MORPHOLOGICAL, BIOCHEMICAL AND PRODUCTIVITY VARIATIONS IN SUNFLOWER (*HELIANTHUS ANNUUS* L.) HYBRIDS

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Abstract. *Sunflower (Helianthus annuus L.) is one of the cultivated species with great use potential, which leads to as need of finding permanent solutions for the efficient valorisation of this plant as a source of lipids, proteins, and carbohydrates, especially in the context of the continuous diversification of energy sources and raw materials for the industrial and agricultural sectors. The paper analyses the reaction of Helianthus annuus L. genotypes to the soil, temperature, and humidity conditions of the Crișurilor Plain, in conjunction with the cultivation technology recommended for this species. The results were obtained during the years 2021 - 2022, the experiment being single-factor, in four replicates, with five established hybrids. The sunflower genotypes used as experimental variants were as follows: V1 - Performer; V2 - Ilinca 115; V3 - Inkasun IR; V4 - Bravo SU; V5 – Florasun. Among the parameters analysed in the tested hybrids, we mention: vegetation period, plant height, capitulum diameter, the mass of 1000 achenes, hectolitre mass of achenes, achene production, as well as percentage content of achenes in lipids, proteins, and carbohydrates. The results obtained were then interpreted in terms of economic efficiency, recommending the Crișurilor Plain as a suitable region for growing the tested hybrids.*

Keywords: *Helianthus annuus, sunflower, genotype, productivity, valorisation.*

INTRODUCTION

Sunflower is one of the most important oilseed crops cultivated in the world (13% of world oil production), and the most important plant producing vegetable oils for Romania (FOY, 2022; UNGUREANU, 2017). Sunflower seed proteins have high biological value, with all essential amino acids in their chemical composition (UNGUREANU, 2017). Sunflower seeds contain 33-56% significant oil with a high content of vitamins (A, D, E, K), and aromatic substances (AXINTE ET AL., 2006). The oil has a moderate iodine index and an excellent nutritional value, conferred by the presence of unsaturated fatty acids: linoleic (44 - 75%), an essential polyunsaturated fatty acid in the human diet, as the body cannot synthesize it, oleic (14 - 43%), palmitic and stearic acids, below 15%. Linolenic acid is found in trace amounts (2%), which gives the oil its stability and long shelf life (UNGUREANU, 2017; FAQIR ET AL., 2012). As an example, Figure 1a and b show the spectra of palmitic and linoleic acids, from a sample of sunflower oil, obtained from HPLC analysis using theYL9100 series chromatograph system (UNGUREANU, 2017).

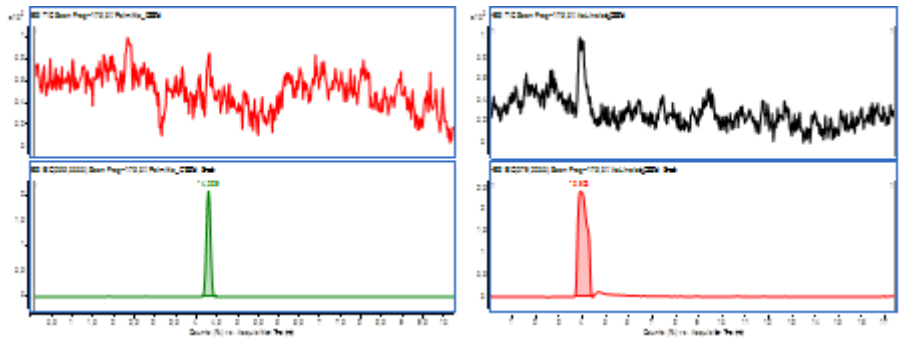

Figure 1. Spectra of palmitic (a) and linoleic (b) acids recorded in a sample of sunflower oil from HPLC analysis (UNGUREANU, 2017).

