Analele Universităţii din Craiova, seria Agricultură – Montanologie – Cadastru (Annals of the University of Craiova - Agriculture, Montanology, Cadastre Series) Vol. 55/1/2025

CAPITALIZING ON THE PEDOCLIMATIC RESOURCES IN THE SOUTHERN AREA OF OLTENIA THROUGH THE SUNFLOWER CULTURE

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Abstract

The purpose of this study was to monitor the biological potential of sunflower cultivation to capitalize on the pedoclimatic conditions in the sandy soil area of southern Oltenia. The results obtained during 2024-2025 showed that sunflowers capitalized on the microclimate in this area, carrying out all the physiological processes of plant growth and development over a period of about 108,9 days, under conditions in which the air recorded a total thermal resource of 2491°C. Positive correlations were highlighted between the soil humus content and the morphological characteristics of the plant, namely, plant height and leaf area index. The seed production obtained from sunflowers varied within the limits of 3281-4326.5 kg, with a thousand-seed weight of 55.8-66.7 g and a hectoliter weight of about 28.7-34.05 kg/hl. The 0.23% increase in soil humus content led to statistically significant differences in seed production and seed quality indices (thousand-seed weight and oil).

Key words: soil fertility, climate resources, leaf area index, productivity,

INTRODUCTION

Sunflower (*Helianthus annus*) is an important oilseed crop, currently cultivated worldwide, valued for its nutritional and medicinal properties and its significant role in the cooking oil market, owing to its high levels of unsaturated fatty acids (Pal et al., 2015; Amankulova et al., 2023). Sunflower seeds contain 33-56% oil, with high nutritional value, determined by the presence of unsaturated fatty acids, represented mainly through linoleic (44-75%, high content) and oleic (14-43%, medium level) acids, but also by the presence of less than 15% saturated fatty acids (especially palmitic and stearic). This fact gives it stability and long-term preservation capacity (Duca et al., 2011). The pedoclimatic conditions of sandy soils favor the cultivation of heliophilous plants, such as sunflower, given that this species possesses anatomical and physiological adaptations that confer high drought tolerance (Gheorghe et al., 2009; Draghici et al., 2017; Netcu et al., 2023). The drought resistance of the sunflower plant is conferred by its very well-developed root system, which can accumulate water reserves in the stem pith, supporting temporary dehydration of the tissues (Vrînceanu, 2000). Also, through the large number of stomata at the leaf level and through the deep root system, the sunflower has tolerance to thermo-hydric stress in droughty areas (Tabără et al., 2018; Marinică and Dascălu, 1984). The breeding of new varieties resistant to stress factors is a priority for both conventional and modern (biotechnological) breeding (Pacureanu et al., 2007; Vilverta et al., 2018). Research conducted in Arad by Pojar et al. (2023) showed that the sunflower plant's high-water needs occur from the second half of June to the first part of August, and during the period from sunrise to the appearance of the inflorescence, sunflower calatheas consume around 20-25% of the total. Research has shown that under stress conditions, stem height, calathidium diameter, number of leaves/plant, and leaf area are significantly reduced (Fulda et al., 2011; Drăghici et al., 2020). The decrease in sunflower yield is mainly due to biotic and abiotic stress factors, and one of the main problems facing farmers today is the decline in production caused by damage from natural environmental changes (Eisenach, 2019). The results obtained by Marinică and Dascălu (1984), on sunflower grown on sandy soils, showed that prolonged drought, as well as its repeated return during the growing season, has negative repercussions on production; therefore, it is necessary to ensure a water consumption of approximately 1200-2400 m^3/ha. It has been established that by adjusting the sowing time and selecting the optimal sowing density, the growth and development of sunflower plants can be influenced, bypassing critical periods during the growing season (Pinkovskyi and Tanchyk, 2021).

Given recent climate changes and increased drought in June-July, research was initiated to examine sunflower plant behavior under different soil fertility conditions to mitigate the adverse effects of thermohydric stress.

