ANNALS OF THE UNIVERSITY OF CRAIOVA

Series: ✓ *Biology*
✓ *Horticulture*
✓ *Food products processing technology*
✓ *Environmental engineering*

Vol. XXX (LXVI) - 2025

PRELIMINARY STUDIES ON THE PHYSIOLOGICAL CHANGES INDUCED BY THERMAL AND WATER STRESS IN SWEET POTATO GROWN IN SOUTHWEST ROMANIA

Paraschiv Alina-Nicoleta[1], Bîrsoghe Cristina[1], Coteț Gheorghe[1]*, Diaconu Aurelia[1], Nanu Ștefan[1], Drăghici Reta[1]

[1] Research and Development Station for Plant Culture on Dăbuleni Sands, 217 Petre Baniță street, Dolj County, Romania, 207170, phone: 0040251334402, ccdcpn.dabuleni@asas.ro, office@scdcpndabuleni.ro

* *Correspondence author. E-mail*: georgecotet@yahoo.ro

Keywords: *sweet potato, photosynthesis, transpiration, sandy soils, stress factors*

ABSTRACT

This scientific paper presents the results of a study carried out at Dăbuleni Research-Development Station for Plant Culture on Sands, in 2023, regarding the physiological changes in sweet potato plants grown in Southwest Romania, on sandy soils and in different irrigation regimes. In the phenophase of intense growth of tuberous roots, determinations were made regarding the rate of photosynthesis, transpiration and stomatal conductance in correlation with air temperature and solar radiation. Dabu 23 variety recorded the highest values for all the indices studied and the most sensitive variety to heat and water stress was found to be Ro-Ch-M.

INTRODUCTION

Sweet potato (*Ipomoea batatas* L.) belonging to the family *Convolvulaceae* is an important tuber crop widely grown in the tropics, subtropics and warm-temperate regions of the world. Besides being rich in starch, the tubers are good source of vitamin C, B2, B6 and E as well as dietary fibre and minerals like K, Cu, Mn and Fe. The high nutrient content coupled with its anticarcinogenic and cardiovascular disease preventing properties has gained recognition for the crop as a health food. The orange-fleshed sweet potatoes are an important source of β-carotene which is the major provitamin A carotenoid (Chassy et al. 2008), while purple-fleshed sweet potato varieties are rich in anthocyanins and other polyphenolic components (Teow et al. 2007; Steed & Truong 2008). The level of β-carotene and anthocyanin in sweet potato is as high as in carrot juice and pumpkin (Woolfe 1992; Steed & Truong 2008). Plants of sweet potato are considered as the most efficient converters of solar energy, producing 240 x 10^3 cal. ha^{-1} day^{-1} as compared to 176 x 10^3 cal. ha^{-1} day^{-1} for rice,110 x 10^3 cal. ha^{-1} day^{-1} for wheat and 200 x 10^3 cal. ha^{-1} day^{-1} for maize (Kumari Swadija et al. 2016).

Drought or moisture deficit is a major environmental stress condition which limits crop production. Drought stress can be managed by identifying varieties with high yield under drought condition and by giving supplementary irrigation during drought period. Allocation of water for irrigation is a big challenge in the context of surging population and current climate change (Kumari Swadija et al. 2016)