The expansion of sunflower cultivation in Europe took place after 1700 in Russia and Ukraine (SEILER ET AL., 2017). Throughout the world, including Romania, the sunflower market has continued to develop over the last 25 years and the crop has become the fourth most important oilseed crop after palm, soya and rapeseed. The global top five sunflower producers are Ukraine, Russia, Argentina, Romania, China (Foy, 2022; Faostat, 2019). In Romania, the area cultivated with sunflower has increased from 394,741 ha in 1990 to 998,415 ha in 2017, and 1,123,960 ha in 2021 (INS, 2022a), the most cultivated areas being the Romanian Plain, the Western Plain, Dobrogea and the Danube Plain, the Moldavian Plain and the Transylvanian Plain (SĂNDOIU, 2012, INS, 2022b,c). Globally, sunflower areas are expected to continue to increase in the coming period, but at a slower pace, with a general trend towards a stabilisation of areas due to technological constraints (share in crop structure), and the productive and quality performance of new hybrids (RADANOVIĆ ET AL, 2018; SEILER ET AL., 2017). Hybrids should have a number of advantages, such as increased disease and herbicide resistance, drought tolerance, improved oil properties to maintain health-conscious consumer appeal, and lower oil content for consumer seed (Jităreanu et al., 2020).

The phosphates produced during the oil extraction process allow the large-scale production of lecithin, which is highly valued in the food industry: in bakery, chocolate, cakes, or sausages (UNGUREANU, 2017).

Although its price is quite high compared to soybean oil, which would limit its use as an industrial oil, its properties make it suitable for a wide range of technological applications. It can be used for the production of special varnishes, resins and for numerous energy uses. The oilcake resulting from oil extraction, in appreciable quantity (about 300 kg per tonne of seed) contains, on average, 19 - 22% carbohydrates, 6 - 10% oil, 15 - 20% cellulose, 5 - 10% mineral salts, and 30 - 35% protein (Axinte et al., 2006). By processing sunflower kernels, it is possible to obtain flours, concentrates and protein isolates. The inflorescence remains can be used as fodder (7% protein and 57% carbohydrates), and ethyl alcohol and furfural can be extracted from the ground husks (pericarp) and used to prepare feed yeast (MOGÂRZAN, 2012).

The stem is rich in potassium, and can be used to obtain potassium carbonate or as a source of heat or in industry, for the manufacture of antiphonic plates (JITĂREANU ET AL., 2020; MOGÂRZAN, 2012).

Sunflower is also an excellent melliferous plant, and from an agricultural point of view, it clears land early, allowing good preparation for other crops such as wheat (JITĂREANU ET AL., 2020).

The most common diseases of sunflower plants are: *Plasmopara helianthi*, *Sclerotinia sclerotiorum*, *Botrytis cinerea*, *Puccinia helianthin*, *Septoria helianthin*, *Alternaria helianthin*, *Phoma macdonaldi*, *Phomopsis helianthin*, *Sclerotium bataticola*, and the main pests are: *Opatrum sabulosum*, *Tanymecus dilaticolis*, *Agriotes dilaticolis*, *Homoeosoma nebulella*, *Opatrum sabulosum* (RADANOVIĆ ET AL., 2018; DIMITRIJEVIC & HORN, 2018; GONTCHAROV, 2014).

Due to its morphological peculiarities and high degree of adaptation, sunflower can be grown on soils with sandy-loamy to loamy-clay texture, with pH ranging from weak acid to weak alkaline, from lowland to lowland areas, and can withstand water stress well. Also, the cultivation technology does not require sophisticated agricultural equipment and the timing of agricultural work can be carried out without disturbing the work for other crops (SĂNDOIU, 2012; L. MA ET AL., 2019).

At the current stage, the goal of sunflower breeding worldwide is to create hybrids that merge a number of segments: improving homogeneity to facilitate mechanized harvesting; increasing seed yield per hectare and oil content; increasing resistance to disease; to drooping and achene hulling to mechanical manipulation, aspects that merge in the creation of hybrids (MA ET AL., 2019; RADANOVIĆ ET AL., 2018; DIMITRIJEVIC & HORN, 2018; GONTCHAROV, 2014).

In view of the current problems, this paper tests the response of five sunflower hybrids under soil and climatic conditions in the Crișurilor Plain through morphological, biochemical and production observations, in order to implement efficient alternatives for the optimal use of this multifunctional plant.