MATERIALS AND METHODS

The research was conducted in 2024-2025 at the Research and Development Station for Plant Culture on Sands in Dăbuleni, located on sandy soils in southern Oltenia, to examine the behavior of sunflower plants in relation to soil fertility. In this regard, the sunflower hybrid *P64LE162* was sown in 3 experimental plots of approximately 1000 m^2 each, differentiated by soil fertility level: Soil 1, Soil 2, Soil 3 (control). Before performing the basic plowing, soil samples were taken at depths of 0-20 cm and 20-40 cm (Table 1), to evaluate the soil fertility status, namely the soil content in total nitrogen (N_{total}), extractable phosphorus (P-AL), exchangeable potassium (K-AL), organic carbon (C_{org}) and the soil reaction in water (pH_{H2O}). The soil samples were recorded and conditioned in the laboratory, using standard methods for determining soil fertility (Croitoru, 2022):

- N_{total} was determined by the Kjeldahl method;
- P-AL was determined by the Egner–Riem Domingo method, in which phosphates are extracted from the soil sample with an ammonium acetate–lactate solution at pH 5.75, and the extracted phosphate anion is determined colorimetrically in the form of molybdenum blue;
- K-AL was determined by the Egner–Riem Domingo method, in which the hydrogen

and ammonium ions of the extraction solution replace the exchangeable potassium ions in the soil sample, which are thus passed into the solution. The potassium concentration in the solution is determined by flame-emission photometry;

- C_{org} was determined by the wet oxidation method and titrimetric dosage (after Walkley – Blak in the Gogoaşă modification);
- pH_{H2O} was determined by the potentiometric method.

Table 1. The sandy soil fertility in the experimental variants in which sunflower was sown

No. experimental version	*Soil depth (cm)*	N_{total} %	P-AL ppm	K-AL ppm	C_{org} %	Humus (C_{org} x 1,724) (%)	pH_{H2O}
Soil 1	*0-20*	0.06	101.98	95.50	0.55	0.95	7.30
	20-40	0.04	89.41	37.00	0.42	0.72	7.20
Average		*0,05*	*95.70*	*66.25*	*0.49*	*0.84*	*7.25*
Soil 2	0-20	0.05	88.60	68.30	0.46	0.79	7.29
	20-40	0.05	77.75	40.90	0.36	0.62	7.26
Average		*0,05*	*83.17*	*54.60*	*0.41*	*0.71*	*7.27*
Soil 3 (Control)	0-20	0.04	78.37	48.17	0.45	0.77	7.23
	20-40	0.04	75.22	35.70	0.27	0.46	7.20
Average		*0,04*	*76.80*	*41.94*	*0.36*	*0.61*	*7.21*
Soil nutrient supply range (Davidescu et. al., 1981)	Poorly stocked	<0.10	8.1 - 18	<66	<0.58	<1	5,01-5,80 Weakly acidic
	Mediumly stocked	0.11-0.15	18.1-36	66.1-132	0.59-1.16	*1.01-2*	5,81-6,8 Moderately acidic
	Well stocked	0.16-0.20	36.1-72	132.1-200	1.17-2.32	*2.01-4*	6,81-7,20 Neutral

During the vegetation of the sunflower plant, observations and determinations were made regarding:
- the progression of the vegetation phenophases and the recording of daily climatic conditions during the vegetation period;
- the biometric properties of the plant in the flowering phase: plant height, stem diameter, calathidium diameter;
- the leaf area was determined in the flowering phase by the following methodology: number of leaves/plant x surface area of a leaf, measured in the laboratory with the AM 300 device x 5.5 plants/m^2.

At maturity, the grain production and its quality (thousand-seed weight, hectoliter weight, and oil content) were determined. The oil content was determined by the spectrophotometric method using the NIR analyzer model INFRAMATIC 9200 from Perten.

The results were analyzed using the analysis of variance (ANOVA) method and mathematical functions.

RESULTS AND DISCUSSIONS

Soil quality assessment

The soil quality analysis, carried out in the spring before the experiment was set up, revealed low natural soil fertility at depths of 0-20 and 20-40 cm (Table 1). Compared to the supply range in the specialized literature (Davidescu et al., 1981), the soil was poorly supplied with nitrogen and organic carbon, moderately supplied with exchangeable potassium, and well supplied with extractable phosphorus, with a neutral to slightly alkaline soil reaction. Of the three soil types on which the experiment was set up, soil no. 1 stood out, with a humus content of 0.84%, followed by soil no. 2 (0.81% humus) and soil no. 3 (0.61% humus).

Evolution of climatic conditions

The climatic conditions recorded during 2024-2025 highlighted an increase in thermohydric stress during the sunflower crop's vegetative cycle (April-August) relative to the multiannual average (Table 2).

