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Original scientific article

GENOTYPE-BY-ENVIRONMENT INTERACTION FOR SEED YIELD AND OIL CONTENT OF SAFFLOWER (*Carthamus tinctorius L.)* GENOTYPES

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This research was carried out to determine genotype-by-environment interaction of safflower genotypes tested from 2014 to 2017. Konya, where the research was carried out, is the location with the most irregular and the lowest precipitation in Turkey. In this research, the variance analysis over years and genotypes showed that the main effects on genotypes made by year and genotype-by-year interaction were statistically significant ($p<0.01$) for all characteristics examined. The climatic conditions, especially the amount and distribution of precipitation, over the years allowed genotypes to perform substantially differently in seed yield and oil content of safflower genotypes. The biplot analysis provided significant advantages in identifying the promising genotypes. The genotypes showed similar patterns of performance across the years, while the amount and distribution of precipitation showed similar patterns. The experimental results revealed that the desired genotypes in terms of both stability and high yield, such as Göktürk, G7, and Dinçer, G5 and G9 and oil content, such as Göktürk, Balcı, and Linas, existed. In comparison to oil content, seed yield was more sensitive to environmental factors.
Keywords: GGE (Genotype + Genotype-by-Environment)-biplot, oil content, safflower, seed yield, stability

INTRODUCTION

The demand for vegetable oils will further increase in the coming years due to the increase in nutritional and energy requirements. Therefore, the utilization of plants such as safflower for vegetable oil production in Turkey has become a necessity (BAYRAMIN and KAYA, 2009).

Safflower is a valuable oil plant, rapidly increasing in the world due to the high quality oil obtained from its seeds and its high adaptability to arid regions (UYSAL *et al.*, 2006).

Safflower is adaptable to different environmental conditions. In addition, it has a deep root system tolerant to drought and heat stresses (LI and MÜNDEL, 1996). Due to these traits, it is becoming an economically important oil plant (MACHADO, 2004).

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The most important safflower breeding targets are high seed yield, high oil yield, earliness, low shell rate and high oil content, high linoleic or oleic acid content, suitability to mechanical harvesting and resistance to diseases and pests (KNOWLES, 1982; ROBBELEN *et al*., 1989; WEISS, 2000). High adaptation and yield performance ability is paramount for safflower varieties and lines, which have been affected by the change in amount and distribution of annual precipitation in Turkey during the last decades (ÖZTÜRK *et al*., 2009).

When genotypes are tested under the rain-fed conditions, due to insufficient precipitation in some years, their yield and quality performance cannot be fully demonstrated (AKTAŞ, 2014).

Mega-environments must be determined before any new varieties are introduced (ALIZADEH *et al*., 2008).

It is difficult to determine superior genotypes in multi-environment yield trials due to the high interaction between genotype and environment (KAYA *et al*., 2006).

Evaluation of GE (Genotype-by-Environment) interaction with biplot analysis is an important component of the genotype selection process in multi-environment trials. This method will enable analyses of the genotype-by-environment interaction and determine the genotypes that exhibit both the average performance and high stability (POURDED and MOGHADDAM, 2013).

Evaluation of genotypes and specification of mega-environment are among the most important targets of multi-environment trials. GGE biplot analysis visually shows the genotype-by-genotype-by-environment interaction graphically in multi-environment trials in order to facilitate the evaluation of the varieties and specification of the mega-environment (YAN *et al*., 2000).

Biplot analysis has become an important technique in crop improvement and agricultural research. GGE biplot analysis provides an easy and comprehensive solution for genotype with environmental data analysis, which is a challenge for plant breeders, geneticists and agronomists. It not only allows for the evaluation of genotypes efficiently, but also provides a comprehensive understanding of the target environment and test environments. Specifically, biplot graphical analysis can help a researcher understand the target environment as a whole, i.e. whether it consists of single or multiple mega-environments that determine whether GE can be used or avoided. At the same time, on the subject of whether or not genotypes are similar, biplot analysis can help to evaluate the genotypes in terms of both average performance and stability across environments. Therefore, GGE biplot analysis of the genotype with environmental data not only addresses short-term, applied questions, but also provides insights into long-term fundamental problems (YAN and TINKER, 2006).