MATERIAL AND METHODS

The experiments were conducted over two years, 2021 and 2022, on alluvial soil with luteous-clay texture, having the following characteristics: humus 3.4 - 3.8%; clay 33-34%; depth to groundwater 55 - 60 cm; pH 7.1-7.3; total nitrogen 0.16 - 0.18 mg/100g soil; mobile phosphorus 13.44 mg/100g soil. Sunflower achenes of hybrids Performer, Ilinca 115, Inkasun IR, Bravo SU and Florusan were cultivated on plots of 42 m2, L 10 m, w 4.2 m, keeping a 2.8 m wide buffer, 1.4 m between repetitions, and 0.7 m between variants. Autumn ploughing was carried out at 25-28 cm depth with the plough in aggregate with the star harrow and the seedbed with the combiner at 4-5 cm depth. In the first decade of April, the seeds were sown at a density of 55 thousand b.g./ha, 4-5 cm deep and at a row spacing of 70 cm respectively. Plots were kept free of weeds, diseases and pests by specific care works and fertilization was done with NPK complex fertilizer thus: N 80 kg/ha, P 70 kg/ha and K 60 kg/ha.

In order to achieve the proposed objectives, a single-factor experiment was conducted with five sunflower hybrids under optimal technology conditions in four replicates, the experimental variants being represented by the following genotypes: V1 - Performer, V2 - Ilinca 115, V3 - Inkasun IR, V4 - Bravo SU, V5 - Florusan and V6 - media (www.madr.ro/ISTIS, 2020).

The analysis was carried out to determine morphological indices: plant height, calatid diameter, 1000-grain mass (GMB), hectolitre mass (MH), quality indices: percentage protein and carbohydrate content in achene and lipid content in seed, and

productivity/economic indices: grain yield (kg/ha), value of grain production (lei/ha) and profit (euro/ha).

RESULTS AND DISCUSSIONS

Climate conditions during the years 2021-2022 in Arad area

The climatic conditions in 2021 did not differ significantly from the multi-year average, but the 2022 was a dry year with high temperatures that affected plant growth and development.

High temperature coupled with low relative humidity did not provide optimal conditions for plant growth.

Relative humidity during the growing season ranged from 40-80% in 2021 to 30-65% in 2022. While rainfall was sufficient in 2021, especially during the achene formation and filling period, in 2022, the absence of rainfall was noticeable, especially in June and July.

The wind speed during the two years of study did not exceed the multi-year average, being normal for the Arad area.

Analysing the overall climatic conditions in 2021 and 2022, it can be stated that they were good in 2021 and less favourable in 2022 for sunflower cultivation (Figure 2a and b).

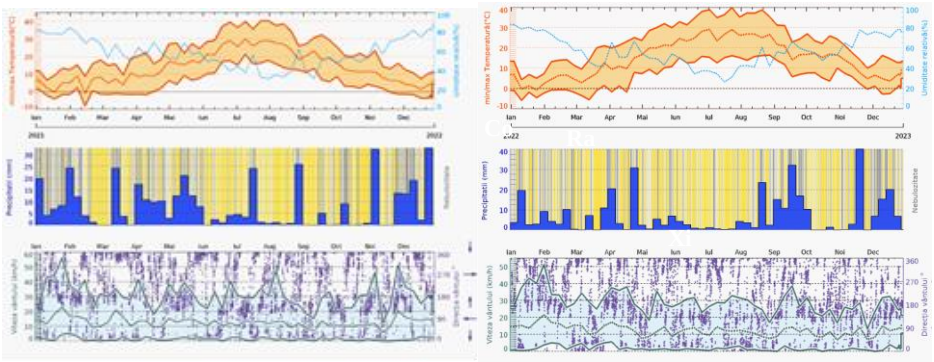

Figure 2. Average temperature and precipitation values: January-December 2021 (a) and January -December 2022 (b) in Arad. (https://www.meteoblue.com - Arad Weather Archive, 2021, 2022).

The vegetation period

During the period from sowing to harvest, sunflower plants go through several stages of development, such as vegetative, reproductive, ripening and maturation.

The hybrids taken in the study had a vegetation period ranging from 113 days in the Ilinca 115 hybrid in 2022 to 123 days in the Florasun hybrid in 2021. The average vegetation period over the two years of the study was 117.5 days ranging from 116 days in 2022 to 119 days in 2021. Above average growing season was also found in the hybrid Inkasun IR with 120.5 days, the rest of the cultivated genotypes being below average (Table 1).

