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PRODUCTIVITY OF SOME SUNFLOWER HYBRIDS - COMPARATIVE ANALYSIS

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Abstract

The study comparatively analyzed the productivity level of 48 commercial sunflower hybrids, under the specific crops conditions of the Western Plain of Romania. The field experiment took place within ARDS Lovrin, agricultural year 2021-2022. 27 hybrids from the Imazamox class (IH; IH1 to IH27) and 21 hybrids from the Tribenuron Methyl class (TMH; TMH1 to TMH21) were cultivated. The cultivation of the 48 hybrids was carried out under the conditions of a chernozem type soil, and non-irrigated system. In the case of Imazamox class hybrids (IH), the production varied between 2012.47 kg ha^{-1} (IH4) and 3,545.08 kg ha^{-1} (IH1, and IH23). In the case of hybrids from the Tribenuron Methyl class (TMH), production varied between 2,437.64 kg ha^{-1} (TMH17) and 3,713.15 kg ha^{-1} (TMH4, and TMH19). Based on the production data recorded for each hybrid, the average value was calculated for each class of hybrids (IH-Avg=3,038.13 kg ha^{-1}, TMH-Avg=3,287.98 kg ha^{-1}). In order to verify whether there are differences between the two groups IH (N=27) and TMH (N=21) regarding the recorded production, the Null Hypothesis (H0) was defined. The application of the t-test for Equality of Means, led to the value of t=2.302 with p=0.02. Additionally, the non-parametric Mann-Whitney test was applied. The U=180 value with p=0.03 also indicated significantly different productions between the related series of the two classes of hybrids. The increase in production (kg ha^{-1}, %) was calculated for each class of hybrids (ΔIH, ΔTMH) and a classification was made within each class. The cluster analysis facilitated the clustering of sunflower hybrids in relation to the recorded production.

Key words: *classification, hybrids categories, Mann-Whitney test, production, sunflower*

INTRODUCTION

Sunflower (*Helianthus anuus* L.), is a highly important crop plant, with food benefits [2, 25], pharmaceutical and medicinal benefits [2, 5, 16], for feeding animals through residual products [4, 13], for different industrial sectors [14], and in ornamental interest [23, 30]. The sunflower is an oleaginous plant, which occupies high areas within the crop plants in different agricultural areas of the world [15, 22, 24].

From the perspective of cultivated plants, the sunflower is an environmentally friendly plant, with protective technologies, a plant that fits well into the structure of cultivated plants, crop rotations and crop rotation [9]. At the same time, the sunflower is considered and studied as a bioindicator plant regarding environmental pollution [18].

The sunflower was studied in relation to the soil and climate conditions, in order to establish the most suitable culture areas for different genotypes [3, 10, 27].

Numerous sunflower genotypes have been studied in terms of diversity and variability, from the perspective of breeding programs [1, 29], but also from the perspective of agricultural technologies [20], and improving oil production [19].

Production, yield, economic aspects and certain quality indices in sunflower production were studied in relation to different genotypes and culture conditions [8, 15].

Santos et al. (2018) [26] used a multivariate evaluation to analyze and quantify yield potential in sunflower genotypes from different genetic classes. Sunflower breeding programs aim at the production of hybrids adapted to different pedoclimatic conditions, pollination conditions and pollinators, with high production potential, customized to the specifics of certain agricultural technologies, with economic yield, with very good quality indices in relation with the destination of seed production [6, 11, 21].

The present study comparatively analyzed the productivity of 48 sunflower hybrids, by hybrid classes (Imazamox – IH, Tribenuron Methyl – TMH), hybrids grown in representative soil and climate conditions, specific to the Western Plain of Romania, within ARDS Lovrin.

MATERIALS AND METHODS

The study analyzed, based on production and yield, the response of some sunflower hybrids from two classes, to the crop conditions. The study and field experiments took place at the Agricultural Research and Development Station Lovrin, Romania, Photo 1, in specific climatic conditions, Figure 1.

Photo. 1. Aspect from the experimental field of comparative crops, sunflower hybrids, agricultural year 2021 – 2022
Source: Original photo taken by authors (UAV image).

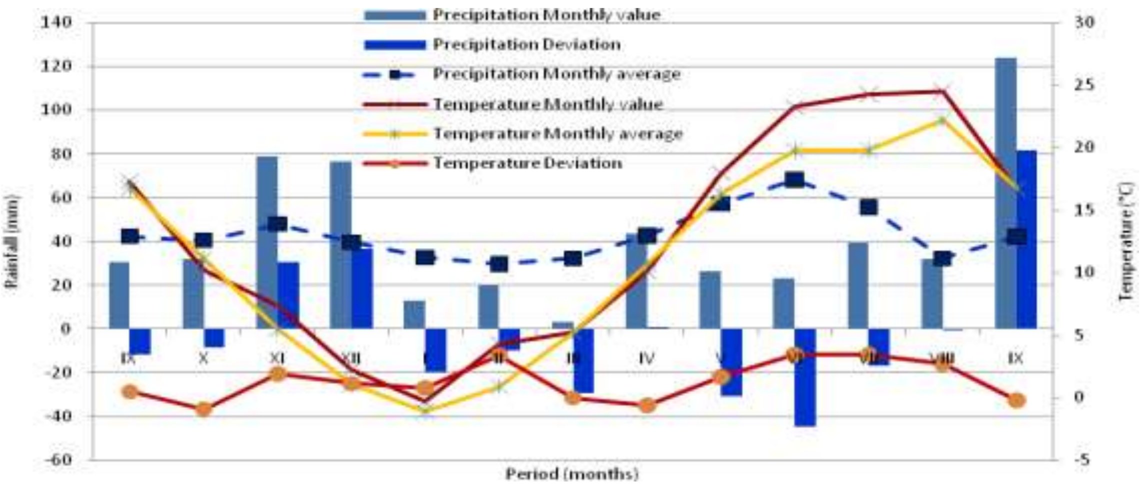

Fig. 1. Climatic conditions during the study period, Lovrin locality
Source: Original figure, generated based on the data recorded at ARDS Lovrin.