Notwithstanding that safflower is a valuable oil crop, the increase of safflower growing area both in Turkey and in the world is hindered by the fact that its seed yield and oil rate remain relatively low compared to other oil crops. Therefore, breeding studies for increasing seed yield and oil content in safflower have gained great importance in the recent years. This study aimed to determine genotype-by-year (environment) interaction and stability levels of safflower genotypes of different origin in terms of seed yield and oil content.

MATERIALS AND METHODS

This research was conducted in Konya, Turkey, at Bahri Dağdaş International Agricultural Research Institute, with 4 registered varieties and 17 genotypes for a period of 4 years (2014-

2017). The experiment was set up as a randomized block design with four replications. Seeds were planted with experimental drill into plots 1.2 meters in width, and 5 meters in length, occupying a total of 6 square meters. Planting was done in the last week of March with 125 seeds per square meter, in all years. Harvest was carried out in the second week of August using a plot combine harvester.

Table 1. Genotypes and origins used in the research

No	Genotip	Accession number	Origin	Appearance
1	G1	PI 537110	Mexico	Spiny, yellow-orange florets
2	G2	PI 560172	United States	Spiny, yellow-orange florets
3	G3	PI 537606	United States	Spiny, red florets
4	G4	PI 525458	United States	Spiny, yellow-orange florets
5	G5	PI 451952	India	Spiny, yellow-orange florets
6	G6	PI 537598	United States	Spiny, yellow florets
7	Göktürk	BDYAS-4	Turkey	Spiny, yellow-orange florets
8	G7	PI 537702	United States	Spiny, red florets
9	Dinçer	GKTAE	Turkey	Spineless, red florets
10	G8	PI 537703	United States	Spiny, yellow-orange florets
11	G9	PI 306686	Israel	Spiny, yellow florets
12	Linas	TTAE	Turkey	Spiny, yellow-orange florets
13	Balcı	EGKTAE	Turkey	Spiny, yellow florets
14	G10	PI 537607	United States	Spiny, orange florets
15	G11	PI 537665	United States	Spiny, yellow-orange florets
16	G12	PI 537607	United States	Spiny,
17	G13	PI 544059	China	Spiny, yellow-orange florets

Soil characteristics of the experimental site are given in Table 2. Organic matter content was medium with 2.28%. The amount of lime was 29.26%, ranking in the high class. The pH was 7.82, slightly alkaline. Although it was rich in phosphorus and potassium, it was insufficient in zinc. There was no salinity problem.

Table 2. Soil characters at two depth

soil depth (cm)	Structure				pH	organic matter (%)	Lime (%)	Salt (µS/cm)	P_2O_5 (mg/kg)	K_2O (mg/kg)	Zinc (mg/kg)
	Sandy (%)	Clay (%)	Silty (%)	Texture							
0-30	30.83	41.62	27.55	Clayey	7.82	2.28	29.26	272	4.64	92.31	0.262
30-60	37.5	31.3	31.2	Clayey	7.52	1.10	28.20	282	3.62	77.10	0.122

The average monthly temperatures in the test years were similar to the long-term averages. The thermal time in total in the vegetation phase (March-August) was higher than the long-term in total, with 5.8°C (104.8°C) in 2014 and 2016.

Since both the monthly average temperatures and total temperature values in study years were close to each other, it could be stated that temperature had limited effect, but precipitations were rather effective in variations encountered in terms of yield and oil content.

Table 3. Average temperature (°C) in vegetation period

Months	2014	2015	2016	2017	TM
March	7.2	5.9	7.7	6.9	5.5
April	12.3	8.1	14.5	11.0	11.0
May	15.5	15.7	15.9	15.4	15.8
June	19.7	18.7	22.2	20.0	20.1
July	25.1	24.0	24.9	25.2	23.5
August	25.0	24.6	19.6	24.0	23.1
TOTAL	104.8	97	104.8	102.5	99

TM: Temperature Means (1929-2017)

Total annual precipitation was 44 mm above the long-term average with 366 mm in 2014. In 2015 and 2017, precipitation was about long-term average (322 mm) with 309-320 mm.

