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Evaluation of Morphological Characteristics of Different Sunflower (*Helianthus annuus* L.) Genotypes that Can Grow in Muş Conditions with Different Analysis Methods

Nurettin BARAN [1*]
[1] Muş Alparslan University, Faculty of Applied Sciences, Department of Plant Production and Technologies, Muş
*Corresponding author: n.baran@alparslan.edu.tr

Abstract
The sunflower (*Helianthus annuus* L.) plant is produced in the world and in Türkiye for the vegetable oil obtained from its seeds. It is an economically significant oil plant in the world and Türkiye with its high oil content (45-50%). It is grown as oil and snack food in different ecological regions of Türkiye. This study was conducted in irrigated conditions in Muş province in the 2023 production season. It was established as 5 blocks according to the Augmented trial design, using 81 genotypes as research material. In line with the parameters obtained from the research, it varied between 108.78-200.05 cm plant height, 14.33-23.33 cm head diameter, 38.38-106.58 g 1000 seed weight, 157.63-390.61 kg da^{-1} seed yield. Plant height of genotypes compared to control varieties in terms of all examined traits; 4, head diameter; 6, 1000 seed weight; 16, seed yield; 13 genotypes were found to be superior to control varieties. According to all analysis methods, SLP was found to have high levels of adherence to HD and SUD, and the remaining other examined characteristics were determined to be interrelated. Also the study; G67, G66, G41 and G30 genotypes were found to be higher than the control varieties in terms of all characteristics. In conclusion; It is anticipated that, in the light of the data obtained in the study, it will help local producers and scientists plan similar research.

Research Article

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1. Introduction

Factors such as the rapid increase in the world population, climate change, which is one of the most challenging and difficult to solve global problems faced by humanity, and recent epidemics and wars, reveal the strategic importance of agriculture day by day. Contribution to people's nutrition and the stable maintenance of many industrial areas depending on agriculture can only be achieved through agricultural production. The contribution of vegetable oils to human nutrition is quite high. In Türkiye, the need for vegetable oil is increasing parallel to the human population. As a result of this situation, there is a need for more oil than many other countries. Oilseed plants are an indispensably important source of raw materials for many different sectors such as oil, feed and chemicals.

Since there is not enough production of oilseed plants in Türkiye, crude oil production is insufficient. For this reason, since the required crude oil consumption is not met sufficiently, a large amount of crude oil is imported from foreign countries every year.

According to the usage status of oilseed plants in the world, there are soybean, sunflower, cotton, rapeseed, peanut, sesame, safflower, castor oil, poppy, flax, hemp, jojoba, olive, palm and coconut, while in Türkiye, sunflower, cotton, soybean, peanut, poppy, sesame, safflower, rapeseed, corn and olive, and the most production belongs to the sunflower plant (49.8%) (Durmaz, 2012; Killi and Beycioglu, 2019; Arioglu et al., 2020; Andirman and Baran, 2023).

Sunflower is among the important oil crops in the world and in Türkiye. According to USDA data, total sunflower production in the world is 52.4 million tons in the 2023 production season. Russia ranks first with (16.3%), Ukraine ranks second (12.2%) and the EU ranks third (9.2%). Türkiye ranks 6th in world sunflower production with a share of 3%. According to Tuik data, in 2023, the oil sunflower cultivation area is determined as 952.605 ha, the production amount is 2 million tons and the yield is 227.0 kg da^{-1}. The provinces with the highest production are; Tekirdağ, Edirne, Konya, Kırklareli, Adana, Çorum and Çanakkale (Figure 1) (Anonymous, 2024).

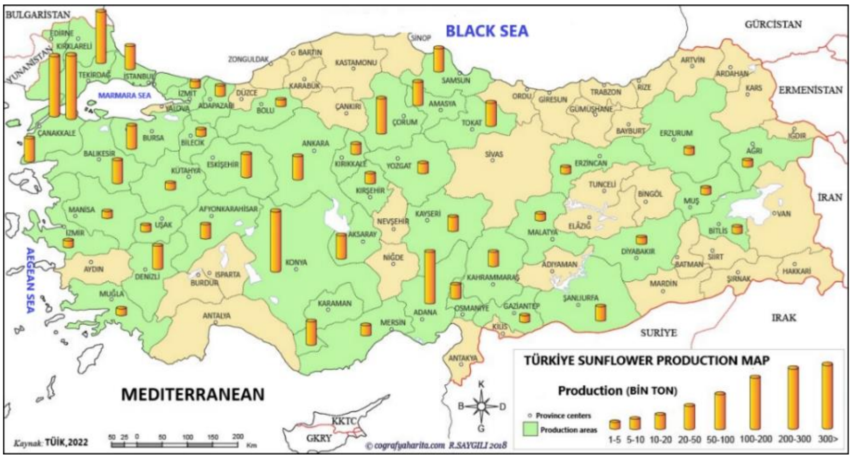

Figure 1. Türkiye sunflower production map

In Türkiye, sunflower is an oil plant with the largest cultivation area and production amount, and its importance is increasing day by day, as it is the product that people prefer most as edible oil. For this reason, it is essential to exceed the current production amount by aiming to increase seed yield and oil rate. Although sunflower cultivation occurs almost everywhere in our country, a significant share of the cultivation areas belongs to the Thrace Region. Sunflower is a plant of strategic importance for this region. The yield to be obtained from the plant produced; It is under the joint interaction of genotype and environment and is especially affected by factors such as climate and soil structure (Gul et al., 2017).

Depending on the cultivation of sunflower in different ecologies, factors such as variety and agricultural practices have positive or negative effects on the components that create yield and quality (seed yield, oil ratio, oil yield, fatty acid composition, head diameter, number of seeds, plant height, etc.). Therefore, in order to increase the yield per unit area of sunflower; Necessary cultural practices should be in accordance with the physiological and morphological characters of the varieties, and planting should be carried out by selecting varieties suitable for the region (Cosge and Ulukan, 2005).

When the sunflower plant, which has a high adaptability and is partially drought resistant, is grown in areas suitable for irrigation, there is an increase in yield and productivity parameters (seed yield, plant height, oil rate, number of seeds, head diameter, etc.). Recently, due to the high premium support paid to the sunflower plant and its alternation with sugar beet and potatoes, a significant increase has been achieved in the cultivation areas.

