***
1901/12	1.55	49.84	-1.56	ooo	95.09	-0.08	ns
1895/4	2.02	65.06	-1.09	ooo	124.13	0.39	***
1927/1	3.33	107.07	0.22	*	204.29	1.70	***
22-1941/8	3.96	127.44	0.85	***	243.15	2.33	***
Ervant (control 2)	1.63	52.41	-1.48	ooo	100.00	0.00	Control 2
DL		5% = 0.17		1% = 0.24		0.01% = 0.32	

Table 3. Stomatal conductance in potatoes grown on sandy soils from Dăbuleni - 2024

Genotypes	Stomatal conductance ($mol/m^2/s$)						
	Average value	Compared to Redsec (control 1)			Compared to Ervant (control 2)		
		Relative	Difference	Significance	Relative	Difference	Significance
TS 09-1441-1525	0.063	52.78	-0.057	ooo	134.75	0.016	***
TS 16-1515-1856	0.080	66.67	-0.040	ooo	170.21	0.033	***
TS 16-1527-1867	0.060	50.00	-0.060	ooo	127.66	0.013	***
TS 16-1526-1883	0.083	69.44	-0.037	ooo	177.30	0.036	***
TS 12-1489-1576	0.020	16.67	-0.100	ooo	42.55	-0.027	ooo
Redsec (control 1)	0.120	100.00	0.000	Control 1	255.32	0.073	***
1901/12	0.050	41.67	-0.070	ooo	106.38	0.003	ns
1895/4	0.070	58.33	-0.050	ooo	148.94	0.023	***
1927/1	0.127	105.56	0.007	*	269.50	0.080	***
22-1941/8	0.167	138.89	0.047	***	354.61	0.120	***
Ervant (control 2)	0.047	38.89	-0.073	ooo	99.29	0.000	Control 2
DL		5% = 0.007		1% = 0.009		0.01% = 0.013	

A particularly important role in determining the intensity of physiological processes in leaves is played by stomata, the degree of their opening being in close correlation with environmental factors (especially light and temperature). The higher the values of stomatal conductance, the more intense the gas exchange between plants and the environment. In periods of very high temperatures and extremely strong solar radiation, plants defend themselves by closing the stomatal ostioles, which also determines the reduction of the intensity of physiological activity in leaves. Under conditions of thermal stress, stomatal conductance recorded average values ranging between 0.020 mol/m²/s at *TS 12-1489-1576* and 0.167 mol/m²/s at *22-1941/8* genotype (Table 3).

Statistically significant correlations were established between stomatal conductance and the physiological processes of photosynthesis and foliar transpiration (Figure 2). The higher the stomatal conductance values, the more the two physiological processes analyzed were intensified.

The increase in temperature is also accompanied by an increase in the intensity of solar radiation, which can exceed the saturation degree of the photoreceptor antennas. Under these conditions, the activity of the oxygen-producing complex is affected and the photoreceptor activity of photosystem II decreases, which determines the inhibition of photosynthesis and the generation of the photoinhibition process. This can be seen in Figure 3, which illustrates the negative correlations established between the solar radiation active in photosynthesis and the two processes analyzed. Both photosynthesis and foliar transpiration intensified up to solar radiation values of 1900 μmol/m²/s, after which a reduction in the intensity of physiological activity is observed, with potato plants activating their natural defense mechanisms against thermal stress (hydropassive closure of stomata and photoinhibition).

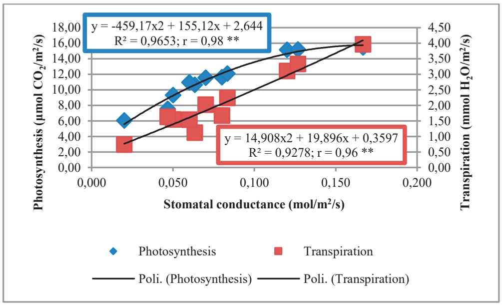

Figure 2. Correlations between stomatal conductance, photosynthesis and transpiration in potatoes

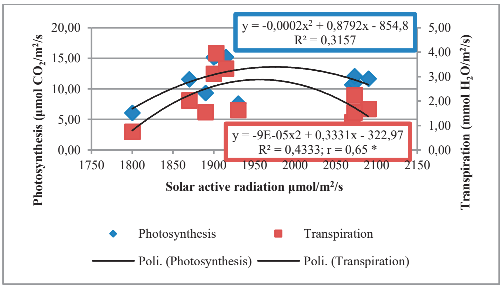

Figure 3. Correlations between solar radiation, photosynthesis and transpiration in potatoes

CONCLUSIONS

To determine the suitability of certain potato genotypes for cultivation on sandy soils, it is necessary to study their behavior over several years.

The partial results obtained highlighted differences depending on the genetic potential and tolerance of each genotype to thermo-hydric stress, from this point of view the genotypes *1927/1* and *22-1941/8* stand out.

Climate change will probably further aggravate the productivity of potatoes by intensifying the exposure of potato plants to these stress conditions. Therefore, there is an urgent need to adapt to the new challenges generated by climate change, improving the adaptability of potato plants to environmental stress and obtaining new varieties, tolerant to heat, drought, phytopathogenic stresses, being the most important and challenging objectives.

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