Table 4. Monthly precipitations for the study years (2014-2017) and long-term averages (1929-2017) for monthly precipitations (mm)

	Precipitation (mm)				
Months	2014	2015	2016	2017	YM
January	58.8	24.6	42.4	18	37.5
February	17.4	23.5	2.8	3	29
March	**20.4**	**55.9**	**37.8**	**98**	**28.4**
April	**19.2**	**7.6**	**9.4**	**21**	**32.1**
May	**26.0**	**53.2**	**35.2**	**41**	**43.5**
June	**31.4**	**39.6**	**18.4**	**18.4**	**24.7**
July	**3.0**	**8.6**	**0.2**	**0**	**6.4**
August	4.6	17.2	0.0	19	4.7
September	31.4	31.4	23.0	0	12.5
October	89.6	39.0	0.0	13	29.9
November	32.2	5.8	16.0	70	31.7
December	32.1	2.6	16.4	18.6	42
Annual Precipitation	366	309	201	320	322
PVP	100	165	101	178	135

PVP: Precipitation in vegetation period, **YM:** Years Means(1929-2017)

In 2016, the annual precipitation was 201 mm, which was 121 mm lower than the long-term average. The precipitation in the vegetation phase was 100 and 101 mm in 2014 and 2016, well below the long-term average (135 mm), while in 2015 and 2017 it was above the long-term average, with 165 mm and 178 mm.

The analysis of variance was performed using the JMP 5.0 program. Differences between means of genotypes and the years were examined using the LSD comparison test. The GGE-biplot analysis XLSTAT program was used to assess the genotype-by-year (environment) relationship. In this study, each year was evaluated as an environment due to different climate values, especially precipitation.

RESULTS

The results of the analysis of variance are given in Table 5. In terms of all characteristics examined, the main effects of genotypes and years, and genotype-by-year interaction, were statistically significant ($p<0.01$).

Table 5. Analysis of the combined variance of the properties studied in the study

SV	DF	Seed yield	Oil content	Oil yield
		MS	MS	MS
Replication	3	3135	0.39	399.6
Year	3	250152**	25**	27556**
Genotyp	16	9356**	53**	895**
Year x Genotyp	48	5113.5**	10.2**	754.4**
Error	201	1250	0.3497	147.13
Total	271	5189.1**	5.48**	605**

SV: Source of Variance**, DF**: Degrees of Freedom, , MS: Mean Square , **P<0.01 significant, *P<0.05 significant

Seed yield mean was determined at 3480 kg ha^{-1} in 2015, 2590 kg ha^{-1} in 2014, 2200 kg ha^{-1} in 2017, and 2190 kg ha^{-1} in 2016 (Table 6).

Table 6. Mean yield and oil content of 17 safflower genotypes tested across 4 years

Year	Genotype	SY	OC	OY	Year	Genotype	SY	OC	OY
	G1	3340	35.6	1190		G9	4350	36.4	1580
	G2	3100	32.7	1010		G8	4330	34.0	1470
	G3	3080	33.2	1020		G7	3980	30.3	1210
	G4	2950	33.3	980		G5	3870	32.3	1250
	G5	2910	34.5	1000		Göktürk	3780	33.0	1240
	G6	2750	36.5	1000		G13	3680	33.5	1230
	Göktürk	2700	35.6	960		G6	3680	36.6	1340
	G7	2690	33.9	910		Dinçer	3640	30.4	1060
	Dinçer	2690	30.7	820		G4	3400	30.2	1030
2014	G8	2560	35.0	890	2015	G3	3330	31.4	1040
	G9	2400	32.8	790		G1	3330	36.3	1070
	Linas	2280	34.9	800		G10	3120	34.0	1060
	Balcı	2270	35.8	810		G12	3090	34.9	1080
	G10	2200	32.2	710		Linas	3030	35.0	1060
	G11	2190	39.1	850		Balcı	2970	34.6	1030
	G12	2120	33.6	710		G11	2880	36.2	1040
	G13	1870	33.8	630		G2	2770	32.3	890
	Mean	**2590**	**34.3**	**890**		**Mean**	**3480**	**33.3**	**1160**
	LSD(%5)	**530**	**0.9**	**180**		**LSD(%5)**	**650**	**0.9**	**230**
	CV/%)	**14**	**1.9**	**13**		**CV/%)**	**13**	**2**	**13**