Table 2. Climatic conditions recorded during the growing season of sunflower crops

Climatic conditions		April	May	June	July	August	April-August
Air temperature 2024-2025 (°C)	average	13.88	16.39	24.71	26.13	24.93	21,208
	minimum	-3.97	1.53	9.74	10.69	7.53	-3,97
	maximum	34.1	29.87	40.51	41.21	40.95	41,21
Rainfall, 2024-2025 (mm)		28,5	84.7	22	17.1	13.9	166.2
Relative air humidity (%)	Average	64.44	71.75	61.08	56.1	53.82	61,438
	Minimum	10.2	22.18	14.08	13.81	13.07	10,2
	Maximum	100	100	100	100	100	100
Multiannual average temperature (1956-2024) (°C)		11,92	16.95	21.59	23.37	22.75	19.316
Rainfall multiannual average (1956-2024) (mm)		46,97	63.41	69.32	53.83	36.04	269.57
Deviation from multiannual temperature (°C)		1,96	-0.56	3.12	2.76	2.18	1.892
Deviation from multiannual rainfall (mm)		-18,47	21.29	-47.32	-36.73	-22.14	-103.37

Except May, which, compared to the multiannual average, recorded a surplus of precipitation of 21.29 mm and a deficit of thermal resources in the air of -0.56 °C, the other calendar months (April, June, July and August) exceeded the multiannual average by 1.96-3.12 °C in the air and recorded a deficit of precipitation in the range: -18.47...-47.32 mm. These conditions, against the background of low relative air humidity (minimums of 10.02-22.18%), produced a severe drought. Climatic conditions were particularly poor in June-July, during the period of finalization of leaf development and formation of the calathidium-flowering, when maximum air temperatures of 40.51-41.21 °C were recorded, exceeding multiannual averages by 2.76-3.12 °C. The water resource provided by precipitation, of only 166.2 mm, which was about 60% of the multiannual precipitation recorded, was supplemented in the two experimental years by applying six waterings with norms of 250 m^3 water/ha, to ensure the water needs of the sunflower plants during the plant's vegetation period. Creating a favorable microclimate through irrigation is essential on sandy soils because both high air temperatures and soil drought can seriously affect corn yield, and the plant's growth and development can even be blocked under their combined effects (Yan-Yan et al., 2023). Precipitation and atmospheric humidity largely determine sunflower crop productivity, and ensuring adequate water from sowing to flowering is decisive (Veska et al., 2024; Anton et al., 2024). Sunflower is a plant with high water needs in specific vegetation periods, which start from the second half of June to the first part of August, when the plant's transpiration coefficient can be 480-580 (Pojar et al., 2023). In these two months, water consumption represents approximately 65% of the total.

Sunflower plant phenology

The results regarding the monitoring of the onset of vegetation phenophases in the sunflower crop (hybrid *P64LE162*) are presented in Table 3.

Table 3. Calendar recording of the vegetation phenophases of the sunflower crop in the conditions of 2024-2025

Sowing	Emergence	5-6 leaves	Calathidium formation	Flowering >80% of plants	Definitive seed formation	Physiological maturity
10.04.2024	22.04.2024	13.05.2024	05.06.2024	25.06.2024	15.07.2024	18.08.2024
28.04.2025	09.05.2025	26.05.2025	17.06.2025	05.07.2025	21.07.2025	17.08.2025

Analyzing the climatic resources recorded on average over the two years for the completion of these phenophases (Table 4), it can be seen that emergence was achieved after 11.5 days from sowing, under the conditions of recording an average air temperature of 16.0°C, a temperature that was optimal for seed germination, given that the specialized literature mentions a minimum germination temperature of 7-8°C and an optimal germination temperature of 25°C (Ion and Bălașa, 2021). The precipitation regime of 4.0 mm, recorded during this period, correlated with a low relative air humidity, with an average of 62.7% and a minimum of 16.3%, which was insufficient to ensure the emergence of sunflower plants, making it necessary to supplement it with an emergence watering, with a norm of 250 m^3 water/ha.

The specialized literature states that the sunflower is a mesothermal plant, relatively heat-demanding, which, in the conditions of 2024-2025, required about 2491°C accumulated in the air to complete the vegetation period from emergence to maturity.