In Türkiye, all regions except the Eastern Black Sea Region are suitable for sunflower cultivation. It has started to gain importance as a very important rotation plant for irrigable areas in the Eastern Anatolia Region. Muş, which has one of the largest plains in Türkiye, has significant potential with its fertile soil suitable for growing various products. Since there was no water in the Muş Plain for years, there were limitations in the production patterns of many agricultural areas. Later, with the completion of the Alparslan 2 Dam, which is the largest irrigation project and started to retain water, and the canal network between the lands, farmers started to produce under irrigated conditions and product diversity began to emerge in the region.

The aim of this research is to determine the genotypes that are most suitable for the region among different sunflower genotypes that can grow under Muş conditions and to determine their effects on yield and yield parameters. As a result of the study, it is thought that it will help local farmers and shed light on the planning of similar research by scientists.

2. Material and Methods

The study was carried out in irrigated conditions in the application area of Mus Alparslan University campus in 2023. A total of 81 genotypes obtained from Trakya Agricultural Research Institute and commercial companies were used as research material (Table 1).

Table 1. Information on sunflower genotypes used in the study

S.N.	Genotype Name		Breeder Organization Name
G1	TTAE-IMI-21-16	Genotype	Trakya Agricultural Research Institute
G2	TTAE-IMI-21-02	Genotype	Trakya Agricultural Research Institute
G3	TTAE-21-85	Genotype	Trakya Agricultural Research Institute
G4	TTAE-IMI-21-17	Genotype	Trakya Agricultural Research Institute
G5	TTAE-21-58	Genotype	Trakya Agricultural Research Institute
G6	TTAE-IMI-21-45	Genotype	Trakya Agricultural Research Institute
G7	TTAE-IMI-21-44	Genotype	Trakya Agricultural Research Institute
G8	TTAE-21-03	Genotype	Trakya Agricultural Research Institute
G9	TTAE-IMI-21-126	Genotype	Trakya Agricultural Research Institute
G10	TTAE-IMI-21-120	Genotype	Trakya Agricultural Research Institute
G11	TTAE-IMI-21-142	Genotype	Trakya Agricultural Research Institute
G12	TTAE-21-09	Genotype	Trakya Agricultural Research Institute
G13	TTAE-IMI-21-31	Genotype	Trakya Agricultural Research Institute
G14	TTAE-IMI-21-99	Genotype	Trakya Agricultural Research Institute
G15	TTAE-IMI-21-49	Genotype	Trakya Agricultural Research Institute
G16	TTAE-21-61	Genotype	Trakya Agricultural Research Institute
G17	TTAE-IMI-21-87	Genotype	Trakya Agricultural Research Institute
G18	TTAE-IMI-21-122	Genotype	Trakya Agricultural Research Institute
G19	TTAE-IMI-21-17	Genotype	Trakya Agricultural Research Institute
G20	TTAE-IMI-21-103	Genotype	Trakya Agricultural Research Institute

G21	TTAE-21-70	Genotype	Trakya Agricultural Research Institute
G22	TTAE-21-07	Genotype	Trakya Agricultural Research Institute
G23	TTAE-IMI-21-10	Genotype	Trakya Agricultural Research Institute
G24	TTAE-21-27	Genotype	Trakya Agricultural Research Institute
G25	TTAE-IMI-21-08	Genotype	Trakya Agricultural Research Institute
G26	TTAE-IMI-21-56	Genotype	Trakya Agricultural Research Institute
G27	TTAE-21-64	Genotype	Trakya Agricultural Research Institute
G28	TTAE-IMI-21-63	Genotype	Trakya Agricultural Research Institute
G29	TTAE-21-30	Genotype	Trakya Agricultural Research Institute
G30	TTAE-IMI-21-9	Genotype	Trakya Agricultural Research Institute
G31	TTAE-IMI-21-06	Genotype	Trakya Agricultural Research Institute
G32	P-119	Variety	CORTEVA
G33	P64KL62	Variety	CORTEVA
G34	P64HH106	Variety	CORTEVA
G35	11TR077	Variety	Trakya Agricultural Research Institute
G36	SY GRANIT	Variety	SYNEGNTA
G37	SUOMI	Variety	SYNEGNTA
G38	M98CL88	Variety	MAY
G39	LG-50505	Variety	LG
G40	LG-59580	Variety	LG
G41	P64LC108	Variety	CORTEVA
G42	LG50521-CLP	Variety	LG
G43	LG50501-CLP	Variety	LG
G44	SY-SANTOS	Variety	SYNEGNTA
G45	P64LL62	Variety	CORTEVA
G46	LG50480	Variety	LG
G47	M94CLP80	Variety	MAY
G48	SY-CHELSEA-CLP	Variety	SYNEGNTA
G49	LG50559-SX	Variety	LG
G50	SUZUKA	Variety	SYNEGNTA
G51	OR-21015	Genotype	Trakya Agricultural Research Institute
G52	LG5669-CLP	Variety	LG
G53	OR-21034	Genotype	Trakya Agricultural Research Institute
G54	P113	Variety	CORTEVA
G55	OR21027	Genotype	Trakya Agricultural Research Institute
G56	OR21040	Genotype	Trakya Agricultural Research Institute
G57	OR21055	Genotype	Trakya Agricultural Research Institute
G58	OR21026	Genotype	Trakya Agricultural Research Institute
G59	OR21035	Genotype	Trakya Agricultural Research Institute
G60	OR21075	Genotype	Trakya Agricultural Research Institute
G61	OR21056	Genotype	Trakya Agricultural Research Institute
G62	OR21064	Genotype	Trakya Agricultural Research Institute
G63	OR21030	Genotype	Trakya Agricultural Research Institute
G64	OR2108	Genotype	Trakya Agricultural Research Institute
G65	OR21063	Genotype	Trakya Agricultural Research Institute
G66	OR2107	Genotype	Trakya Agricultural Research Institute
G67	OR21010	Genotype	Trakya Agricultural Research Institute
G68	OR21017	Genotype	Trakya Agricultural Research Institute
G69	OR2109	Genotype	Trakya Agricultural Research Institute
G70	LG50550-CLP	Variety	LG
G71	P64LP130	Variety	CORTEVA
G72	LG50455-CLP	Variety	LG
G73	LG50511-CLP	Variety	LG
G74	LG50797-CLP	Variety	LG
G75	SURELI	Variety	SYNEGNTA
G76	LG50689-SX	Variety	LG
G77	LG5485	Variety	LG
G78 (K1)	LG50501	Variety	LG
G79 (K2)	SY NEBRASKA	Variety	SYNEGNTA
G80 (K3)	ALCANTARA	Variety	SYNEGNTA
G81 (K4)	LG50635-CLP	Variety	LG

S.N: Sequence number

Sampling was done from 0-30 depth to determine the soil properties of the trial area. For this purpose, it was determined that the soil of the trial area was clayey-loamy, slightly saline, moderate in organic matter and low in lime (Table 2).