Year	Genotype	SY	OC	OY	Year	Genotype	SY	OC	OY
	Linas	2570	35.2	900		Dinçer	3000	27.9	830
	G5	2560	30.2	770		G13	2720	34.4	940
	G9	2480	37.3	920		G3	2600	34.0	880
	G3	2420	34.1	830		G7	2510	31.1	780
	G13	2390	32.3	770		Göktürk	2480	35.3	870
	Balcı	2380	34.5	820		G9	2370	37.2	880
	G7	2240	31.8	710		Balcı	2370	35.5	840
	G1	2220	31.8	710		G1	2360	32.5	760
	G4	2220	35.1	780		G5	2290	33.5	760
2016	Göktürk	2170	33.9	740	2017	G10	2090	34.3	720
	Dinçer	2090	27.4	570		G4	2070	35.1	730
	G2	2040	31.2	640		G8	1860	28.7	530
	G6	2020	33.2	670		G12	1860	33.0	610
	G11	1920	34.0	650		G2	1820	35.7	650
	G10	1920	33.9	650		Linas	1810	36.7	670
	G12	1790	32.4	580		G11	1710	37.3	640
	G8	1760	31.9	560		G6	1600	34.2	550
	Mean	**2190**	**32.9**	**720**		**Mean**	**2200**	**33.9**	**740**
	LSD(%5)	**350**	**0.7**	**120**		**LSD(%5)**	**230**	**0.6**	**80**
	CV/%)	**11**	**1.6**	**11**		**CV/%)**	**7**	**1.3**	**7**

Considering the monthly average temperature values of 2015 with the greatest seed yield, it was observed that average temperatures especially throughout the vegetative stage of rapeseed (March, April and June with 5.9°C, 8.1°C and 18.7°C, respectively) were lower than the other years, but close to the other years in May (Table 3).

Spring temperature values in 2015 indicated that the vegetative phase of safflower, from germination to budding, was relatively cooler compared to other test years, but in July-August, they were similar to the long-term average.

In 2015, precipitation level was higher in the safflower vegetation period (May, June, July) compared to other test years. During this period, higher precipitation and cooler vegetation phase caused an increase in seed yield in 2015 (3480 kg ha^{-1}).

Similar temperature values were recorded in 2014, 2016 and 2017, while precipitation was the dominant factor of genotype differences.

In 2014, precipitation in the vegetation cycle was lower compared to other test years. But the reason for the high average seed yield in this year was that the total annual precipitation was higher compared to other test years (366 mm).

In 2016, the lowest recorded average seed yield was the result of both the annual precipitation (201 mm) and its received amount during safflower vegetation period (101 mm), which were the lowest in all test years.

In 2017, the annual precipitation was around the long-term average (320 mm), while it was 178 mm in the vegetation period, quite higher than the long-term average and the other test years. However, there was no expected increase in seed yield. It was due to the fact that precipitation in the 2017 vegetation cycle was mostly received in March (98 mm), when safflower was just sown, germinated and emerged, whereas it was lower when the plant needs higher water supply.

Oil content means were not affected by environmental factors as much as seed yield means.

The highest mean of oil content was achieved in 2014 with 34.3%, while the lowest in 2016 with 32.9%. The similar oil content was obtained in 2015 and 2017, with 33.3% and 33.9%, respectively.

In 2016, both the annual precipitation and its amount received in the vegetation period were quite lower, which reduced the oil content.

In 2014, as the annual average precipitation was the highest and the safflower was able to benefit from the water stored in the soil after a certain period of its development, the oil content was higher despite the low precipitation level in the vegetation period.

Since oil yield values were obtained by multiplying seed yield and oil content values, all factors affecting these properties directly affected the oil content (Table 6).