Two categories of sunflower hybrids, from different classes of culture technology, were considered in the comparative study; Imazamox class (I) 27 hybrids (H); class Tribenuron Methyl (TM) 21 hybrids (H). For facilities associated with the study (calculations and graphic representations), the hybrids were assigned a code, which contains the class (Imazamox - I, Tribenuron Methyl - TM), hybrid (H) and the order number of the hybrids (the presentation was made associated with the companies, in alphabetical order of the companies). There were 27 trial codes for hybrids from the Imazamox class (IH1 to

IH27) and 21 trial codes for hybrids from the Tribenuron Methyl class (TMH1 to TMH21). The study was conducted based on the flow chart, presented in Figure 2.

The culture of sunflower hybrids from the two technology classes was in non-irrigated conditions. At physiological maturity, the production for each sunflower hybrid was harvested, and based on the recorded data, studies and comparative yield analysis were made.

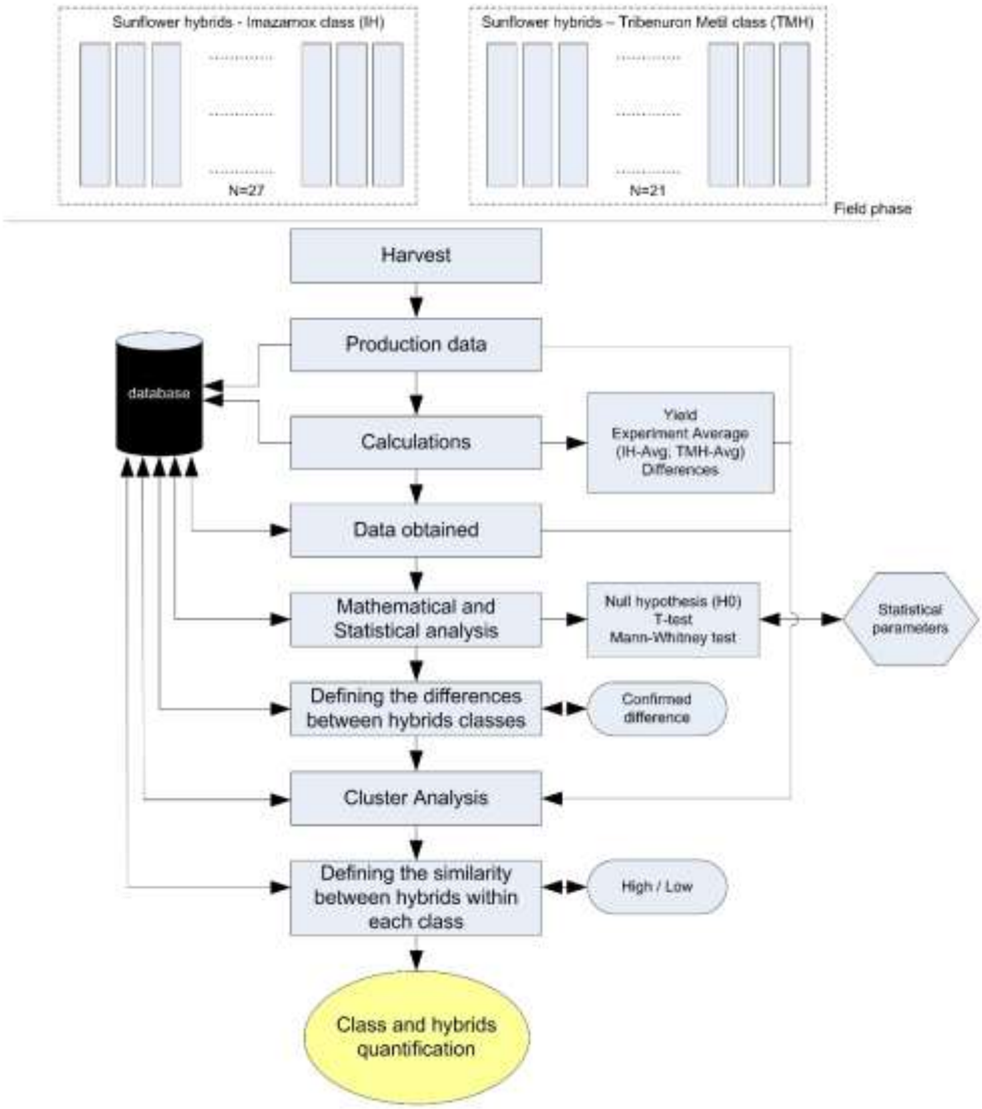

Fig. 2. Flowchart for the comparative study of sunflower hybrids
Source: Original figure.

The recorded production results and results from the calculations were analyzed to evaluate the safety of the data and the presence of variance, to evaluate the growth of each hybrid, on the two classes, compared to the average of each class (IH-Avg; TMH-Avg), and compared to the average hybrids within each company on each technology class (IH, TMH). A cluster classification of the hybrids was also made in relation to the yield, for each technology class (IH, TMH). Appropriate mathematical and statistical tools were used, in relation to the purpose of the study [17].

RESULTS AND DISCUSSIONS

Sunflower production results varied in relation to the hybrids grown on the two classes, Imazamox and Tribenuron Methyl.

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The recorded values (average values per class and group of hybrids per company), as well as the calculated differences, are presented in Tables 1 and 2. In the case of hybrids from the Imazamox class (IH), production varied between 2,012.47 kg ha^{-1} (IH4) and 3,545.08 kg ha^{-1} (IH1, and IH23). In the case of hybrids from the Tribenuron Methyl (TMH) class, production varied between 2,437.64 kg ha^{-1} (TMH17) and 3,713.15 kg ha^{-1} (TMH4, and TMH19). The analysis of the distribution of the data series confirmed their statistical reliability (r=0.967 for IH data series; r=0.965 for TMH data series.

The two series of data were analyzed comparatively, by classes of hybrids, respectively class IH with 27 hybrids, and class TMH with 21 hybrids. In order to check whether there are differences between the two classes IH (N=27) and TMH (N=21) regarding the recorded production, the Null Hypothesis (H0) was defined, which consists in the fact that the averages of the two statistical series are not different.