In the interval from the emergence of the plant to the appearance of the inflorescence, for the sunflower plant to develop normally, the average air temperature must be 15-16°C, and during the flowering and seed formation period, moderate temperatures of 18-24°C are necessary (Bîlteanu et al., 1991; Anton et al., 2023). Compared to data from the specialized literature, the weather data recorded this year revealed that until the calathidium formation phase, the average temperatures of 14.8°C (emergence-5-6 leaves) and 20.4°C (5-6 leaves-calathidium formation) were favorable for normal plant development, but starting from the flowering-seed formation period, the thermal regime was excessive, the daily average during this period being 25.4°C. From emergence to maturity of the sunflower plant, all physiological processes took place over 108.5 days, under conditions of an average air temperature of 22.7°C, and with maximums of 41.1°C and minimum relative humidity of 14.4% in the interval between flowering and seed formation. Except for the period between plant emergence and the formation of 5-6 leaves/plant, when 77.6 mm of rainfall was recorded, rainfall during the other vegetation stages was reduced to 54.6 mm, insufficient for plant growth and development, necessitating irrigation.

Table 4. Monitoring of climatic resources recorded during the growing season of the sunflower crop (average 2024-2025)

Climatic conditions		Sowing-Emergence	Emergence –5-6 leaves	5-6 leaves-Calathidium	Calathidium - Flowering >80%	>80% Flowering – Seed Formation	Seed formation - Physiological maturity	Vegetation period (emergence-maturity)
Number of days		11.5	18.5	22.5	19.0	18.0	30.5	108.5
Total thermal resources (°C)		190.7	280.1	458.3	487.0	458.7	806.9	2491.0
Air temperature (˚C)	Average	16.0	14.8	20.4	25.6	25.4	26.5	22.7
	Minimum	2.5	2.3	9.4	10.5	11.3	12.3	2.3
	Maximum	31.9	28.8	33.5	39.2	40.6	41.1	41.1
Rainfall (mm)		11.5	76.6	18.5	13.6	11.1	11.4	131.2
Relative air humidity (%)	Average	62.7	72.9	68.4	55.8	56.8	54.3	61.4
	Minimum	16.3	22.8	21.4	15.8	14.4	15.2	13.7
	Maximum	99.8	100.0	100.0	100.0	100.0	100.0	100.0

Under these conditions, although irrigation was carried out during the phases of maximum consumption, the high air temperatures and very low relative humidity reduced pollen viability, so that the biological potential of the genotype was not fully realized. Of the total thermal resources of 2491.0°C, recorded during the growing season of the sunflower crop, the most degrees Celsius accumulated in the periods between seed formation and physiological maturity (32.39%).

Morphological and productivity characters

The determinations made at plant flowering regarding plant growth and development revealed differentiated values depending on the fertility level of the experimental soil (Table 5). Thus, the plant recorded heights ranging from 146.5 to 158.1 cm, with an average of 150.58 cm, and stem diameters of 2.21 to 2.44 cm. The humus content had a positive influence on the development of the calathidium, which presented a diameter of 18.54-20.7 cm, and on the leaf area index, which recorded values in the range of 3.74-4.34, the maximum values being recorded in the variant in which the soil had a humus content of 0.84%. The results obtained in this experiment are in correlation with research carried out worldwide, which emphasizes that better fertility of the soil substrate on which the sunflower plant is sown significantly influences deeper root growth, improving nitrogen absorption, so that the plants grow more vigorously and can have a greater productive potential (Wenhao et al., 2024).

The research results showed that soil fertility positively affected the growth and development of sunflower plants.

Table 5. Variability of some morphological characters of the sunflower plant depending on soil fertility

Experimental version		Plant height (cm)	Leaf area index (LAI)	Stem diameter (cm)	Calathidium diameter (cm)
No	Humus content in the soil %				
Soil 1	0.84	158.10	4.34	2.44	20.70
Soil 2	0.71	146.50	3.91	2.21	19.00
Soil 3 (Control)	0.61	147.15	3.74	2.33	18.40
Average		150.58	3.99	2.33	19.37

Thus, the statistical analysis, performed using mathematical functions, highlighted positive correlations between soil humus content and plant height and leaf area index (Figure 1). It has been demonstrated that soil humus has a positive impact on sunflower development, improving soil fertility and ensuring healthier plants and richer harvests by accumulating and releasing nutrients essential for growth (Morad et al., 2020; Abdullah et al., 2023).