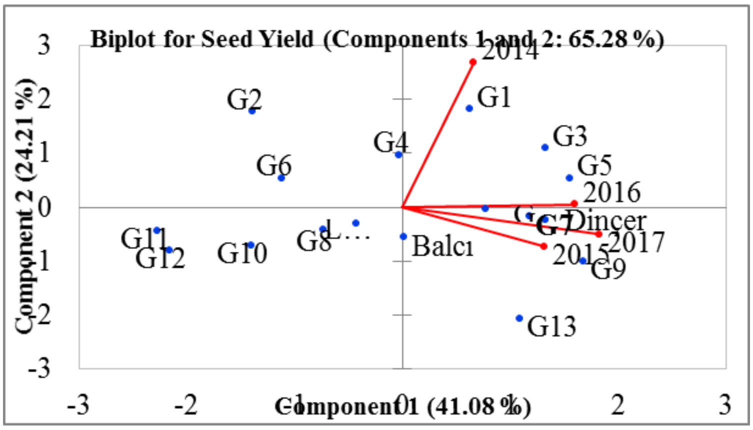

Figure 1. Biplot for obtained from seed yield data of 17 genotypes across four years

In order to understand the genotype-by-year (environment) interaction in detail, a Biplot graph for seed yield was given in Figure 1. Components 1 and 2 accounted for 65.8% of variation in the genotype-by-year interaction. The genotype-by-environment interactions and stability levels of genotypes over the years are included in the biplot graph.

The varieties located in the right of the line cutting the axis, representing the average seed yield according to average center of coordinates, yielded higher crops than the average, while the varieties on the left yielded lower crops than the average.

Genotypes close to the line that intersect the origin horizontally are considered as the most stable genotypes (KARAMAN, 2019). In this study, G1, G3, G5, G7, Göktürk, Dinçer, G9, G13 genotypes yielded higher crops than the average, while Balcı and G4 genotypes yielded stable seed crops close to the trial average. Other genotypes remained below the average.

In all the years, Göktürk, G7, Dinçer, G5, G9 were the most stable genotypes and had yields higher than the mean. Linas, G8 and G6 genotypes were stable, but yielded below the mean. Due to the fact that the 2014 annual precipitation was higher than the total of all other test years (366 mm), it is located in a separate section of the biplot graph.

In 2014, Genotype G1 had the best performance under high annual precipitation in terms of seed yield (Figure 1). Genotypes G9, G5, and Dinçer showed the best performance in 2015, 2016, and 2017, respectively.

Due to the similar annual precipitation and its received amount in the vegetation period in 2015 and 2017, genotypes were found in regions close to each other in the graph in terms of seed yield, too (Figure 1).

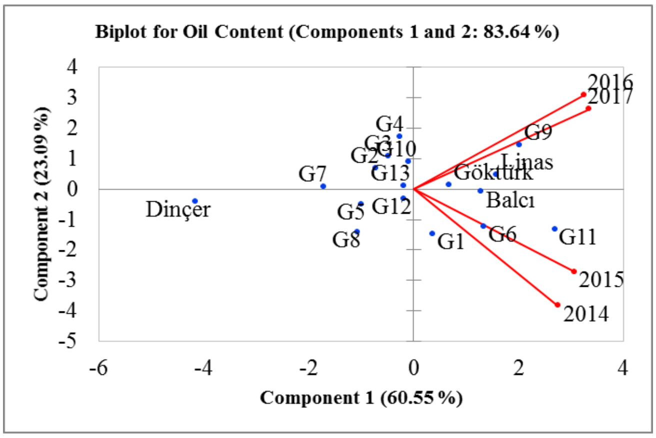

Figure 2. Biplot for obtained from oil contents data of 17 genotypes across four years

In order to understand genotype-year (environment) interaction in terms of oil content, a biplot graph is given in Figure 2. Components 1 and 2 accounted for 83.64% of variation of genotype-by-year interaction. Considering all the years, G11, G9, Linas, Balcı, G6, Göktürk, G1 genotypes had an oil content above the mean. The average oil content of the other genotypes was lower than the trial mean. The most stable genotypes, with oil content higher than the mean, belong to varieties Göktürk, Balcı and Linas. The years 2016 and 2017 were in the same region concerning the oil rate, while 2014 and 2015 were in the other region (Figure 2). Oil content was also affected by environmental factors and this effect was found to be different from that of the seed yield.

The biplot graphs in Figure 1 and Figure 2 revealed that G1, G9 and Göktürk genotypes had seed yield and oil contents over the averages in both graphs.