Table 2. Soil characteristics of the trial area.

Years	Depth (cm)	Structue (%)	Electrical conductivity/ Salt (dS m^{-1})	pH 'sç'	Lime ($CaCO_3$) (%)	Phosprus 'P_2O_5' (kg da^{-1})	Organic Matter (%)
2023	0-30	Clay loamy	0.43	7.1	2.65	2.25	2.39

When the climate data for the sunflower growing period of 2023 was examined, it was determined that the total amount of precipitation during the period was 29.9 mm less than the long-term average, and that the amount of precipitation, especially in june, july, august and september, was much less than the long-term average. During the growing period, the highest rainfall occurred in October, while the lowest rainfall occurred in July (Figure 2). High rainfall in October has been adjusted so that it does not affect the harvesting process.

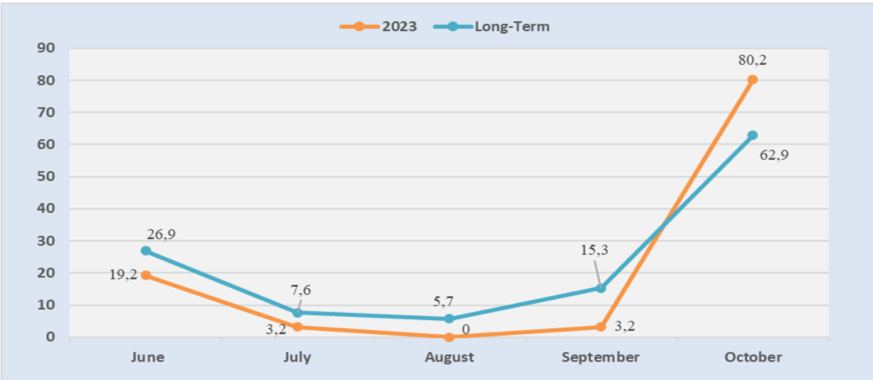

Figure 2. Average rainfall values (mm) of Muş province for the 2023 growing season and long years

When average temperature values were examined, it was determined that all months during the growing season were above the average for many years. In the climate data for the 2023 sunflower growing period, it was determined that the temperature values on a monthly basis were generally higher than the long-term average. It is thought that the rapid transition from the vegetative phase to the generative phase due to the temperature values on a monthly basis being above the long-term average in the season in which the research was conducted, negatively affected the yield and yield parameters of the plant (Figure 3).

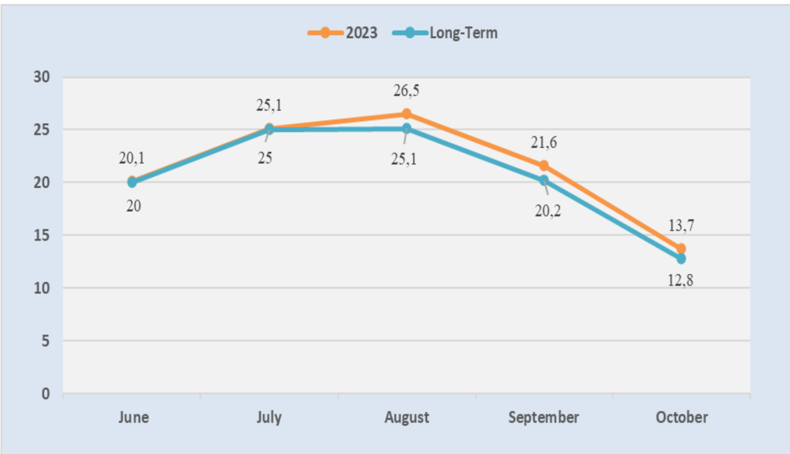

Figure 3. Average temperature values (ºC) of Muş province for the 2023 growing season and long years

The research was conducted according to the augmented trial design with a total of 5 blocks, each of the 4 blocks consisting of 22 rows and the last block consisting of 9 rows. While the control varieties (LG50501, SY Nebraska, Alcantara and LG50635-CLP) were repeated in each block, other sunflower genotypes used for the research were distributed to the blocks respectively without repetition (Peterson,1994). The trial area was left empty with an isolation distance of 3 meters between the blocks. Planting procedures were arranged so that the row length of each genotype used in the research was 6 m, row spacing was 70 cm, within row spacing was 30 cm, and each plot had 2 rows. Before planting, 15 kg/da of Diammonium phosphate (18-46-0) bottom fertilizer was applied, and then 15 kg/da of urea (46-0-0) was applied as top fertilizer along with the hoe when the plant was 30-40 cm tall. Trial care was carried out in the form of thinning and hand hoeing, approximately 2 weeks after the plant emerged on the soil surface. When the plants were 10-15 cm height, hoeing, throat filling and singling were carried out on the rows.

Irrigation in the trial; Since there was not enough moisture, it was applied in 4 stages in total after planting, namely the head formation period (R1), the beginning of flowering (R5) and the milk formation period (R5.5-8). The critical periods for irrigation in sunflowers are the formation of the first head, the beginning of flowering, and the beginning of milk formation in the grains, when it needs water the most. Since the flowering period is the most critical period due to temperature, irrigation during this period is also important for yield.

In the research, plant height (cm), head diameter (cm), stem lower part diameter (mm), diameter of the upper part of the stem (mm), 1000 seed weight (g), seed width (mm), seed length (mm) and seed yield (kg/da) characteristics were examined.

The experiment was established in an Augmented trial design with a total of 81 oil sunflower genotypes, including 4 control varieties. The morphological characteristics examined were determined by taking the average of 10 randomly selected plants representing each parcel. JMP 7.0 package program was used for analysis, and the significance levels between groups were determined according to the LSD test ($p \leq 0.01$ and $p \leq 0.05$) (Kalayci, 2005). Visual graphics, comparison were created with the help of GraphPad Prism 9 (GraphPad Software, USA) software and the heat map was created with the help of Heatmap clustering-ClustVis.

3. Results and Discussion

Differences between genotypes for each trait were evaluated according to the LSD test. In the study, it was determined that the values obtained from the examined characteristics of many genotypes were superior to the control varieties.