Specifically, the average value of the data from the IH series was IH-Avg=3,038.13 (kg ha^{-1}) while for the TMH series the average production value of TMH-Avg=3,287.98 (kg ha^{-1}) was obtained. The application of the t-test for Equality of Means, led to the value of t=2.302, with p=0.02. This fact indicated the rejection of the Null Hypothesis, therefore there are significant differences between the two groups of hybrids (IH, and TMH).

Table 1. Production results in sunflower hybrids, Imazamox class (IH)

Company Name	Imazamox hybrids	Trial code	Y	Experiment Average (IH-Avg)	Differences compared to Avg (IH-Avg)		Average per company (C-Avg)	Differences compared to C-Avg
			(kg ha^{-1})	(kg ha^{-1})	(kg ha^{-1})	(%)	(kg ha^{-1})	(kg ha^{-1})
BASF	Acordis	IH1	3,543.08	3,038.13	504.95	116.62	3,042.33	500.76
	Aluris	IH2	3,429.71	3,038.13	391.58	112.89	3,042.33	387.38
	Coloris	IH3	2,862.81	3,038.13	-175.32	94.23	3,042.33	-179.52
	Dracaris	IH4	2,012.47	3,038.13	-1025.66	66.24	3,042.33	-1,029.86
	Insun 200	IH5	2,919.50	3,038.13	-118.63	96.10	3,042.33	-122.83
	Insun 222	IH6	3,486.39	3,038.13	448.26	114.75	3,042.33	444.06
Chemirol	Rustica	IH7	2,239.23	3,038.13	-798.90	73.70	2,239.23	0.00
Corteva	LP180CL	IH8	2,834.47	3,038.13	-203.66	93.30	2,834.47	0.00
	LP170CL	IH9	2,834.47	3,038.13	-203.66	93.30	2,834.47	0.00
Donau-Saat	Jonasun	IH10	3,458.05	3,038.13	419.92	113.82	3,202.95	255.10
	Irinasol	IH11	3,032.88	3,038.13	-5.25	99.83	3,202.95	-170.07
	Florasun	IH12	3,117.91	3,038.13	79.78	102.63	3,202.95	-85.04
KWS	Delicio	IH13	2,947.85	3,038.13	-90.28	97.03	2,670.07	277.78
	Achiles	IH14	2,777.78	3,038.13	-260.35	91.43	2,670.07	107.71
	Apache	IH15	2,692.74	3,038.13	-345.39	88.63	2,670.07	22.67
	Fourios	IH16	2,551.02	3,038.13	-487.11	83.97	2,670.07	-119.05
	Tahiti	IH17	2,380.95	3,038.13	-657.18	78.37	2,670.07	-289.12
MASS Seeds	MAS 92 CP	IH18	3,174.60	3,038.13	136.47	104.49	3,344.67	-170.07
	MAS 920 CP	IH19	3,514.74	3,038.13	476.61	115.69	3,344.67	170.07
RAGT	Charlotte	IH20	3,089.57	3,038.13	51.44	101.69	3,214.29	-124.72
	Sillos	IH21	3,004.54	3,038.13	-33.59	98.89	3,214.29	-209.75
	Guillermo	IH22	3,401.36	3,038.13	363.23	111.96	3,214.29	187.07
	Valencia	IH23	3,543.08	3,038.13	504.95	116.62	3,214.29	328.79
	Vollcano	IH24	3,032.88	3,038.13	-5.25	99.83	3,214.29	-181.41
Syngenta	SY Barilio	IH25	3,231.29	3,038.13	193.16	106.36	3,382.46	-151.17
	SY Michigan	IH26	3,514.74	3,038.13	476.61	115.69	3,382.46	132.28
	SY Onestar	IH27	3,401.36	3,038.13	363.23	111.96	3,382.46	18.90

Source: Original data from experiment.

Table 2. Production results of sunflower hybrids, Tribenuron Methyl class (TMH)

Company Name	Tribenuron Metyl hybrids	Trial code	Y	Experiment Average (TMH-Avg)	Differences compared to Avg (TMH-Avg)		Average per company (C-Avg)	Differences compared to C-Avg
			(kg ha^{-1})	(kg ha^{-1})	(kg ha^{-1})	(%)	(kg ha^{-1})	(kg ha^{-1})
BASF	Averon	TMH1	3,032.88	3,287.98	-255.10	92.24	3,032.88	0.00
Corteva	P64le25	TMH2	3,202.95	3,287.98	-85.03	97.41	3,395.69	-192.74
	Pe64le162	TMH3	3,458.05	3,287.98	170.07	105.17	3,395.69	62.36
	Pe64le137	TMH4	3,713.15	3,287.98	425.17	112.93	3,395.69	317.46
	P64le99	TMH5	2,976.19	3,287.98	-311.79	90.52	3,395.69	-419.50
	HE144	TMH6	3,628.12	3,287.98	340.14	110.34	3,395.69	232.43
Donau-Saat	Bravosu	TMH7	3,146.26	3,287.98	-141.72	95.69	3,127.36	18.90
	Prontosol	TMH8	3,061.22	3,287.98	-226.76	93.10	3,127.36	-66.14
	Helesun	TMH9	3,174.60	3,287.98	-113.38	96.55	3,127.36	47.24
Expert Fundulea	Hestia	TMH10	3,231.29	3,287.98	-56.69	98.28	3,287.98	-56.69
	Hera	TMH11	3,458.05	3,287.98	170.07	105.17	3,287.98	170.07
	Soleea	TMH12	3,373.02	3,287.98	85.04	102.59	3,287.98	85.04
	Demetera	TMH13	3,089.57	3,287.98	-198.41	93.97	3,287.98	-198.41
MASS Seeds	MAS 83	TMH14	3,543.08	3,287.98	255.10	107.76	3,458.05	85.03
	MAS 85	TMH15	3,373.02	3,287.98	85.04	102.59	3,458.05	-85.03
RAGT	Volter	TMH16	2,976.19	3,287.98	-311.79	90.52	2,706.92	269.27
	Interstelar	TMH17	2,437.64	3,287.98	-850.34	74.14	2,706.92	-269.28
Syngenta	Suvex 1	TMH18	3,486.39	3,287.98	198.41	106.03	3,543.08	-56.69
	NX02267	TMH19	3,713.15	3,287.98	425.17	112.93	3,543.08	170.07
	Suomi	TMH20	3,344.67	3,287.98	56.69	101.72	3,543.08	-198.41
	Sureli	TMH21	3,628.12	3,287.98	340.14	110.34	3,543.08	85.04

Source: Original data from experiment.