The plants' height and capitula diameter

The cultivation technology recommended by specialists for sunflower cultivation (JITĂREANU ET AL., 2020), was also applied in the current research, and this

revealed plant growth and development in all five cultivated hybrid variants under good agrotechnical conditions.

Table 1

Influence of climate and soil conditions on the vegetation period in sunflowers

No.	Genotype	Vegetation period (days)		Average for 2021/2022		Difference (days)
		2021	2022	days	%	
1	Performer	117	114	115,5	98	-2
2	Ilinca 115	116	113	114,5	97	-3
3	Inkasun IR	122	119	120,5	103	3
4	Bravo SU	117	115	116	99	-1
5	Florasun	123	119	121	103	3
6	Control (average)	119	116	117,5	100	-

One of the important morphological factors in sunflowers with a major influence on plant life is height. This is the result of the interaction between the ability of the genotype to exploit the applied phytotechnical factors, the environmental conditions and the growth potential of the hybrid.

The sunflower hybrids studied had average plant height values ranging from 167.5 cm in the Performer hybrid to 197 cm in the Inkasun IR hybrid.

The shortest plants appeared in 2022 in Performer and Ilinca 115 hybrids with a height of 164 cm and 171 cm respectively, and the tallest plants in 2021 in Florasun and Inkasun IR hybrids - 201 cm and 203 cm respectively (Table 2).

Table 2

Influence of climate and soil conditions on plant height in sunflowers

No.	Genotype	Plant height (cm)		Average for 2021/2022		Difference (cm)
		2021	2022	cm	%	
1	Performer	171	164	167,5	90	-18
2	Ilinca 115	185	171	178	96	-7,5
3	Inkasun IR	203	191	197	106	11,5
4	Bravo SU	195	185	190	102	4,5
5	Florasun	201	189	195	105	9,5
6	Control (average)	191	180	185,5	100	-

The sunflower inflorescence is a capitulum protected by modified leaves called involucral bracts or phyllaries, comprising a row of ligulate flowers, sterile on the outside (ray flowers), and numerous tubular, fertile flowers on the inside (disk flowers).

In the current study, the capitulum diameter averaged over the two years between 17.5 cm (Ilinca 115) and 23 cm (Inkasun IR). Above the average of 20 cm capitula was present in the Performer hybrid (diameter 22 cm), and below the two-year average in the Bravo SU (diameter 18.5 cm) and Florusan (diameter 19 cm) hybrids. The largest capitulum was found in Performer and Inkasun IR hybrids in 2021 with inflorescence diameter of 24 cm, and the smallest capitulum was found in 2022 in Ilinca 115 hybrid where inflorescence diameter did not exceed 17 cm (Table 3).

Table 3

Influence of climate and soil conditions on capitulum diameter in sunflower

No.	Genotype	Capitulum diameter (cm)		Average for 2021/2022		Difference (cm)
		2021	2022	cm	%	
1	Performer	24	20	22	110	2
2	Ilinca 115	18	17	17,5	88	-2,5
3	Inkasun IR	24	22	23	115	3
4	Bravo SU	19	18	18,5	93	-1,5
5	Florasun	20	18	19	95	1
6	Control (average)	21	19	20	100	-

Quantitative analysis of achenes

The characteristics of the genotypes studied in conjunction with soil and climatic conditions and cultivation technology influenced the 1000 achene mass (MMB) of the plants. On average it was 56.5 g, which is at a satisfactory level. Due to climatic conditions in 2022, achenes from the five hybrids tested were lighter recording a value of 55 g, so 3 g less than that recorded in 2021. The highest MMB values were found in Performer hybrids with 63.5 g and Ilinca 115 with 61 g, and the lowest in Florasun with 49 g and Bravo SU with 49.5 g (Table 4).