Although sweet potato is tolerant to long periods of drought, root yield and quality may be compromised. It requires 500 mm water for 16–20 weeks' growth period (Ravi 2000), and an annual rainfall of 750–1,000 mm is considered the best (Nair 2000). It can tolerate considerable periods of drought, but yields are very much reduced if water shortage occurs at 10–30 days after planting when tuber initiation takes place. Soil moisture deficiency results in physiological and biochemical changes in the leaves and ultimately results in yield reduction. Under water-deficit stress, the leaf total chlorophyll content, relative water content and nitrate reductase activity decrease (Indira 1989; Indira & Kabeerathumma 1988, 1990; Naskar & Chowdhury 1995). The leaf water potential reduction causes increase in stomatal resistance to CO_2 exchange (Indira and Kabeerathumma 1988, 1990) causing reduction in net photosynthetic rate (Ravi & Indira 1996). The water condition in the soil and the plant strongly affects stomatal movement, causing a large change in leaf net photosynthetic rate (Chaves 1991). The effect of ageing on leaf photosynthesis varies with soil water content, and effect of ageing and water content vary with cultivars. Tuber yield is affected by amount, timing and distribution of water. Tuber yield decreases under water-deficit stress particularly when the available soil moisture decreases below 20 % (Indira & Kabeerathumma 1988; Nair et al. 1996). The tuber initiation period is the most sensitive stage to water-deficit stress due to its effect on tuber number (Indira & Kabeerathumma 1988; Nair et al. 1996; Ravi & Indira 1996). The drought stress for 20 days during the critical growing stage decreased yield by 15–39 % (Gong & Wang 1990). Water-deficit stress during tuber initiation period induces lignification of tubers and hampers tuber growth as any lignification of developing roots may impair their potential for the lateral thickening associated with carbohydrate storage (Lewthwaite & Triggs 2012). Lignification and reduction in tuber yield are greater in cultivars with weak sink capacity than those with higher sink capacity (Ravi & Indira 1996). The sustainable solution is to develop drought-tolerant/drought-resistant varieties. Variation in the degree of expression of physiological and phenotypic traits depending on severity of drought stress and genotypes (Yang et al. 1991) should be considered for developing drought-tolerant varieties. In this sense, a study was initiated regarding the physiological changes induced by thermal and water stress in sweet potato grown in South-West Romania, in order to promote the most suitable varieties for areas with sandy soils and arid climate.

MATERIAL AND METHODS

The research was carried out in 2023 at the Dabuleni Research Development Station for Plant Culture on Sands on the sweet potato culture studied within a bifactorial experience placed in the field according to the method of subdivided parcels with 2 factors. The study factors were:

A. The amount of water applied through irrigation during the growing season	**B. Variety (Figure 1)**
a_1- 250 m³ water/ha, applied once every 3 days x 37 irrigations = 9250 m³ water/ha	b_1 - *Koretta*
a_2- 250 m³ water/ha, applied once every 5 days x 24 irrigations = 6000 m³ water/ha	b_2 - *Hayanmi*
a_3- 250 m³ water/ha, applied once every 7 days x 19 irrigations = 4750 m³ water/ha	b_3 - *Ro-Ch-M*
	b_4 - *Dabu 23*

Koretta variety

Hayanmi variety

Dabu 23 variety

Ro-Ch-M variety

Figure 1. Factor b - the 4 varieties studied

In the climatic conditions of Romania, the sweet potato is propagated vegetatively, by shoots. Shoots were obtained in a double-walled greenhouse. The substrate for planting was made up of a mixture of black soil, sand and peat, in equal proportions. About 50 days after planting, the shoots obtained in the greenhouse were harvested and transplanted in the experimental field according to the technology of cultivating sweet potatoes on sandy soils (Diaconu et al. 2018, Diaconu et al. 2024). The shoots were planted at a distance of 90 cm between rows and 25-30 cm between plants per row, the land having previously been shaped, mulched with black polyethylene film, under which the drip irrigation system was installed. In the phenophase of intense growth of tuberous roots, determinations were made regarding the rate of photosynthesis, transpiration and stomatal conductance in correlation with air temperature and solar radiation. For this purpose, the LC Pro SD device was used, a non-invasive device for plants, with which all these physiological indices were determined directly in the experimental field, in three repetitions, for each experimental variant 3 distinct plants being analyzed. During the entire vegetation period, meteorological data were also monitored with the help of a weather station provided by the research unit.