In order to verify in an additional way the existence of differences between the two groups of hybrids, the non-parametric Mann-Whitney test was also applied. The U=180 value with p=0.03 also indicated significantly different productions between the related series of the two groups of hybrids.

In order to compare the two classes of hybrids (IH, TMH), the average production value (IH-Avg; TMH-Avg) was calculated for each class. In the class of Imazamox hybrids, the average production of the 27 tested hybrids was IH-Avg=3,038.13 kg ha^{-1}. Within the class of Tribenuron Methyl hybrids, the average production of the 21 tested hybrids was TMH-Avg=3,287.98 kg ha^{-1}. From the analysis of the two average values, a higher value was found in the case of the TMH hybrid class, with 249.85 kg ha^{-1}, compared to the IH hybrid class. Within the class of Imazamox hybrids (IH), Table 1, in relation to the average of the experiment (3,038.13 kg ha^{-1}), the increase in production generated by the hybrids (ΔIH) varied between 101.69% (3,089.57 kg ha^{-1}) for the hybrid Charlotte (IH20) and 115.62% (3,543.08 kg ha^{-1}) in the case of Acordis (IH1) and Valencia (IH23) hybrids. Within the class of Tribenuron Methyl hybrids (TMH), Table 2, in relation to the average of the hybrids of the experiment (3,287.98 kg ha^{-1}), the increase in production generated by the hybrids (ΔTMH) varied between 101.72% (3,344.67 kg ha^{-1}) at hybrid Soumi (TMH20), and 112.93% (3,713.15 kg ha^{-1}) in the case of hybrids Pe64le137 (TMH4), and NX02267 (TMH19) respectively.

In order to evaluate the degree of similarity of the hybrids in relation to the production level, Cluster Analysis was applied to each class of hybrids (IH, and TMH). Within the class of IH hybrids, the cluster analysis led to the dendrogram from Figure 3 (Coph corr.= 0.827), and within the class of TMH hybrids, the cluster analysis led to the dendrogram from Figure 4 (Coph corr.=0.860). The 27 hybrids, from class IH, were grouped into two distinct clusters. A C1 cluster included three hybrids (IH4, IH7 and IH17) with low production levels. The other 24 IH hybrids were grouped within one C2 cluster, in several sub-clusters, in relation to the level of similarity for production.

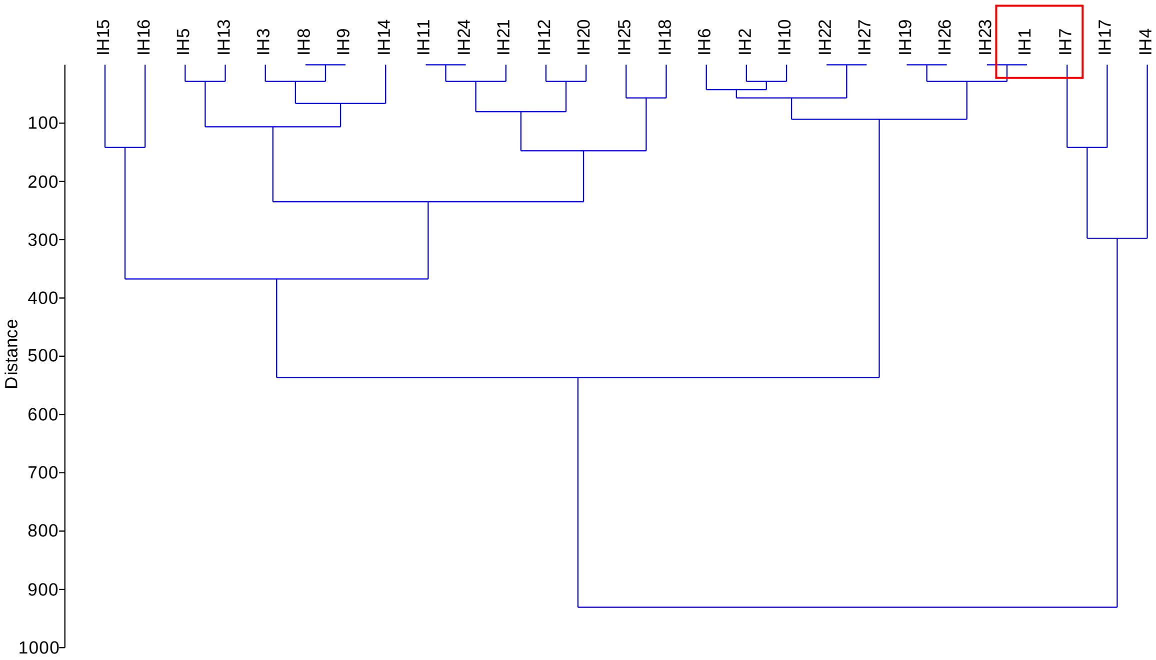

Fig. 3. Cluster dendrogram in the case of sunflower hybrids, class IH
Source: Original figure.