Table 4

Influence of climate and soil conditions on the mass of 1000 achenes (MMB) in sunflower

No.	Genotype	MMB (g)		Average for 2021/2022		Difference (g)
		2021	2022	g	%	
1	Performer	66	61	63,5	112	7
2	Ilinca 115	63	59	61	108	4,5
3	Inkasun IR	62	57	59,5	105	3
4	Bravo SU	50	49	49,5	88	-7
5	Florasun	49	49	49	87	-7,5
6	Control (average)	58	55	56,5	100	-

The hectolitre mass (MH), which is of major importance for assessing the quality of achenes and their storage in silos, ranged from 39.5 kg for the hybrid Ilinca115 to 41.5 kg for Performer. It is worth noting that the average hectolitre weight averaged 40.5 kg over the two years, being 39 kg in 2022 and 42 kg in 2021. A good hectolitre mass was recorded in 2021 in hybrids Performer 43 kg, Inksun IR 42.5, Florasun 42.5 kg, given the favourable climate and soil conditions (Table 5).

Table 5

Influence of climate and soil conditions on hectolitre mass (HM) in sunflower

No.	Genotype	HM (kg)		Average for 2021/2022		Difference (kg)
		2021	2022	kg	%	
1	Performer	43	40	41,5	1102	1
2	Ilinca 115	41	38	39,5	98	-1
3	Inkasun IR	42,5	38,5	40,5	100	0
4	Bravo SU	41	39	40	99	-0,5
5	Florasun	42,5	39,5	41	101	0,5
6	Control (average)	42	39	40,5	100	-

The application of appropriate cultivation technology for sunflower crops together with the environmental conditions resulted in good plant growth and development, which is also reflected in the achene yield per unit area.

A first analysis shows that the yield of the five hybrids tested is satisfactory, ranging from 3230 kg/ha for the Florasun hybrid to 3515 kg/ha for the Ilinca115 hybrid. Also the Performer hybrids with a yield of 3455 and Inkasun IR with a yield of 3385 kg/ha performed well, exceeding the control of 3380 kg/ha.

From the point of view of achene production, the studied hybrids adapted well in the Arad area, with good quantitative results, which recommends them for cultivation by the farmers in the area (Table 6).

Table 6

Influence of climate and soil conditions on achene production in sunflowers

No.	Genotype	Achene production (kg/ha)		Average for 2021/2022		Difference (kg/ha)
		2021	2022	kg/ha	%	
1	Performer	3850	3060	3455	102	75
2	Ilinca 115	3930	3100	3515	104	135
3	Inkasun IR	3820	2950	3385	100	5
4	Bravo SU	3750	2880	3315	98	-65
5	Florasun	3650	2810	3230	96	-420
6	Control (average)	3800	2960	3380	100	-

Lipid, protein and carbohydrates content of achenes

The lipid/oil content of sunflower achenes was determined by the Soxhlet method (extraction with organic solvents), and was of 42,6%, resulting a production of 1440 kg oil/ha. The biggest oil percentage from seeds was obtained for the Performer and Ilinca 115 hybrids, with 46% and 45,5%, respectively, while the smallest oil percentages were for Florasun and Bravo SU hybrids, with 40% and 40,5%, respectively. The fact that all tested hybrids lead to oil productions of over 1292 kg/ha can be considered a positive aspect in considering the expantion of these genotypes in agricultural crops (Table 7).

Table 7

Influence of climate and soil conditions on achenes lipid/oil content

No.	Genotype	Lipids/Oil (%)		Average for 2021/2022		Difference (%)
		2021	2022	kg/ha	%	
1	Performer	47,5	44,5	1589	46,0	3,4
2	Ilinca 115	47,5	43,5	1599	45,5	2,9
3	Inkasun IR	41,5	40,5	1388	41	-1,6
4	Bravo SU	41	40	1343	40,5	-2,1
5	Florasun	40,5	39.5	1292	40	-2,6
6	Control (average)	43,6	41,6	1440	42,6	-

The protein content in seeds is an important qualitative parameter, gived the beneficial aspects over metabolic processes and their contribution to prolonged satiety. The average content of proteins in the tested sunflower seeds was determined by fast, non-destructive methods based on sensors, using the INFRATEC machine by Kjeltec. On average, from 1 ha sunflower crop was obtained 642 kg of proteins (19%). The Florasun hybrid had seeds with the highest protein content, its average procentage of

19,6% overcoming by 1,2% the Performer hybrid. Regarding the content of brute protein, the analysis of the plants reaction over the two years of study shows that the best results were obtained in the year 2021 for the Florasun and Bravo SU hybrids, with values of 19,8% and 19,7%, respectively. In the year 2022 the protein content dropped for all variants, the smallest percentage being 18,3% for Performer hybrid (Table 8).