DISCUSSION

While seed yields are much influenced by environmental factors, oil ratios are rather influenced by genetic factors (KAYA *et al*, 2009). Present biplots of seed yield and oil ratios revealed that oil content values were more stable as compared to seed yield values because oil content values are less influenced by environmental factors as compared to the seed yield values.

Safflower is very sensitive to water scarcity, especially in the vegetative phase. Water scarcity during this phase significantly reduces seed yield (ISTANBULLUOĞLU *et al.*, 2009). In this study, total precipitation in the vegetative phase (April, May, June) in 2014 and 2016 was 76.6 and 63 mm, respectively. The recorded values were considerably lower than the long-term average (100.3 mm). When the seed yield was evaluated in the biplot graph, it was seen that genotypes such as G3 and G5 can be tolerant to low precipitation in the vegetative phase.

NACAR *et al*., (2016) found that safflower plant consumes the most water during flowering and seed forming. SAINI and WESTAGE (2000) stated that water stress in the early reproductive stages of safflower causes decrease in the number of flowers and/or seeds.

In the vegetative phase, water supply increased by precipitation or irrigation increased safflower yield. As a result of the study carried out on safflower varieties, ÖZTÜRK *et al*. (2009) determined a significant increase in seed yield and oil yield after irrigation two times, before budding and flowering.

In this study, the lowest precipitation was recorded in 2014 (34.4 mm) and the highest in 2017 (59.4 mm), in June and July, which are the generative stages of safflower, i.e. budding and seed forming.

The biplot graph on seed yield revealed that the year 2014 was placed into a different region as compared to the other years. In 2014, G1 and G4 genotypes with greater seed yields than the general average well-tolerated low precipitations throughout the vegetative stage.

Evaluation of GE interaction with biplot analysis is an important component of the genotype selection process in multi-environment trials. With this method, it can be possible to analyze the genotype-by-environment interaction and to determine the genotype that has both the average performance and the high stability (POURDAD and MOGHADDAM, 2013). Different genotypes respond to environmental conditions differently in different years. For this reason, environmental effects are important in understanding plant growth. In safflower cultivation, the response of different genotypes to different environmental conditions should be considered, as well as choosing stable genotypes with fewer of these reactions (MAHASI *et al*., 2006).

In this research, as well as the most stable genotypes in all test years, the most prominent genotypes showed different results of seed yield and oil content in different years.

ALESSI *et al*., (1977) and OAD *et al*., (2002) reported that water stress reduced oil content. In contrast, HANG and EVANS (1985), and MOZAFFARI and ASADI (2006) found that safflower oil content did not respond to increasing irrigation rates. In their study with 20 safflower genotypes MOQADDAM *et al*., (2010) found that genotype-by-environment interaction was not significant in terms of oil content. In this study, oil content was less affected by genotypes, but was significantly affected by environmental factors.

In the variance analysis (Table 5), genotype-by-year interaction was found to be important in terms of oil content. When the biplot graph regarding oil content was evaluated, the years 2014 and 2015 were located in the same sector, while 2016 and 2017 were in different sectors. The most stable genotypes regarding oil content were Balcı, Göktürk and Linas.

Since oil yield was obtained by multiplying oil content and seed yield, all factors increasing seed yield and oil content increased oil yield as well. BALJANI *et al.* (2015) reported that genetic improvement in oil yield was important in safflower breeding and that seed yield and oil content should be taken into consideration in the genetic improvement of oil yield.

Biplot analysis can help researchers understand the genotype as an integrated system with interconnected components that form the basis for determining realistic breeding objectives and selection criteria. Simultaneously, it helps to uncover the strengths and weaknesses of genotypes important for identifying superior varieties and parents (YAN and TINKER, 2006). In this study, superior and weak aspects of genotypes, and their adaptation to environmental conditions in different years, were determined in terms of both seed yield and oil content.