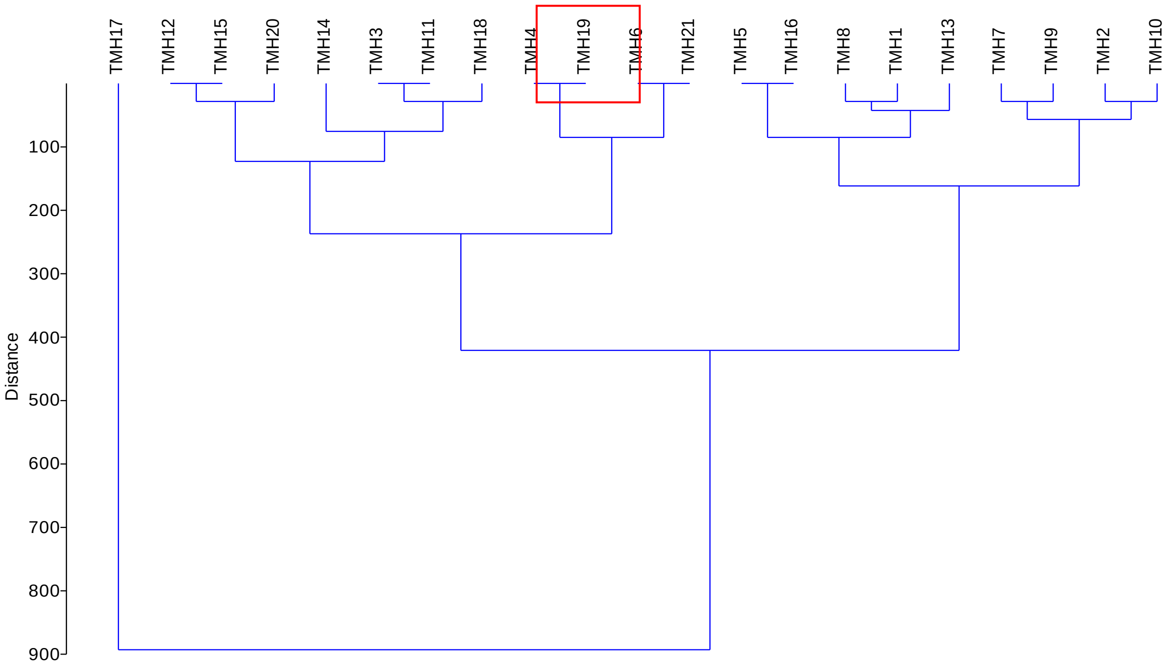

Fig. 4. Cluster dendrogram in the case of sunflower hybrids, class TMH
Source: Original figure.

Within the class of TMH hybrids, the MH17 hybrid was placed in a separate position, with the lowest level of production.
The other 20 IH hybrids were grouped within one C2 cluster, in several sub-clusters.
The level of similarity was evaluated based on SDI values, Tables 3 and 4.

Table 3. SDI values for sunflower hybrids, class IH (Imazamox hybrids)

	IH1	IH2	IH3	IH4	IH5	IH6	IH7	IH8	IH9	IH10	IH11	IH12	IH13	IH14	IH15	IH16	IH17	IH18	IH19	IH20	IH21	IH22	IH23	IH24	IH25	IH26	IH27
IH1		113.4	680.3	1,530.6	623.6	56.7	1,303.8	708.6	708.6	85.0	510.2	425.2	595.2	765.3	850.3	992.1	1,162.1	368.5	28.3	453.5	538.5	141.7	0.0	510.2	311.8	28.3	141.7
IH2	1,13.37		566.9	1,417.2	510.2	56.7	1,190.5	595.2	595.2	28.3	396.8	311.8	481.9	651.9	737.0	878.7	1,048.8	255.1	85.0	340.1	425.2	28.4	113.4	396.8	198.4	85.0	28.4
IH3	680.27	566.9		850.3	56.7	623.6	623.6	28.3	28.3	595.2	170.1	255.1	85.0	85.0	170.1	311.8	481.9	311.8	651.9	226.8	141.7	538.6	680.3	170.1	368.5	651.9	538.6
IH4	1,530.6	1,417.2	850.3		907.0	1,473.9	226.8	822.0	822.0	1,445.6	1,020.4	1,105.4	935.4	765.3	680.3	538.6	368.5	1,162.1	1,502.3	1,077.1	992.1	1,388.9	1,530.6	1,020.4	1,218.8	1,502.3	1,388.9
IH5	623.58	510.2	56.7	907.0		566.9	680.3	85.0	85.0	538.6	113.4	198.4	28.4	141.7	226.8	368.5	538.6	255.1	595.2	170.1	85.0	481.9	623.6	113.4	311.8	595.2	481.9
IH6	56.69	56.7	623.6	1,473.9	566.9		1,247.2	651.9	651.9	28.3	453.5	368.5	538.5	708.6	793.7	935.4	1,105.4	311.8	28.4	396.8	481.9	85.0	56.7	453.5	255.1	28.4	85.0
IH7	1,303.8	1,190.5	623.6	226.8	680.3	1,247.2		595.2	595.2	1,218.8	793.7	878.7	708.6	538.6	453.5	311.8	141.7	935.4	1,275.5	850.3	765.3	1,162.1	1,303.8	793.7	992.1	1,275.5	1,162.1
IH8	708.61	595.2	28.3	822.0	85.0	651.9	595.2		0.0	623.6	198.4	283.4	113.4	56.7	141.7	283.5	453.5	340.1	680.3	255.1	170.1	566.9	708.6	198.4	396.8	680.3	566.9
IH9	708.61	595.2	28.3	822.0	85.0	651.9	595.2	0.0		623.6	198.4	283.4	113.4	56.7	141.7	283.5	453.5	340.1	680.3	255.1	170.1	566.9	708.6	198.4	396.8	680.3	566.9
IH10	85.03	28.3	595.2	1,445.6	538.6	28.3	1,218.8	623.6	623.6		425.2	340.1	510.2	680.3	765.3	907.0	1,077.1	283.5	56.7	368.5	453.5	56.7	85.0	425.2	226.8	56.7	56.7
IH11	510.2	396.8	170.1	1,020.4	113.4	453.5	793.7	198.4	198.4	425.2		85.0	85.0	255.1	340.1	481.9	651.9	141.7	481.9	56.7	28.3	368.5	510.2	0.0	198.4	481.9	368.5
IH12	425.17	311.8	255.1	1,105.4	198.4	368.5	878.7	283.4	283.4	340.1	85.0		170.1	340.1	425.2	566.9	737.0	56.7	396.8	28.3	113.4	283.5	425.2	85.0	113.4	396.8	283.5
IH13	595.23	481.9	85.0	935.4	28.4	538.5	708.6	113.4	113.4	510.2	85.0	170.1		170.1	255.1	396.8	566.9	226.8	566.9	141.7	56.7	453.5	595.2	85.0	283.4	566.9	453.5
IH14	765.3	651.9	85.0	765.3	141.7	708.6	538.6	56.7	56.7	680.3	255.1	340.1	170.1		85.0	226.8	396.8	396.8	737.0	311.8	226.8	623.6	765.3	255.1	453.5	737.0	623.6
IH15	850.34	737.0	170.1	680.3	226.8	793.7	453.5	141.7	141.7	765.3	340.1	425.2	255.1	85.0		141.7	311.8	481.9	822.0	396.8	311.8	708.6	850.3	340.1	538.6	822.0	708.6
IH16	992.06	878.7	311.8	538.6	368.5	935.4	311.8	283.5	283.5	907.0	481.9	566.9	396.8	226.8	141.7		170.1	623.6	963.7	538.6	453.5	850.3	992.1	481.9	680.3	963.7	850.3
IH17	1,162.1	1,048.8	481.9	368.5	538.6	1,105.4	141.7	453.5	453.5	1,077.1	651.9	737.0	566.9	396.8	311.8	170.1		793.7	1,133.8	708.6	623.6	1,020.4	1,162.1	651.9	850.3	1,133.8	1,020.4
IH18	368.48	255.1	311.8	1,162.1	255.1	311.8	935.4	340.1	340.1	283.5	141.7	56.7	226.8	396.8	481.9	623.6	793.7		340.1	85.0	170.1	226.8	368.5	141.7	56.7	340.1	226.8
IH19	28.34	85.0	651.9	1,502.3	595.2	28.4	1,275.5	680.3	680.3	56.7	481.9	396.8	566.9	737.0	822.0	963.7	1,133.8	340.1		425.2	510.2	113.4	28.3	481.9	283.5	0.0	113.4
IH20	453.51	340.1	226.8	1,077.1	170.1	396.8	850.3	255.1	255.1	368.5	56.7	28.3	141.7	311.8	396.8	538.6	708.6	85.0	425.2		85.0	311.8	453.5	56.7	141.7	425.2	311.8
IH21	538.54	425.2	141.7	992.1	85.0	481.9	765.3	170.1	170.1	453.5	28.3	113.4	56.7	226.8	311.8	453.5	623.6	170.1	510.2	85.0		396.8	538.5	28.3	226.8	510.2	396.8
IH22	141.72	28.4	538.6	1,388.9	481.9	85.0	1,162.1	566.9	566.9	56.7	368.5	283.5	453.5	623.6	708.6	850.3	1,020.4	226.8	113.4	311.8	396.8		141.7	368.5	170.1	113.4	0.0
IH23	0	113.4	680.3	1,530.6	623.6	56.7	1,303.8	708.6	708.6	85.0	510.2	425.2	595.2	765.3	850.3	992.1	1,162.1	368.5	28.3	453.5	538.5	141.7		510.2	311.8	28.3	141.7
IH24	510.2	396.8	170.1	1,020.4	113.4	453.5	793.7	198.4	198.4	425.2	0.0	85.0	85.0	255.1	340.1	481.9	651.9	141.7	481.9	56.7	28.3	368.5	510.2		198.4	481.9	368.5
IH25	311.79	198.4	368.5	1,218.8	311.8	255.1	992.1	396.8	396.8	226.8	198.4	113.4	283.4	453.5	538.6	680.3	850.3	56.7	283.5	141.7	226.8	170.1	311.8	198.4		283.5	170.1
IH26	28.34	85.0	651.9	1,502.3	595.2	28.4	1,275.5	680.3	680.3	56.7	481.9	396.8	566.9	737.0	822.0	963.7	1,133.8	340.1	0.0	425.2	510.2	113.4	28.3	481.9	283.5		113.4
IH27	141.72	28.4	538.6	1,388.9	481.9	85.0	1,162.1	566.9	566.9	56.7	368.5	283.5	453.5	623.6	708.6	850.3	1,020.4	226.8	113.4	311.8	396.8	0.0	141.7	368.5	170.1	113.4	