3.1. Plant height (cm)

According to the variance analysis results obtained in this research conducted to determine the adaptation ability and yield parameters of the sunflower plant, it was found to be statistically significant at the 1% level (Table 2). In the study, it was determined that plant height varied between 108.78 and 200.05 cm (Table 3). G23 (200.05 cm), G67 (189.95 cm), G4 (186.56 cm), G2 (183.14 cm) and K2 (174.45 cm) were determined to be the best genotypes in terms of plant height, respectively. As a result, it was determined that the genotypes in the first four rows were higher than the control group. According to the results of studies conducted by different researchers on sunflower plant height values; Alpman and Sinan (2020), 133.6-159.9 cm; Yazici (2020), 154.3-265.4 cm; Dumlu-Gul and Tan (2016) reported that the length varies between 152.9-191.8 cm. It has been suggested that these differences between varieties arise from the genetic structure of the plant.

3.2. Head diameter (cm)

According to the variance analysis results obtained in this research conducted to determine the adaptation ability and yield parameters of the sunflower plant, it was found to be statistically significant at the 5% level (Table 2). In the study, it was determined that the head diameter varied between 14.33-23.33 cm (Table 3). As a result of the data obtained, G69 (23.33 cm), G58 (21.99 cm), G55 (21.29 cm), G59 (21.29 cm), G2 (21.14 cm) and G44 (21.06 cm) genotypes were found to have higher values than the varieties in the control group. According to the results of studies conducted by different researchers on sunflower head diameter values; Alpman and Sinan (2020), 17.2-21.4 cm; Yazici, (2020) stated that it varies between 17.0-22.2 cm. It is parallel to the findings obtained from the research. Studies conducted with different varieties in different regions of our country have revealed that head diameter is affected by ecological factors, soil structure, cultivation techniques and cultural practices, and is also under the control of genetic structure.

3.3. Stem lower part diameter (mm)

According to the variance analysis results obtained in this research conducted to determine the adaptation ability and yield parameters of the sunflower plant, it was found to be statistically significant at the 5% level (Table 2). The Stem lower part diameter values obtained from this study were determined between 11.40 and 24.64 mm (Table 3). The genotypes with the highest values, G69 (24.64 mm), G55 (24.32 mm) and G4 (24.08 mm), respectively, were determined to have higher values than the varieties in the control group.

3.4. Stem upper part diameter (mm)

According to the variance analysis results, it was found to be statistically significant at the 5% level (Table 2). According to the results of this research, the Stem upper part diameter values were determined as 7.64-21.27 mm (Table 3). The genotypes with the highest values, G69 (21.27 mm), G62 (20.01 mm) and G68 (18.77 mm), respectively, were determined to have higher values than the varieties in the control group.

3.5. 1000 seed weight (g)

According to the variance analysis results obtained in this research conducted to determine the adaptation ability and yield parameters of the sunflower plant, it was found to be statistically significant at the 1% level (Table 2). The weight of 1000 seed obtained from this study was found to be between 38.38-106.58 g (Table 3). It was determined that G30 (106.58 g), G67 (102.14 g) and G31 (99.96 g) genotypes had higher values than the varieties in the control group. In their study, Aydogdu and Haliloglu (2023) reported that 1000 seed weights were obtained between 64.76-71.17 g. In the light of the research results, it has been stated that 1000 seed weight is a feature that varies according to the genetic structure of the variety, climatic conditions, applied cultural processes and growing conditions in studies conducted in different regions.

3.6. Seed width (mm)

According to the results of variance analysis, it was not found to be statistically significant (Table 2). The seed width value was determined to be between 3.08-8.49 mm (Table 3). Many genotypes carried out in the study were found to be higher than the varieties in the control group in terms of seed width. In the study conducted by Yazici (2020), the seed width was determined as 7.9-9.6 mm.

3.7. Seed length (mm)

According to the results of variance analysis, seed length was found to be statistically significant at the 1% level (Table 2). According to the results of this study, the seed length value was determined between 9.33-18.97 mm (Table 3). While the longest seed length was G68 (18.97 mm), the lowest was obtained from the G50 (9.33 mm) genotype. Many genotype values were found to be higher in seed length than the varieties in the control group. In the study conducted by Yazici (2020), the seed length was determined as 20.4-25.9 mm.

3.8. Seed yield (kg da^{-1})

According to the variance analysis results obtained in this research conducted to determine the adaptation ability and yield parameters of the sunflower plant, it was found to be statistically significant at the 5% level (Table 2). Seed yield was determined as 157.63-390.61 kg da^{-1} (Table 3). The genotypes with the highest values were determined as G51 (390.61 kg da^{-1}), G62

(382.57 kg da-1) and G55 (364.07 kg da-1), respectively. Seed yield values of many genotypes were determined to be higher than the varieties in the control group. As a result of the seed yield study conducted by some researchers on the subject; Alpman and Sinan (2020) as 344.6-465 kg da-1; Erbas and Senates (2020) as 235.4-348.6 kg da-1; Yazici (2020) as 180.4-474.0 kg da-1; Yilmaz and Erdem (2021) as 160.0- 255.0 kg da-1; Aydogdu and Haliloglu (2023) as 383.04-419.18 kg da-1. In addition to the genetic factor of the sunflower plant, many factors such as physiological, morphological, agronomic and ecological affect the seed yield. As with other cultivated plants, choosing varieties suitable for the region is one of the main factors that increase yield and quality in sunflower cultivation. Many researchers reported that they obtained different seed yield values in studies conducted under different varieties and ecological conditions. It can be said that the differences in the findings obtained in the study from the results of the researchers are due to the differences in variety characteristics, fertilization, irrigation, ecological conditions, planting and harvest times.

Table 2. Variance Analysis Table of Mean Squares

Sources of Variance	SD	pH (cm)	HD (cm)	SLD (mm)	SUD (mm)	1000 SW (g)	SW (mm)	SL (mm)	SY (kg da^{-1})
Recurrence	4	296.98	32.171	15.68	36.27	47.57	18.34	1.73	9042.18
Genotype	80	21345.92**	269.19*	646.52*	492.94*	18476.27**	84.08^{öd}	394.47**	252711.25*
Mistake	12	535.24	21.99	29.32	36.05	639.39	12.03	2.51	16890.19
General Total	96	26668.58	415.31	725.79	660.15	20019.62	138.43	432.30	295908.35
CV (%)		**4.37**	**7.27**	**8.02**	**13.31**	**12.42**	**19.11**	**3.85**	**13.85**

PH: Plant height, **HD:** Head diameter, **SLD:** Stem lower part diameter, **SUD:** Stem upper part diameter, **1000 SW:** 1000 seed weight, **SW:** Seed width, **SL:** Seed length, **SY:** Seed yield