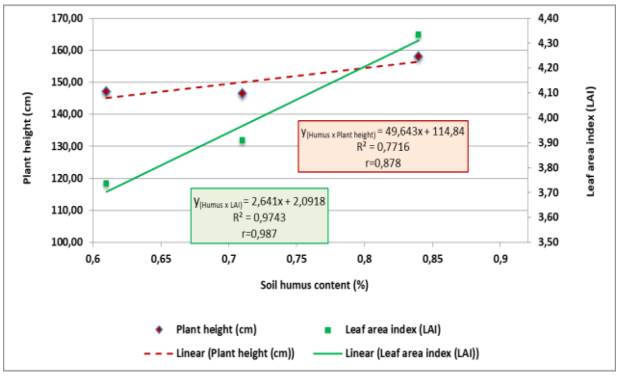

Figure 1. Correlations between soil humus content and height and leaf area index of sunflower plants in the flowering phase

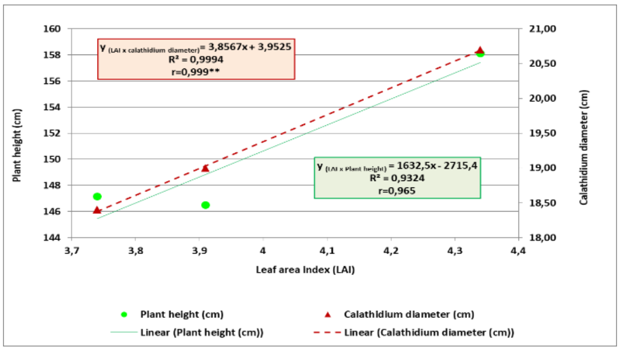

Figure 2. Correlations between leaf area index, plant height, and diameter of the calatidium

Also, the leaf area index was positively correlated with calathidium diameter and plant height (Figure 2), with the correlation between the leaf area index and calathidium diameter being statistically significant (r=0.999**).

Statistical analysis of seed production

The production results for sunflowers ranged from 3281 to 4326.5 kg/ha (Table 6).

Table 6. Results regarding the quantity and quality of seed production recorded in sunflower cultivation, depending on the level of soil fertility

Experimental version		Seed Yield (kg/ha)	Thousand-seed weight (g)	Hectoliter weight (kg/hl)	Oil (%)
No	Humus content in the soil %				
Soil 1	0.84	4326.50**	66.65*	34.05	45.30*
Soil 2	0.71	3820.00*	61.50	31.25	44.65
Soil 3 (Control)	0.61	3281.00	55.80	28.70	42.70
LSD 5%		452.1	7.9	8.98	2.02
LSD 1%		1043.9	18.2	20.75	4.68
LSD 0.1%		3322.1	58.0	66.02	14.88

Growing sunflowers on land with a higher humus content led to the recording of production increases of 539-1045.5 kg/ha, statistically significant and distinctly significant, compared to a soil with lower fertility. In terms of production quality indices, thousand-seed weight (g) (TSG) ranged between 55.8-66.65 g, differing significantly, the Soil 1 variant with 0.84% humus compared to the control (Soil 3), and the hectoliter weight (HW) presented values ranging from 28.7-34.05 kg/hl, not statistically different.

Regarding the oil content of sunflower seeds, it reached a maximum of 45.3% in the Soil 1 variant, with 0.84% humus, significantly higher than in the Soil 3 control (0.51% humus). The results obtained are supported by studies abroad, which show that phenotypic traits, in general, and production components, in particular, such as the diameter of the calathidium, the number of seeds in the calathidium, and the weight of the seeds, significantly improve quality or yield (Abdullah et al., 2023).

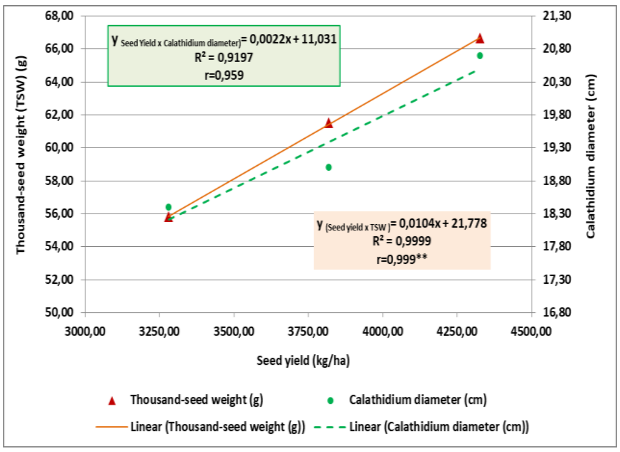

Figure 3. Correlations between seed yield, thousand-seed weight, and calathidium diameter in sunflower

Sunflower seed production was positively influenced by thousand-seed weight (TSW) and leaf area index (LAI), as indicated by statistical analysis using linear regression (Figure 3). Analysis of correlation coefficients showed that seed production was significantly correlated with 1000-seed weight and, though non-significantly, positively correlated with leaf area index.