Source: Original data.

Table 4. SDI values for sunflower hybrids, class TMH (Tribenuron Methyl hybrids)

	TMH1	TMH2	TMH3	TMH4	TMH5	TMH6	TMH7	TMH8	TMH9	TMH10	TMH11	TMH12	TMH13	TMH14	TMH15	TMH16	TMH17	TMH18	TMH19	TMH20	TMH21
TMH1		170.1	425.2	680.3	56.7	595.2	113.4	28.3	141.7	198.4	425.2	340.1	56.7	510.2	340.1	56.7	595.2	453.5	680.3	311.8	595.2
TMH2	170.1		255.1	510.2	226.8	425.2	56.7	141.7	28.4	28.3	255.1	170.1	113.4	340.1	170.1	226.8	765.3	283.4	510.2	141.7	425.2
TMH3	425.2	255.1		255.1	481.9	170.1	311.8	396.8	283.5	226.8	0.0	85.0	368.5	85.0	85.0	481.9	1,020.4	28.3	255.1	113.4	170.1
TMH4	680.3	510.2	255.1		737.0	85.0	566.9	651.9	538.6	481.9	255.1	340.1	623.6	170.1	340.1	737.0	1,275.5	226.8	0.0	368.5	85.0
TMH5	56.7	226.8	481.9	737.0		651.9	170.1	85.0	198.4	255.1	481.9	396.8	113.4	566.9	396.8	0.0	538.6	510.2	737.0	368.5	651.9
TMH6	595.2	425.2	170.1	85.0	651.9		481.9	566.9	453.5	396.8	170.1	255.1	538.6	85.0	255.1	651.9	1,190.5	141.7	85.0	283.5	0.0
TMH7	113.4	56.7	311.8	566.9	170.1	481.9		85.0	28.3	85.0	311.8	226.8	56.7	396.8	226.8	170.1	708.6	340.1	566.9	198.4	481.9
TMH8	28.3	141.7	396.8	651.9	85.0	566.9	85.0		113.4	170.1	396.8	311.8	28.4	481.9	311.8	85.0	623.6	425.2	651.9	283.5	566.9
TMH9	141.7	28.4	283.5	538.6	198.4	453.5	28.3	113.4		56.7	283.5	198.4	85.0	368.5	198.4	198.4	737.0	311.8	538.6	170.1	453.5
TMH10	198.4	28.3	226.8	481.9	255.1	396.8	85.0	170.1	56.7		226.8	141.7	141.7	311.8	141.7	255.1	793.7	255.1	481.9	113.4	396.8
TMH11	425.2	255.1	0.0	255.1	481.9	170.1	311.8	396.8	283.5	226.8		85.0	368.5	85.0	85.0	481.9	1,020.4	28.3	255.1	113.4	170.1
TMH12	340.1	170.1	85.0	340.1	396.8	255.1	226.8	311.8	198.4	141.7	85.0		283.5	170.1	0.0	396.8	935.4	113.4	340.1	28.4	255.1
TMH13	56.7	113.4	368.5	623.6	113.4	538.6	56.7	28.4	85.0	141.7	368.5	283.5		453.5	283.5	113.4	651.9	396.8	623.6	255.1	538.6
TMH14	510.2	340.1	85.0	170.1	566.9	85.0	396.8	481.9	368.5	311.8	85.0	170.1	453.5		170.1	566.9	1,105.4	56.7	170.1	198.4	85.0
TMH15	340.1	170.1	85.0	340.1	396.8	255.1	226.8	311.8	198.4	141.7	85.0	0.0	283.5	170.1		396.8	935.4	113.4	340.1	28.4	255.1
TMH16	56.7	226.8	481.9	737.0	0.0	651.9	170.1	85.0	198.4	255.1	481.9	396.8	113.4	566.9	396.8		538.6	510.2	737.0	368.5	651.9
TMH17	595.2	765.3	1,020.4	1,275.5	538.6	1,190.5	708.6	623.6	737.0	793.7	1,020.4	935.4	651.9	1,105.4	935.4	538.6		1,048.8	1,275.5	907.0	1,190.5
TMH18	453.5	283.4	28.3	226.8	510.2	141.7	340.1	425.2	311.8	255.1	28.3	113.4	396.8	56.7	113.4	510.2	1,048.8		226.8	141.7	141.7
TMH19	680.3	510.2	255.1	0.0	737.0	85.0	566.9	651.9	538.6	481.9	255.1	340.1	623.6	170.1	340.1	737.0	1,275.5	226.8		368.5	85.0
TMH20	311.8	141.7	113.4	368.5	368.5	283.5	198.4	283.5	170.1	113.4	113.4	28.4	255.1	198.4	28.4	368.5	907.0	141.7	368.5		283.5
TMH21	595.2	425.2	170.1	85.0	651.9	0.0	481.9	566.9	453.5	396.8	170.1	255.1	538.6	85.0	255.1	651.9	1,190.5	141.7	85.0	283.5	