RESULTS AND DISCUSSIONS

The Dabuleni Research Development Station for Plant Culture on Sands is located in the vast area of sandy soils (>100,000 ha) located in the southern part of Oltenia, an area generically named `Oltenia's Sahara`. In the current climatic conditions, generated by the changes that have occurred at the global level, the thermal regime of the air in this area has an increasing tendency, especially in the summer months, when the phenomenon of heat often sets in. The sandy soil of the area contributed to the creation of the warm topoclimate of this area through its properties and the way it interacts with solar radiation. The sandy surface heats up quickly and strongly under the influence of solar radiation, and from this, the air also heats up strongly and quickly. The intense summer heat causes a strong and rapid evaporation of water from the surface layers, reducing the available water reserve in the soil and an intense transpiration of the plants, producing their wilting. In this context, it becomes essential to know the physiological response of sweet potato plants to the stressful action of environmental factors, in order to establish the most suitable varieties for areas with sandy soils and arid climate. From a climatic point of view, the year 2023 was very warm, during the sweet potato vegetation period (May-September) the average temperatures being higher than the multiannual averages for the analyzed period. Also, the amount of rainfall was insufficient for the normal growth and development of the sweet potato plants (Table 1).

Table 1

The climatic conditions during the vegetation period of the sweet potato grown on the sandy soils of Dăbuleni

The climatic element	Sweet potato vegetation period				
	May	June	July	August	September
Average temperature (°C)	16.8	21.2	25.4	25.4	21.2
Maximum temperature (°C)	29	37.6	42	41.6	36.5
Minimum temperature (°C)	7.4	11.4	10.2	10.6	9
Rainfall amount (mm)	81.6	81.4	73.6	22.3	46.8
Number of days with rain	16	13	9	7	3
Relative air humidity (%)	66.9	70.6	61.6	55	58.5
Multiannual average temperature (1956-2023), (°C)	16.947	21.544	23.321	22.700	17.986
Multiannual monthly average of rainfall (1956-2023), (mm)	62.672	70.008	54.288	36.547	44.950

During the physiological determinations the active solar radiation in photosynthesis varied between 1900-1960 μmol/m²/s, the ambient temperature was between 39.1 - 40.3 °C and the atmospheric pressure was 1010 hPa. At the level of the analyzed leaves, the temperature reached 41.5 °C. Regarding the influence of the amount of water applied through irrigation on the physiological processes in sweet potato plants, it was found that the application of 250 m^3 water/ha, once every 3 days led to the intensification of both photosynthesis, transpiration and stomatal conductance, with significant differences compared to the control (Table 2).

Table 2

The influence of the amount of water applied through irrigation (A factor) on the physiological processes in sweet potato plants

A factor	Photosynthesis (μmol $CO_2/m^2/s$)	%	The difference from the control	LSD	Significance
a1	16.86	119.47	2.75	5 % = 1.27 1 % = 2.10 0.1 % = 3.92	**
a2	14.83	105.12	0.72		-
a3	14.11	100.00	0.00		(control)
A factor	**Transpirațion (mmol $H_2O/m^2/s$)**	**%**	**The difference from the control**	**LSD**	**Significance**
a1	4.61	107.61	0.33	5 % = 0.20 1 % = 0.33 0.1 % = 0.63	**
a2	4.28	99.98	0.00		-
a3	4.28	100.00	0.00		(control)
A factor	**Stomatal conductance (mol/m^2/s)**	**%**	**The difference from the control**	**LSD**	**Significance**
a1	0.19	109.00	0.016	5 % = 0.012 1 % = 0.020 0.1 % = 0.037	*
a2	0.17	98.58	-0.003		-
a3	0.18	100.00	0.000		(control)

Regarding the influence of the variety on the intensity of physiological processes in sweet potato plants under heat stress conditions, it was found that the control variant, *Dabu 23*, recorded the highest values for all the indices studied (Table 3). The most sensitive variety to heat and water stress was found to be *Ro-Ch-M*.

Table 3

The influence of the variety (B factor) on the physiological processes in sweet potato plants

B factor	Photosynthesis (μmol $CO_2/m^2/s$)	%	The difference from the control	LSD	Significance
Koretta	17.17	93.81	-1.13	5 % = 2.855 1 % = 4.007 0.1 % = 5.657	-
Hayanmi	16.22	88.63	-2.08		-
Ro-Ch-M	9.36	51.17	-8.94		ooo
Dabu 23	18.30	100.00	0.00		(control)
B factor	**Transpirațion (mmol $H_2O/m^2/s$)**	**%**	**The difference from the control**	**LSD**	**Significance**
Koretta	3.00	41.39	-4.25	5 % = 0.27 1 % = 0.38 0.1 % = 0.53	ooo
Hayanmi	4.61	63.61	-2.64		ooo
Ro-Ch-M	2.69	37.11	-4.56		ooo
Dabu 23	7.25	100.00	0.00		(control)