Table 3. Values and groupings of genotypes in terms of examined features

Genotype	PH (cm)	HD (cm)	SLD (mm)	SUD (mm)	1000 SW (g)	SW (mm)	SL (mm)	SY (kg da^{-1})
G1	156.99 f-w	18.36 b-p	18.31 e-c1	11.09 g-p	42.61 o-v	6.52 a-j	11.01 f-u	292.75 a-y
G2	183.14 a-d	21.14 a-g	22.54 a-a1	14.33 b-q	96.94 a-c	7.91 a-d	18.87 a	322.09 a-y
G3	154.23 f-x	16.38 ı-p	16.90 p-c1	11.85 e-p	45.93 m-v	6.28 a-j	10.93 f-u	278.53 a-y
G4	186.56 a-c	17.71 b-p	24.08 a-a1	16.04 a-q	84.21 a-g	**8.49 a**	**18.85 a**	294.8 a-y
G5	153.56 f-z	15.50 k-p	16.01 t-d1	12.03 e-p	44.62 n-v	5.70 a-k	9.57 s	208.89 o-y
G6	171.85 b-h	17.36 b-p	22.22 a-a1	14.53 b-q	63.30 f-u	7.41 a-j	11.39 e-u	279.34 a-y
G7	162.9 d-p	17.38 b-p	19.65 a-a1	12.25 e-p	53.41 h-v	**3.08 ı-k**	11.8 d-u	187.14 s-x
G8	143.56 l-ı1	18.14 b-p	18.10 e-c1	12.69 d-p	40.69 p-v	5.73 a-k	11.14 f-u	188.2 s-x
G9	139.36 s-k1	18.91 a-p	20.45 a-a1	12.49 d-p	50.75 h-v	6.49 a-j	11.03 f-u	238.89 c-y
G10	160.56 e-t	18.50 b-p	21.60 a-a1	14.76 b-q	52.77 h-v	6.45 a-j	12.1 c-u	289 a-y
G11	139.85 q-k1	17.71 b-p	19.91 a-a1	15.47 a-q	64.75 f-u	3.49 h-k	12.13 c-k	214.74 m-y
G12	139.56 q-k1	19.29 a-o	19.82 a-a1	13.03 c-q	52.25 h-v	6.93 a-j	10.84g-u	194.35 r-x
G13	159.14 e-v	19.29 a-o	22.37 a-a1	15.02 b-q	43.62 o-v	6.40 a-j	9.8 r-t	234.37 d-y
G14	171.71 b-n	19.71a-m	19.01 d-z	13.70 c-q	51.96 h-v	6.30 a-j	11,24 f-u	212.28 m-y
G15	144.06 l-ı1	16.63 d-p	19.60 a-a1	11.81 e-p	38.90 s-v	6.46 a-j	9.74 r-t	192.87 r-x
G16	143.42 m-ı1	17.29 c-p	16.62 r-d1	11.64 e-p	56.35 h-v	3.75 h-k	13.26 c	170.45 u-x
G17	150.33 g-g1	16.75 c-p	17.51 h-c1	11.47 g-p	63.40 f-u	5.15 a-k	11.24 f-u	351.67 a-ı
G18	136.19 v-k1	16.54 f-p	18.44 f-c1	11.90 f-p	53.62 h-v	4.84 b-k	10.05 q-t	255.12 b-y
G19	157.65 e-w	15.70 j-p	17.13 k-c1	9.55 l-p	**38.38 t-v**	4.38 e-k	10.79 ı-u	229.8 f-y
G20	159.05 e-u	17.25 c-p	15.85 v-d1	9.51 l-p	45.78 m-v	4.54 d-k	10.55 l-u	217.67 l-y
G21	144.55 k-ı1	17.48 b-p	17.30 ı-c1	11.80 f-p	46.91 k-v	5.32 a-k	11.85 c-u	241.13 c-y
G22	156.9 f-w	16.40 ı-p	17.85 g-c1	9.16 m-p	44.83 n-v	4.48 d-k	11.52 d-u	207.22 p-x
G23	**200.05 a**	15.82 j-p	21.25 a-a1	11.04 g-p	91.70 a-e	7.44 a-j	17.96 a-b	318.92 a-y
G24	128.05 f1-l1	14.82 o-p	13.49 b1-d1	9.09 m-p	46.63 k-v	5.36 a-k	11.43 e-u	221.39 j-y
G25	162.48 d-q	17.47 b-p	17.49 h-c1	12.20 e-p	49.09 ı-v	5.80 a-k	10.68 j-u	215.88 l-y
G26	161.05 d-t	17.40 b-p	21.93 a-a1	16.29 a-q	58.18 h-v	6.19 a-k	11.45 e-u	339.25 a-n
G27	158.3 e-w	18.25 b-p	23.34 a-a1	17.11 a-q	66.30 f-u	5.08 a-k	11.61 d-u	296.71 a-y
G28	144.38 k-ı1	17.81 b-p	21.49 a-a1	14.10 b-q	50.27 ı-v	5.66 a-k	10.73 ı-u	326.46 a-y
G29	129.65 c1-l1	18.60 b-p	15.41 y-d1	11.95 f-p	46.51 k-v	4.45 e-k	11.29 f-u	232.24 f-y