Table 8

Influence of climate and soil conditions on the brute protein content in sunflower achenes

No.	Genotype	Brute protein (%)		Average for 2021/2022		Difference (%)
		2021	2022	kg/ha	%	
1	Performer	18,5	18,3	636	18,4	-0,6
2	Ilinca 115	18,8	18,6	657	18,7	-0,3
3	Inkasun IR	19,1	18,7	639	18,9	-0,1
4	Bravo SU	19,7	19,1	643	19,4	0,4
5	Florasun	19,8	19,4	633	19,6	0,6
6	Control (average)	19,2	18,8	642	19,0	-

The carbohydrates content in achenes was determined by Luff-Schoorl method. The analysis of experimental data show an average carbohydrates content of 14,75%, registering a maximum of 14,85% for Performer and Ilinca115 hybrids, and 14,65% for Florasun and Bravo SU hybrids, respectively (Table 9).

Table 9

Influence of climate and soil conditions on carbohydrates content in sunflower achenes

No.	Genotype	Carbohydrates (%)		Average for 2021/2022		Difference (cm)
		2021	2022	kg/ha	%	
1	Performer	14,8	14,9	513	14,85	0,1
2	Ilinca 115	14,8	14,9	522	14,85	0,1
3	Inkasun IR	14,7	14,8	499	14,75	0,0
4	Bravo SU	14,6	14,7	489	14,65	-0,1
5	Florasun	14,6	14,7	473	14,65	-0,1
6	Control (average)	14,7	14,8	499	14,75	-

Economic efficiency

Regarding the economic aspect of the five tested hybrids, the results highlight their efficiency, the results obtained showing profits between 4150 RON for Ilinca115 hybrid and 3522 RON for Florasun hybrid (Table 10). Considering the average profit of 3852 RON/ha. as well as their overall good adaptation to the pedoclimatic factors in the study area, the cultivated hybrids can be considered a viable solution for the expantion of sunflower crops in the Crișurilor Plain area.

Table 10

Influence of climate and soil conditions on the economic efficiency of sunflower crops

Genotype	Seed production (kg/ha)			Value of seed production (RON/ha)			Profit (RON/ha)			Difference compared to control (RON/ha)
	2021	2022	Average	2021	2022	Average	2021	2022	Average	Average
Performer	3850	3060	3455	7700	7344	7522	4400	3644	4022	170
Ilinca 115	3930	3100	3515	7860	7440	7650	4560	3740	4150	298
Inkasun IR	3820	2950	3385	7640	7080	7360	4340	3380	3860	8
Bravo SU	3750	2880	3315	7500	6912	7206	4200	3212	3706	-146
Florasun	3650	2810	3230	7300	6744	7022	4000	3044	3522	-330
Control (average)	3800	2960	3380	7600	7104	7352	4300	3404	3852	-

Notes: One ton of sunflower seeds in the year 2021 value 2000 RON;
One ton of sunflower seeds in the year 2022 value 2400 RON;
Production costs/ha in the year 2021 was 3300 RON;
Production costs/ha in the year 2022 was 3700 RON;
Profit represents the production value minus the production costs.

CONCLUSIONS

In this study we analysed the reaction of *Helianthus annuus* L. genotypes (Performer, Ilinca115, Inkasun IR, Bravo SU, Florasun) to the soil, temperature, and humidity conditions of the Crișurilor Plain, including morphological, biochemical, production and economic aspects. The Ilinca115 hybrid showed the best performance in regards to the achene production, biochemical composition and profits, while the weakest performance was for Florasun hybrid. Overall, the tested genotypes have shown to be well adapted to the pedoclimatic conditions of the study area, results in average profits of 3852 RON. The results obtained show that the Crișurilor Plain is a suitable region for the cultivation the tested hybrids.

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