B factor	Stomatal conductance (mol/m²/s)	%	The difference from the control	LSD	Significance
Koretta	0.14	48.43	-0.146	5 % = 0.015 1 % = 0.021 0.1 % = 0.030	ooo
Hayanmi	0.20	71.65	-0.080		ooo
Ro-Ch-M	0.10	35.43	-0.182		ooo
Dabu 23	0.28	100.00	0.000		(control)

Regarding the interaction of AxB factors, it was found that each variety analyzed reacts differently to the same culture conditions, *Dabu 23* being the variety with the most intense physiological activity in almost all experimental variants, regardless of the amount of water applied through irrigation (Table 4).

Photosynthetic rate of sweet potato leaves increased with amount of water applied through irrigation at the *Koretta* and *Ro-Ch-M* varieties, decreased in intensity in the Hayanmi variety with the increase in the amount of water, and in the control variant no significant differences were recorded between the irrigation variants.

Table 4

The influence of the interaction of AxB factors on the physiological processes in sweet potato plants

A x B		Photosynthesis (µmol CO_2/m²/s)	%	The difference from the control	LSD	Significance
a1	Koretta	17.87	90.53	-1.87	5 % = 4.945 1 % = 6.941 0.1 % = 9.799	-
	Hayanmi	11.26	57.05	-8.48		oo
	Ro-Ch-M	18.55	93.95	-1.19		-
	Dabu 23	19.74	100.00	0.00		(control)
a2	Koretta	18.99	89.36	2.02		-
	Hayanmi	15.64	92.14	-1.33		-
	Ro-Ch-M	7.72	45.51	-9.25		oo
	Dabu 23	16.97	100.00	0.00		(control)
a3	Koretta	14.65	80.50	-3.55		-
	Hayanmi	21.76	119.60	3.57		-
	Ro-Ch-M	1.82	10.02	-16.37		ooo
	Dabu 23	18.20	100.00	0.00		(control)
A x B		**Transpirațion (mmol H_2O/m²/s)**	**%**	**The difference from the control**	**LSD**	**Significance**
a1	Koretta	2.67	37.95	-4.36	5 % = 0.47 1 % = 0.65 0.1 % = 0.92	ooo
	Hayanmi	3.12	44.45	-3.90		ooo
	Ro-Ch-M	5.60	79.74	-1.42		ooo
	Dabu 23	7.03	100.00	0.00		(control)
a2	Koretta	3.22	231.81	-4.24		ooo

	Hayanmi	4.63	62.04	-2.83		ooo
	Ro-Ch-M	1.81	24.31	-5.64		ooo
	Dabu 23	7.46	100.00	0.00		(control)
a3	Koretta	3.12	42.91	-4.15		ooo
	Hayanmi	6.08	83.75	-1.18		ooo
	Ro-Ch-M	0.65	8.99	-6.61		ooo
	Dabu 23	7.26	100.00	0.00		(control)
A x B		Stomatal conductance (mol/m²/s)	%	The difference from the control	LSD	Significance
a1	Koretta	0.13	45.23	-0.153	5 % = 0.026 1 % = 0.037 0.1 % = 0.052	ooo
	Hayanmi	0.12	42.85	-0.160		ooo
	Ro-Ch-M	0.24	85.71	-0.040		oo
	Dabu 23	0.28	100.00	0.000		(control)
a2	Koretta	0.15	193.47	-0.143		ooo
	Hayanmi	0.19	65.16	-0.103		ooo
	Ro-Ch-M	0.05	16.85	-0.247		ooo
	Dabu 23	0.30	100.00	0.000		(control)
a3	Koretta	0.13	48.14	-0.140		ooo
	Hayanmi	0.29	108.64	0.023		-
	Ro-Ch-M	0.01	3.70	-0.260		ooo
	Dabu 23	0.27	100	0.000		(control)

The transpiration rate was higher in the *Ro-Ch-M* variety, which proved to be the most sensitive of the 4 varieties studied to water deficit.