Source: Original data.

For the IH hybrids, Figure 5, within the C2-1 sub-cluster, the IH1 and IH23 hybrids with the highest production level are marked in red. For the TMH hybrids, Figure 6, within the C2-1 sub-cluster, the TMH4 and TMH19 hybrids with the highest level of production are marked in red. The evaluation of the level of similarity, based on value data, in addition to the graphic distribution (Figures 5 and 6), was made on the basis of the SDI values for the hybrids of each class, Table 3 in the case of the hybrids of the IH class, and Table 4 for the hybrids of the TMH class.

Ebeed et al. (2019) [12] communicated production results and quality indices of certain sunflower hybrids, under conditions of stress (hydric and saline) and of the genotype x environment interaction, as well as the response of the hybrids to irrigation. The comparative analysis of seven sunflower hybrids facilitated the quantification of some physiological and biometric parameters, achene production, yield and quality indices as a response of the hybrids to the crop conditions [28]. Increased production in some types of sunflower (up to 323 kg ha^{-1}) was reported by Brewer et al. (2023) [7] in relation to pollinators (bees), and the authors recommended based on the study, holistic insect management in sunflower, with benefits on yield (bees) and the reduction of harmful insects.

CONCLUSIONS

Sunflower hybrids from the two classes (Imazamox – IH, 27 hybrids; Tribenuron Methyl – TMH, 21 hybrids) ensured different productions in the study conditions (chernozem soil, non-irrigated crop system). Different values were recorded for the average production calculated on the two classes of hybrids (IH-Avg=3,038.13 kg ha^{-1}, TMH-Avg=3,287.98 kg ha^{-1}).

Appropriate mathematical and statistical tests (Null Hypothesis (H0), t-test for Equality of Means; non-parametric Mann-Whitney test) confirmed the differences between the two classes of hybrids (IH, N=27; TMH, N=21), with regarding the registered and calculated production.

By comparing the productions for each hybrid, in relation to the average production calculated on the two classes of hybrids (IH-Avg; TMH-Avg), as well as in relation to the average production per company, within each class (C-Avg), of it was possible to classify the hybrids under the aspect of production and yield.

The cluster analysis of the data on each class of hybrids facilitated the classification of hybrids in relation to the degree of similarity for production, and the results show importance for research and agricultural practice, in order to select genotypes with an adequate response.

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REFERENCES

[1]Abdelsatar, M.A., Ahmed, A.A.E-H., Ibrahim, S.E-L.K., 2020, Genetic variability and selection criteria of some sunflower genotypes under different pollination methods, Acta Agric. Slov., 116(1):35047.

[2]Adeleke, B.S., Babalola, O.O., 2020, Oilseed crop sunflower (*Helianthus annuus*) as a source of food: Nutritional and health benefits, Food Sci Nutr., 8(9):4666-4684.

[3]Agüera, E., de la Haba, P., 2021, Climate change impacts on sunflower (*Helianthus annus* L.) plants, Plants 10(2):2646.

[4]Alharthi, A.S., Al-Baadani, H.H., Al-Badwi, M.A., Abdelrahman, M.M., Alhidary, I.A., Khan, R.U., 2021, Effects of sunflower hulls on productive performance, digestibility indices and rumen morphology of growing awassi lambs fed with total mixed rations, Vet Sci., 8(9):174.

[5]Amirul, R., Muhtadi, 2020, Literature review: Study of antibacterial activity of sunflower (*Helianthus Annuus* L.) extract and its phytochemical profiles, J. Nutraceuticals Herbal Medicine, 3(2):29-37.

[6]Barrio-Conde, M., Zanella, M.A., Aguiar-Perez, J.M., Ruiz-Gonzalez, R., Gomez-Gil, J., 2023, A deep learning image system for classifying high oleic sunflower seed varieties, Sensors, 23:2471.

[7]Brewer, G.J., Miwa, K., Hanford, K., 2023, Measuring bee effects on seed traits of hybrid sunflower, Plants, 12:2662.