G30	172.76 b-f	18.25 b-p	20,88 a-a1	12.90 c-q	**106.58 a**	7.54 a-j	**18.86 a**	318.41 a-y
G31	168.76 b-n	19.04 a-n	22.44 a-a1	17.41 a-q	99.96 a-b	7.70 a-c	17.95 a-b	293.4 a-y
G32	118.38 j1-l1	16.48 h-p	16.32 u-d1	13.95 c-q	60.75 g-v	5.07 a-k	11.55 d-u	286.56 a-y
G33	147.39 j-h1	19.02 a-o	17.02 l-c1	14.26 b-q	73.07 c-ı	5.93 a-k	12.91 c-e	210.251n-x
G34	138.56 t-k1	19.63a-m	16.62 q-d1	13.08 c-q	47.85 l-v	4.93 b-k	12.1 c-u	286.31 a-y
G35	159.71 e-s	17.56 b-p	20.38 a-a1	11.82 e-p	60.88 g-v	6.37 a-k	10.93 h-u	329.08 a-y
G36	154.47 f-w	17.19 c-p	18.42 e-b1	12.90 c-q	55.30 h-v	4.61 b-k	11.64 d-u	283.57 a-y
G37	129.99 b1-l1	17.27 c-p	18.48 e-b1	11.03 g-p	53.08 h-v	5.21 a-k	10.9 h-u	250.38 c-y
G38	132.3 x-k1	15.44 l-p	16.97 m-c1	10.78 g-p	42.49 o-v	4.49 b-k	11.02 f-u	**157.63 x**
G39	149.28 h-g1	18.92 a-p	20.22 a-a1	14.16 b-q	46.81 m-v	4.69 b-k	11.3 f-u	183.15 t-x
G40	165.56 c-o	19.27 a-o	21.38 a-a1	12.89 c-q	59.98 g-v	5.91 a-k	12.01 c-u	337.44 a-o
G41	135.54 w-k1	14.97 n-p	13.23 c1-d1	8.58 n-p	50.65 ı-v	4.93 b-k	11.93 c-u	166.74 w-x
G42	159.85 e-s	20.06a-m	19.75 a-a1	13.95 c-q	71.25 d-k	5.51 a-k	12.27 c-ı	314.39 a-y
G43	170.56 b-n	18.92 a-p	21.65 a-a1	13.55 c-q	55.66 h-v	4.53 b-k	12.39 c-g	295.88 a-y
G44	151.56 f-d1	21.06 a-h	20.72 a-a1	15.53 a-q	61.79 g-v	6.06 a-k	11.04 f-u	231.96 d-y
G45	140.64 p-k1	16.27 ı-p	15.55 x-d1	10.60 g-p	64.23 f-u	5.42 a-k	13.04 c-d	294.95 a-y
G46	154.14 f-w	17.92 b-p	19.79 a-a1	10.29 h-p	64.37 f-u	5.00 b-k	11.84 c-u	313.24 a-y
G47	139.42 r-k1	18.06 b-p	17.97 e-c1	10.09 ı-p	49.49 j-v	5.30 a-k	10.79 j-u	248.99 c-y
G48	154.56 f-w	18.70 a-p	18.98 b-a1	11.33 f-p	61.35 g-v	4.70 b-k	10.96 h-u	294.57 a-y
G49	149.06 g-f1	16.79 e-p	16.29 s-c1	**7.64 p**	42.06 q-v	4.07 e-k	10.64 k-u	325.31 a-y
G50	148.78 ı-f1	19.00 a-o	18.39 e-c1	9.42 m-p	55.10 h-v	4.27 c-k	**9.33 t**	301.87 a-y
G51	130.11 a1-k1	19.95 a-l	19.63 a-a1	11.27 f-p	64.33 f-u	5.65 a-k	11.41 e-u	**390.61 a**
G52	123.78 ı1-l1	17.62 c-p	16.28 s-c2	8.11 o-p	41.25 r-v	3.72 g-k	10.4 n-t	313.84 a-y
G53	147.63 i-g1	19.79 a-l	18.83 e-b1	14.11 c-q	69.51 d-n	5.05 a-k	11.61 d-u	298.13 a-y
G54	122.78 ı1-l1	18.39 b-p	16.68 p-c1	11.81 e-p	41.54 r-v	3.69 g-k	11.2 f-u	253.83 c-y
G55	118.78 j1-l1	21.29 a-g	24.32 a-d	12.88 e-q	70.06 d-m	5.18 a-k	10.92 g-u	364.07 a-c
G56	130.83 y-k1	20.79 a-ı	22.83 a-a1	13.71 c-q	72.64 c-l	5.65 a-k	12.21 c-j	222.5 ı-y
G57	140.28 p-k1	17.04 e-p	14.53 z-d1	12.51 e-p	54.73 h-v	4.89 b-k	11.15 f-u	218.39 k-y
G58	124.78 h1-l1	21.99 a-b	23.87 a-d	15.91 a-q	57.55 h-v	5.32 a-k	10.93 g-u	226.68 h-y
G59	129.28 d1-l1	21.29 a-g	22.78 a-a1	18.41 a-d	58.73 h-v	5.42 a-k	11.03 g-u	236.68 e-y
G60	136.58 u-k1	20.54 a-ı	16.08 t-d1	12.06 e-p	53.43 h-v	4.43 c-k	10.55 l-t	330.09 a-y
G61	129.28 d1-l1	20.54 a-ı	19.06 c-a1	13.58 c-q	65.56 f-u	5.13 a-k	11.97 c-u	358.56 a-f
G62	128.53 e1-l1	18.04 b-p	17.13 j-c1	20.01 a-b	64.18 f-u	5.34 a-k	12.45 c-h	382.57 a-b
G63	**108.78 l1**	15.45m-p	**11.40 d1**	11.34 f-p	46.74 o-v	4.62 b-k	11.59 d-u	234.25 e-y
G64	127.95g1-l1	17.62 c-p	16.45 s-c1	9.69 j-p	54.47 h-v	5.24 a-k	11.11 f-u	348.63 a-j
G65	131.12 y-l1	16.83 c-p	15.23 y-d1	11.70 e-p	57.97 h-v	4.18 e-k	11.06 f-u	210.81 m-y
G66	165.95 c-n	**14.33 p**	18.34 e-c1	9.57 k-p	93.15 a-d	4.94 b-k	16.82 b	196.42 q-x
G67	189.95 a-b	20.71 a-ı	22.47 a-a1	14.95 b-q	102.14 a	6.70 a-j	**18.89 a**	181.74 v-x
G68	166.45 c-n	20.58 a-ı	22.04 a-a1	18.77 a-q	87.96 a-f	6.32 a-k	**18.97 a**	202.91 p-y
G69	161.45 d-t	**23.33 a**	**24.64 a**	**21.27 a**	70.77 d-m	5.35 a-k	11.66 d-u	288.14 a-y
G70	145.16 o-f1	19.54 a-n	18.96 b-a1	14.57 b-q	57.21 h-v	4.55 b-k	11.07 f-u	221.69 g-y
G71	152.62 f-c1	17.66 b-p	19.36 b-a1	14.99 b-q	49.29 ı-v	5.07 a-k	11.61 d-u	211.77 m-y
G72	157.85 e-w	20.03a-m	20.97 a-a1	12.83 d-p	53.08 ı-v	4.57 b-k	11.97 c-u	298.29 a-y
G73	159.02 e-v	20.54 a-ı	20.51 a-a1	14.23 b-q	70.53 e-u	5.70 a-k	11.94 c-u	348.67 a-j
G74	160.12 e-t	17.66 b-p	18.14 e-c1	13.49 c-q	42.76 o-v	4.39 c-k	10.28 p-t	237.59 c-y
G75	167.31 c-n	18.47 b-p	20.51 a-a1	12.43 e-p	43.31 o-v	5.07 a-k	10.48 m-t	209.09 o-y
G76	162.31 d-s	18.33 b-p	16.92 o-c1	11.68 e-p	53.22 ı-v	3.95 g-k	12.12 c-u	216.79 k-y
G77	160.31 d-t	19.26 a-o	20.14 a-a1	13.11 d-p	75.80 b-h	4.87 b-k	11.28 f-u	239.35 c-y
G78 (K1)	160.17 f-o	17.89 c-o	19.73 e-w	13.11 e-m	55.83 ı-v	4.16 h-k	11.74 f-k	257.66 e-y
G79 (K2)	174.45 b-e	20.81 a-g	21.94 a-a1	13.35 e-m	50.56 o-v	4.83 f-k	10.78 o-r	316.06 a-j
G80 (K3)	153.87 ı-z	20.18 a-e	20.17 c-u	13.15 e-m	57.56 h-u	4.83 g-k	11.22 g-u	311.9 a-l
G81 (K4)	165.91 e-n	20.04 a-g	22.46 a-a1	13.35 e-m	67.44 g-j	5.59 b-j	11.62 f-u	322.77 a-h
Maksimum	200.05	23.33	24.64	21.27	106.58	8.49	18.97	390.61
Minimum	108.78	14.33	11.40	7.64	38.38	3.08	9.33	157.63
Average	150.30	18.34	19.13	12.91	58.90	5.34	12.00	264.53
LSD (0.05 ve 0,01)	**20.57****	**4.17** $^{\text{ÖD}}$	**4.82***	**5.34** $^{\text{ÖD}}$	**22.49****	**3.08** $^{\text{ÖD}}$	**1.41****	**115.60** $^{\text{ÖD}}$
Higher Genotype Number than Control Group	**4**	**6**	**9**	**30**	**16**	**28**	**27**	**13**