CONCLUSIONS

The sunflower plant completed all its physiological growth and development over 108.5 days under average air temperatures of 22.7 °C and a total thermal resource of 2491°C.

The determinations carried out during the flowering calathidium phase, revealed values of the plant height ranging between 146.5-158.1 cm, with an average of 150.58 cm, of the stem diameter of 2.21-2.44 cm, a calathidium diameter of 18.54-20.7 cm and a leaf area index of 3.74-4.34, the maximum values being recorded in the variant in which the soil had a humus content of 0.84%.

Positive correlations were observed between soil humus content and the plant morphological characteristics, namely plant height and leaf area index.

The seed production obtained from the sunflower varied between the limits of 3281-4326.5 kg/ha, with a weight of one thousand seeds of 55.8-66.7 g and a hectoliter weight of. 28.7-34.05 kg/hl.

Increasing soil humus content by 0.23% led to statistically significant differences in seed production and seed quality indices (thousand-seed weight, oil).

ACKNOWLEDGEMENTS

This research work was carried out with the support of the Ministry of Agriculture and Rural Development of Romania, financed from ADER 2026, Project No ADER 2.1.1/2023.

REFERENCES

Abdullah, K. N., Jabail, W. A., & Reda Jassim, K. A. (2023). Response genotypes of sunflower (Helianthus annuus L.) and amount of nitrogen fertilizer on growth characteristics, oil yield, and its percentage. *Revista Bionatura*, *8*(2), 25.

Anton, F. G., Contescu, L., Joița-Păcureanu, M., Popa, M., Petcu, V. (2023). Performance of several sunflower hybrids under semicontinental climate of southern Romania. Scientific Papers. Series A. Agronomy, Vol. LXVII, No. 1, 2024ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785.

Bîlteanu, G., Salontai, A., Vasilică, C., Bîrnaure, V., Borcean, I. (1991). Phytotechnics. Didactic and Pedagogical Publishing House, Bucharest.

Croitoru, M. (2021). Plant Chemistry and Biochemistry; Practical laboratory works; Sitech Publishing House: Craiova, Romania, 2021; ISBN 978-606-11-7943-5. Available online: https://www.scdcpndabuleni.ro/wp-content/uploads/Croitoru-M.-2021.- Plant-Chemistry-and-Biochemistry-Laboratory-Notebook.

Davidescu F. și colab., 1981. Agrochimie. Ed. Didactică și Pedagogică. București.

Drăghici, I., Drăghici, R., Croitoru, M. (2020). Utilization of the pedoclimatic potential in the area of sandy soils through sunflower culture. *Annals of the Development Research Station for Plant Culture on Sands Dabuleni*, Vol. 23. ISSN: 2360-0829 ISSN L: 2360-0829, p. 18-26.

Drăghici, I., Joița-Păcureanu, M., Drăghici, R., Croitoru, M., Diaconu, A., Ploae, M., Paraschiv, A.-N. (2017). Reaction of sunflower genotypes to thermal stress conditions in the sandy soils area of southern Oltenia. *Annals of the University of Craiova-Agriculture, Montanology, Cadastre Series*, Vol. XLVII/1 2017, p. 136-143.

Duca, M., Manolache, C., Chilari, R. (2011). Sunflower culture (*Helianthus annuus* l.). historical landmarks. *Akademos-Biologie*, no. 3(22). http://www.akademos.asm.md/files/Cultura%20florii%20soarelui%20Repere%20istorice.pdf.

Eisenach, C. (2019). How plants respond to climate change: A new Virtual Special Issue of Plant, Cell & Environment. *Plant Cell Environ*. 2019;42:2537–2539. doi: 10.1111/pce.13604. [DOI] [PubMed] [Google Scholar].