[8]Chakraborty, N.R., Lakshman, S.S., Debnath, S., Rahimi M., 2022, Yield stability and economic heterosis analysis in newly bred sunflower hybrids

throughout diverse agro-ecological zones, BMC Plant Biol., 22:579.

[9]Debaeke, P., Bedoussac, L., Bonnet, C., Bret-Mestries, E., Seassau, C., Gavaland, A., Raffaillac, D., Tribouillois, H., Véricel, G., Justes, E., 2017, Sunflower crop: Environmental-friendly and agroecological, OCL, 24(3):D304.

[10]Debaeke, P., Casadebaig, P., Langlade, N.B., 2021, New challenges for sunflower ideotyping in changing environments and more ecological cropping systems, OCL, 28:29.

[11]Duruflé, H., Balliau, T., Blanchet, N., Chaubet, A., Duhnen, A., Pouilly, N., Blein-Nicolas, M., Mangin, B., Maury, P., Langlade, N.B., Zivy, M., 2023, Sunflower hybrids and inbred lines adopt different physiological strategies and proteome responses to cope with water deficit, Biomolecules, 13:1110.

[12]Ebeed, H.T., Hassan, N.M., Keshta, M.M., Hassanin, O.S., 2019, Comparative analysis of seed yield and biochemical attributes in different sunflower genotypes under different levels of irrigation and salinity, Egypt. J. Bot., 59(2):339-355.

[13]Gholami-Yangije, A., Pirmohammadi, R., Khalilvandi-Behroozyar, H., 2019, The potential of sunflower (*Helianthus annuus*) residues silage as a forage source in Mohabadi dairy goats, Vet. Res. Forum., 10(1):59-65.

[14]Giannini, V., Maucieri, C., Vamerali, T., Zanin, G., Schiavon, S., Pettenella, D.M., Bona, S., Borin, M., 2022, Sunflower: From Cortuso's description (1585) to current agronomy, uses and perspectives, Agriculture, 12:1978.

[15]Gul, V., Coban, F., 2020, Determination of yield and quality parameters of oil sunflower genotypes grown in Turkey, Turk. J. Field Crops, 25(1):9-17.

[16]Guo, S., Ge, Y. & Na Jom, K., 2017, A review of phytochemistry, metabolite changes, and medicinal uses of the common sunflower seed and sprouts (*Helianthus annuus* L.), Chem. Cent. J., 11:95.

[17]Hammer, Ø., Harper, D.A.T., Ryan, P.D., 2001, PAST: Paleontological Statistics software package for education and data analysis, Palaeontol. Electron., 4(1):1-9.

[18]Krystofova, O., Shestivska, V., Galiova, M., Novotny, K., Kaiser, J., Zehnalek, J., Babula, P., Opatrilova, R., Adam, V., Kizek, R., 2009, Sunflower plants as bioindicators of environmental pollution with lead (II) ions, Sensors (Basel), 9(7):5040-58.

[19]Lakshman, S.S., Chakraborty, N.R., Debnath, S., Kant, A., 2021, Genetic variability, character association and divergence studies in sunflower (*Helianthus annuus* L.) for improvement in oil yield, African J. Biol. Sci., 3(1):129-145.

[20]Lamichhane, J.R., Wojciechowski, A., Bourgeois, C., Debaeke, P., 2022, Genetic variability for early growth traits in second season sunflower, Front. Agron., 4:822456.

[21]Lukomets, V.M., Trunova, M.V., Demurin, Y.N., 2021, Modern trends in breeding and genetic improvement of sunflower varieties and hybrids at VNIIMK. Vavilovskii Zhurnal Genet Selektsii, 25(4):388-393.

[22]Makarchuk, O., Kuts, T. 2022, Features of regional production of sunflower seeds in the period 1990-2021 in Ukraine, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 22(4):387-394.

[23]Mladenović, E., Cvejić, S., Čukanović, J., Žeravica, G., Jocić, S., 2016, Evaluation of sunflower genotypes for ornamental use, Contemporary Agriculture, 65(1-2):39-43.

[24]Nhundu, K., Gandidzanwa, C., Chaminuka, P., Mamabolo, M., Mahlangu, S., Makhura, M.N., 2022, Agricultural supply response for sunflower in South Africa (1947–2016): The partial Nerlovian framework approach, African J. Sci., Technol., Innov. Dev., 14(2):440-450.

[25]Petraru, A., Ursachi, F., Amariei, S., 2021, Nutritional characteristics assessment of sunflower seeds, oil and cake. Perspective of using sunflower oilcakes as a functional ingredient, Plants (Basel), 10(11):2487.

[26]Santos, Z.M., De Oliveira, T.R.A., Gravina, G.A., Sant'Anna, C.Q., Da Cruz, D.P., De Oliveira, G.H.F., Dos Santos Rocha, A., Dos Santos, J.G.C., Daher, R.F., 2018, Yield potential of different sunflower genetic classes: A multivariate approach, Emir. J. Food Agric., 30(12):1036-1041.

[27]Sefaoglu, F., 2023, Investigation on the genotype and environmental relationships on yield and its components in sunflower (*Helianthus annuus* L.) in eastern region of Türkiye, Indian J. Genet., 83(1) :77-87.

[28]Sher, A., Suleman, M., Sattar, A., Qayyum, A., Ijaz, M., Allah, S.-U., Al-Yahyai, R., Al-Hashimi, A., Elshikh, M.S., 2022, Achene yield and oil quality of diverse sunflower (*Helianthus annuus* L.) hybrids are affected by different irrigation sources, J. King Saud Univ. Sci., 34(4):102016.

[29]Zeinalzadeh-Tabrizi, H., Haliloglu, K., Ghaffari, M., Hosseinpour, A., 2018, Assessment of genetic diversity among sunflower genotypes using microsatellite markers, Mol. Biol. Res. Commun., 7(3):143-152.

[30]Zorić, M., Cvejić, S., Mladenović, E., Jocić, S., Babić, Z., Marjanović, Jeromela, A., Miladinović, D., 2020, Digital image analysis using FloCIA software for ornamental sunflower ray floret color evaluation, Front. Plant Sci., 11:584822.