Stomatal conductance correlated positively, distinctly significantly with transpiration of sweet potato plants. The degree of stomatal opening is an important indicator of plant response to thermohydric stress. From the results obtained in Dăbuleni in 2023, regarding the variation of stomatal conductance in sweet potato, it was found that the values of this parameter directly influenced leaf transpiration at the 4 varieties analyzed (Table 5).

Table 5

The influence of the interaction of BxA factors on the physiological processes in sweet potato plants

B x A		Photosynthesis (µmol CO_2/m²/s)	%	The difference from the control	LSD	Significance
Koretta	a1	17.87	121.97	3.22	5 % = 4.46 1 % = 6.33 0.1 % = 9.15	-
	a2	18.99	129.62	4.34		-
	a3	14.65	100.00	0.00		(control)

Hayanmi	a1	11.26	51.75	-10.50		°°°
	a2	15.64	71.84	-6.13		°
	a3	21.76	100.00	0.00		(control)
Ro-Ch-M	a1	18.55	1017.18	16.72		***
	a2	7.72	423.58	5.90		*
	a3	1.82	100.00	0.00		(control)
Dabu 23	a1	19.74	108.48	1.54		-
	a2	16.97	93.25	-1.23		-
	a3	18.20	100.00	0.00		(control)
B x A		Transpiration (mmol $H_2O/m^2/s$)	%	The difference from the control	LSD	Significance
Koretta	a1	2.67	85.56	-0.45	5 % = 0.45 1 % = 0.65 0.1 % = 0.97	°
	a2	3.22	103.20	0.10		-
	a3	3.12	100.00	0.00		(control)
Hayanmi	a1	3.12	51.34	-2.96		°°°
	a2	4.63	76.05	-1.46		°°°
	a3	6.08	100.00	0.00		(control)
Ro-Ch-M	a1	5.60	857.65	4.95		***
	a2	1.81	277.55	1.16		***
	a3	0.65	100.00	0.00		(control)
Dabu 23	a1	7.03	96.74	-0.24		-
	a2	7.46	102.66	0.19		-
	a3	7.26	100.00	0.00		(control)
B x A		Stomatal conductance ($mol/m^2/s$)	%	The difference from the control	LSD	Significance
Koretta	a1	0.127	97.43	-0.003	5 % = 0.025 1 % = 0.037 0.1 % = 0.056	-
	a2	0.153	117.94	0.023		-
	a3	0.130	100.00	0.000		(control)
Hayanmi	a1	0.120	40.90	-0.173		°°°
	a2	0.193	65.90	-0.100		°°°
	a3	0.293	100.00	0.000		(control)
Ro-Ch-M	a1	0.240	2400	0.230		***
	a2	0.050	500	0.040		**
	a3	0.010	100	0.000		(control)
Dabu 23	a1	0.280	103.70	0.010		-
	a2	0.297	109.87	0.027		*
	a3	0.270	100.00	0.000		(control)

CONCLUSIONS

Through this study, the physiological potential of each analyzed sweet potato variety was highlighted. The most sensitive variety to the action of thermohydric stress was *Ro-Ch-M*, and the most resistant was the *Hayanmi* variety.

The application of 250 m³ water/ha, once every 3 days led to the intensification of both photosynthesis, transpiration and stomatal conductance, with significant differences compared to the control.

At 40 °C each variety analyzed reacted differently, *Dabu 23* being the variety with the most intense physiological activity in almost all experimental variants, regardless of the amount of water applied through irrigation.

Stomatal conductance directly influenced leaf transpiration at the 4 sweet potato varieties analyzed. Increase in stomatal resistance due to stomatal closure in response to drought stress affected the photosynthetic rate by decreasing the leaf intercellular CO_2 concentration.

ACKNOWLEDGMENT

This work was supported from the Ministry of Agriculture and Rural Development budget through the ADER 5.1.3 research project - *Identification and promotion of technological measures for the higher valorization of the production obtained from sweet potato - Ipomea batatas cultivated in Romania, in order to obtain products rich in nutrients and safe for consumers*, coordinated by Dabuleni Research-Development Station for Plant Culture on Sands.

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