3.9. PCA plot of heat map clustering and examined parameters

According to the heat map graph, it is observed that the parameters examined are divided into two main groups. 1. main group; it consists of stem upper part diameter (mm), head diameter (cm) and stem lower part diameter (mm), and the 1st main group is divided into two subgroups (Figure 4). In subgroup 1a, only the stem upper part diameter (mm) feature is included. In subgroup 1b; It is seen that it has stem upper part diameter (mm) and head diameter features. 2nd main group; It consists of seed length (mm), 1000 seed weight (g), seed width (mm), plant height (cm) and seed yield (kg/da) and is divided into two subgroups in the 2nd main group. In subgroup 2a; It has seed length (mm), 1000 weight (mm) and seed width (mm) features. In subgroup 2b; It has been observed that plant height (cm) and seed yield (kg/da) characteristics are included (Figure 6). When the heat map was examined in terms of the relationships between genotypes, it was determined that it was divided into two main groups, A and B (Figure 4). Heat mapping is categorized according to the color scale between -2 and +2 colors. It has been determined that the data obtained with the categorized dependent/independent variables are clearly divided into two main groups with a color range (+2 to -2; red to blue). In addition to these categorizations, it can be seen that the data regarding the parameters examined are observed with red and its shades in the range ≥0≤2, and the color tones between ≥2≤0 are coded with blue and shades of blue. Red and its shades have a higher relationship, while blue and its shades have lower values (Figure 4). The heat mapping graph detects the connection between visually examined parameters and genotypes (Metsalu and Vilo, 2015; Stavridou et al., 2021; Yasar et al., 2023; Baran, 2024). According to the results obtained in clustering, it was revealed that the genotypes had different characteristics. In particular, it was found that there were very different genotypes according to the parameters examined (Figure 5).

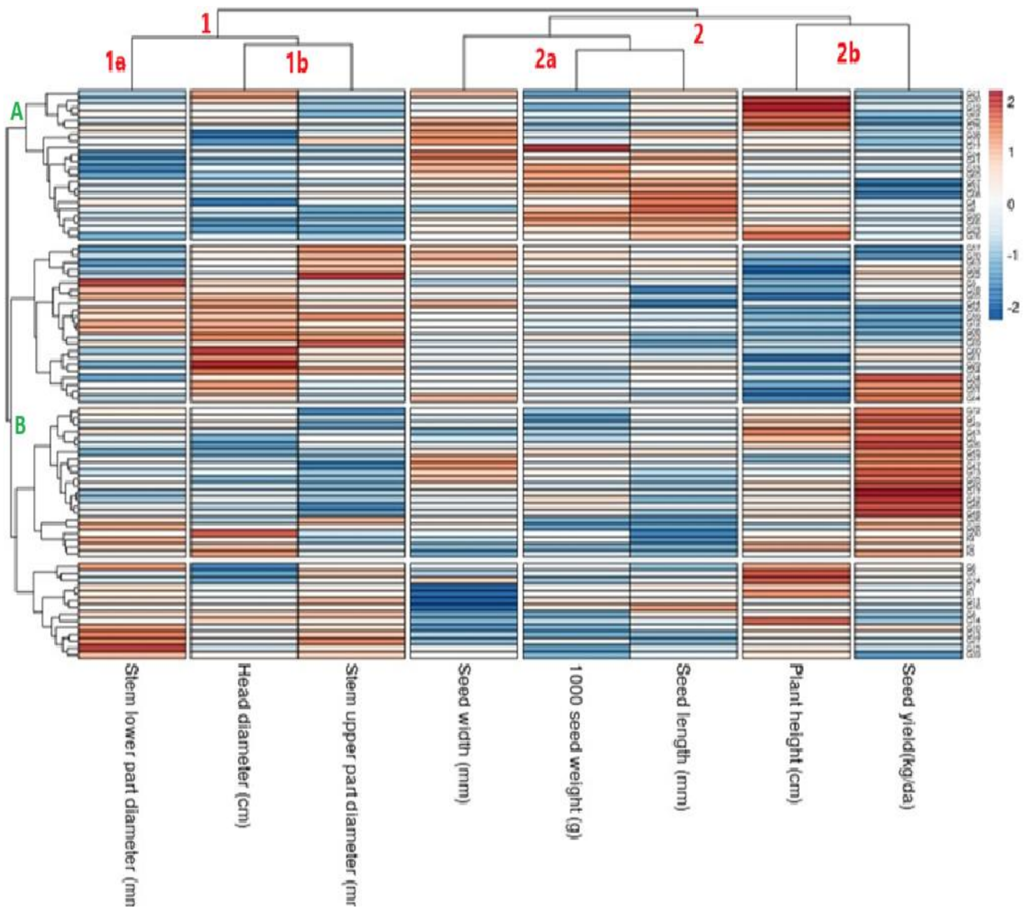

Figure 4. Clustering of sunflower genotypes according to the heat map of the examined traits