Fulda, S., Mikkat, S., Stegmann, H., Horn, R. (2011). Physiologyandproteomics of drought stress acclimation in sunflower (*Helianthus annuus* L.). In: *PlantBiology*, ISSN 1435-8603, vol. 13, pp. 632-642

Gheorghe. D., Drăghici. I., Drăghici, R., Ciuciuc, E., Dima, M., Croitoru, M. (2009). Achievements in the field of cereals, technical, fodder and medicinal and aromatic plants. *"50 years of Research and Development at the Research and Development Station for Plant Culture on Sands*", New Series vol II (XVIII), Ed. Sitech, ISBN 978-606-530-592-2.

Ion, V., and Bălașa, A. G. (2021). Phytotechnics. Oilseed plants, Publishing House. Ex Terra Aurum București. ISBN 978-606-0072-128-4; ISBN online -978-606-072-157-4.

Amankulova, K., Farmonov, N., Mukhtorov, U., & Mucsi, L. (2023). Sunflower crop yield prediction by advanced statistical modeling using satellite-derived vegetation indices and crop phenology. Geocarto international, 38(1), 2197509.

Marinică, G., and Dascălu, D. (1984). Water consumption and irrigation regime for sunflowers on improved sands in southern Oltenia. *Scientific papers. SCCCPN Dăbuleni,* vol. VI., pag. 139-151.

Mourad, K. A. E. G. D., El-Shafey, A. I., & El Mantawy, R. F. (2020). Effect of humic acid application on growth and productivity of sunflower under saline soil conditions. *Journal of Plant Production*, *11*(12), 1193-1200.

Netcu, F., Drăghici, R., Dima, M., Titirică, I., Coteț, G. (2023). Research on the behavior of some sunflower genotypes in the conditions of sandy soils in the south-west of Oltenia. *Annals of the University of Craiova -Agriculture, Montanology, Cadastre Series*. Vol. 53/1/2023, p. 209-218. https://doi.org/10.52846/aamc.v53i1.1463.

Pal, U.S., Patra, R.K., Sahoo, N.R., Bakhara, C.K., Panda, M.K. (2015). Effect of refining on quality and composition of sunflower oil. *J Food Sci Technol.* 52(7):4613–4618.

Păcureanu- Joiţa, M., Vrânceanu, A.V., Stanciu, D. (2007). Fifty years of activity in sunflower breeding at Fundulea, *Annales Fundulea National Institute of Agricultural Research and Development*, VOL. LXXV, 2007, Anniversary Volume, pag. 173- 194.

Pinkovskyi, H., & Tanchyk, S. (2021). Management of productivity of sunflower plants depending on terms of sowing and density of standing in arid conditions of the Right-bank Steppe of Ukraine. *Agronomy science*, *76*(1), 21-38. (1). http://doi.org/10.24326/as.2021.1.2.

Pojar, D., Aioanei, D., Ienciu, A., Manea, D. (2023). The water requirement of the sunflower crop in Arad County. *Research Journal of Agricultural Science*, 55 (4), 2023 ISSN: 2668-926X.

Tabără, O., Rîşnoveanu, L., Gîscă, I., Clapco, S., Joiţa-Păcureanu, M., Duca, M. (2018). Evaluation of some sunflower hybrids regarding drought resistance in the Republic of Moldova and Romania. *Agricultural Science*, No 2/2018. CZU 633.854.78:631.524.85:632.112. ISSN: 1857-0003 (Print); 2587-3202 (Online), pag 8-16.

Veska, G., Kazandjiev, V., Georgiev, S., Rashev, S., Valkova, D., Mihova, G., Valchev, D., Dobreva, V. (2024). Agro-climatic conditions for growing of sunflower in different climatic area in Bulgaria. *Scientific Papers. Series A. Agronomy*, Vol. LXVII, No. 2, 2024 ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785.

Vilverta, E., Lanaa, M., Zandera, P., Siebera, S. (2018). Multi-model approach for assessing the sunflower food value chain in Tanzania. *Agric. Syst.* 2018;159:103–110. doi: 10.1016/j.agsy.2017.10.014.

Vrânceanu, A. V. (2000). Hybrid sunflower. Editura Ceres, Bucureşti.

Pei, Y. Y., Lei, L., Fan, X. W., & Li, Y. Z. (2023). Effects of high air temperature, drought, and both combinations on maize: A case study. *Plant Science*, *327*, 111543.

Ren, W., Li, X., Liu, T., Chen, N., Xin, M., Liu, B., ... & Li, G. (2024). Impact of fertilization depth on sunflower yield and nitrogen utilization: a perspective on soil nutrient and root system compatibility. *Frontiers in Plant Science*, *15*, 1440859.