According to the PCA Plot, it was determined that the heat map clustering results were confirmed and the parameters were located in 2 different main groups (Group 1 and Group 2). The variation between parameters (PC1; 24.4% and PC2; 26.8%) and the combined effect of PC1 and PC2 explained 51.2% of the variance (Figure 6). Additionally, two separate groups (Group A and Group B) were found in the relationships between genotypes (Figure 5). Group A; G76, G68, G67, G66, G65, G45, G41, G36, G35, G33, G30, G24, G23, G22, G19, G4 and G2 genotypes were determined. Group B includes all the remaining genotypes. Variation between genotypes (PC1; 21.3% and PC2; 42.9%) and the combined effect of PC1 and PC2, 64.2% of the variance, were detected (Figure 5). PCA, presented in recent studies, is a method that provides a better visual understanding of traits and genotypes. The PCA plot shows the relationship between the examined parameters and/or genotypes (Baran et al., 2022).

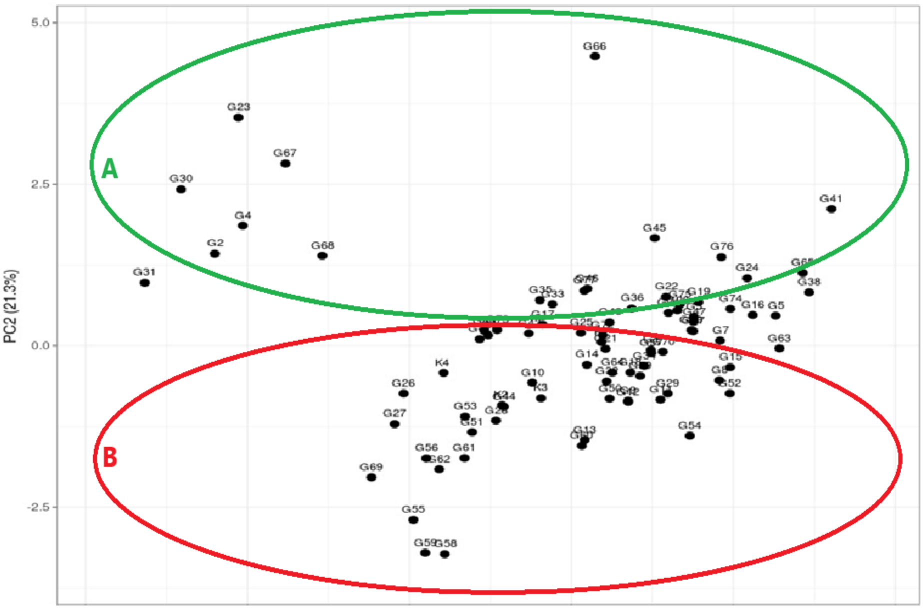

Figure 5. Relationships between sunflower genotypes according to PCA Plot.

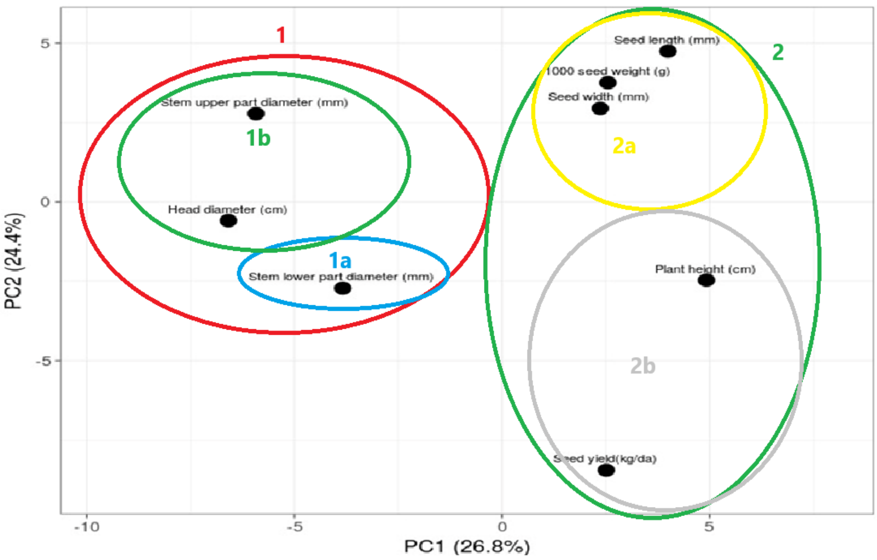

Figure 6. Relationships between parameters examined in sunflower genotypes according to PCA Plot.

4. Conclusion

In this research conducted in irrigated conditions in the application area of Muş Alparslan University campus in 2023, seed yield: G73, G64, G62, G61, G60, G55, G51, G40, G35, G26 and G17, 1000 seed weight; G68, G67, G66, G31, G30, G23 and G4, if the head diameter is; G69, G59, G58, G55, G44 and G2 genotypes were at the forefront. When genotypes were compared with control varieties in terms of all examined characteristics; plant height; 4 genotypes, head diameter; 6 genotypes, stem lower part diameter (mm); 9 genotypes, Stem upper part diameter; 30 genotypes, 1000 seed weight; 16 genotypes, seed width; 28 genotypes, seed length; 27genotypes and in seed yield; It was determined that 13 genotypes were superior to the control varieties. In addition, according to the PCA Plot, it was found that the heat map clustering results were confirmed and the parameters were divided into 2 different main groups, and 2 separate groups (Group A and Group B) were detected in the relationships between genotypes. In the evaluations made, high variation was determined in the study carried out to determine the adaptation ability and yield parameters of the sunflower plant, and it is anticipated that it will shed light on researchers in terms of variety breeding in future breeding studies. Sunflower is a very valuable plant in increasing Türkiye's crude oil production amount. For this reason, its widespread use in the Eastern Anatolia region will make a significant contribution to eliminating the existing oil deficit. In addition, since the remaining pulp after removing the oil provides a good feed source, a very important plant will be introduced to this region, whose source of income is animal husbandry. In parallel with this situation, it is thought that the current unemployment rate will decrease as the region contributes to both crop production and industrialization. It is estimated that significant developments will occur in the field of animal husbandry by enabling local people who have recently left their villages and gone to the city center to return. Thus, it is expected to provide significant input to the country and regional economy by supporting both crop and livestock farming.

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