CONCLUSIONS

In this study, it was determined that genotypes reacted to different environmental conditions in terms of seed yield and oil content. Biplot analysis also provided significant advantages in identifying the suitable genotype. The materials used in the research included desirable genotypes for both stability and high yield and oil content. Seed yield was more affected by environmental factors in comparison with oil content. It is important to determine the appropriate environmental conditions and performance and stability status under changing environmental conditions before introducing a new type to the market. In the years of the study, especially the amount of precipitation and the distribution of precipitation significantly affected the seed yield and oil content of safflower genotypes. Some genotypes responded similarly when the amount and distribution of precipitation were close to each other in the test years. The magnitude of the genotype-by-environment interaction is not desirable when recommending varieties. Genotypes with high interaction have been identified in the study, as well as genotypes which can adapt to changing environmental conditions. In this respect, the study will contribute to both plant breeders and horticulturists.

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REFERENCES

AKTAŞ, H. (2014): Investigation of quality stability and micro elements content of some bread wheat varieties in southeast Anatolia region conditions. (Unpublished doctoral dissertation). Mustafa Kemal University, Tekirdağ, Turkey.

ALESSI, J., J.F., POWER, D.C., ZIMMERMAN (1977): Sunflower yield and water use as influenced by planting date, population, and row spacing. Agronomy J., *69*: 465–469.

ALIZADEH, K., M., ESKANDARI, A., SHARIATI (2008): Study on spring type safflower lines suitable for cold drylands using GGE biplots. World J. Agricultural Sci., *4*: 726-730.

BALJANI, R., F., SHEKARI, N., SABAGHNIA (2015): Biplot analysis of trait relations of some safflower (Carthamus tinctorius L.) genotypes in Iran. Crop Res., 50: 63-73.

BAYRAMIN, S., M., KAYA (2009): Advancement of Safflower and Rapeseed. Tarla Bitkileri Merkez Araştırma Enstitüsü Dergisi, *18*: 43-47.

LI, D., H.H., MÜNDEL (1996): Safflower *(Carthamus tinctorius L.)* promoting the conservation and use of underutilized and neglected crops 7. Institute of Plant Genetics and Crop Plant Research, Gatersleben/International Plant Genetic Resources Institute, Rome, Italy.

HANG A.N., D.W., EVANS (1985): Deficit sprinkler irrigation of sunflower and safflower. Agronomy J., *77*: 588–592.

ISTANBULLUOĞLU, A., E., GÖÇMEN, E., GEZER, C., PAŞA, F., KONUKCU (2009):Effects of water stress at different development stages on yield and water productivity of winter and summer safflower (Carthamus tinctorius L.). Agricultural Water Management, *96*: 1429-1434.

KARAMAN, M. (2019): Sulu koşullarda bazı ekmeklik buğday genotiplerinin tarımsal özellikler bakımından değerlendirilmesi, Türk Tarım ve Doğa Bilimleri Dergisi, *6*: 296-304.

KAYA, Y., M., AKÇURA, S., TANER (2006): GGE-biplot analysis of multi-environment yield trials in bread wheat. Turkish J. Agriculture and Forestry, *30*: 325-337.

KAYA, Y., G., EVCI, V., PEKCAN, T., GÜCER, M.I., YILMAZ (2009): The Determination Relationships between Oil Yield and Some Yield Traits in Sunflower. J. Agricultural Sci., *15*: 310-318.

KNOWLES, P.F. (1982): Safflower genetics and breeding, in: Improvement of oil-seed and ındustrial crops by ınduced mutations. International Atomic Energy Agency, Vienna, Austria.

MAHASI, M.J., R.S., PATHAK, F.N., WACHIRA, T.C., RIUNGU, M.G., KINYUA, J.K., WAWERU (2006): Genotype by Environment (GxE) interaction and stability in safflower (Carthamus tinctorious L.). Asian J. Plant Sciences, *5*: 1017-1021.

MACHADO, S. (2004): Potential Alternative Crops for Eastern Oregon. Oregon Agricultural Experiment Station Special Report 1054, pp. 84-102.

MOQADDAM, J., M., ESKANDARI, M., MIRZAEI, S., AMIR PURDAD (2010): Evaluation of winter safflower spine lines for oil and seed yield under rain-fed condition of cold temperate regions of Iran. Dry Land Agricultural Research Institute.

MOZAFFARI, K., A.A., ASADI (2006): Relationships among traits using correlation, principal components and path analysis in safflower mutants sown in irrigated and drought stress condition. Asian J. Plant Sci., *5*: 977-983.

NACAR, A.S., V., DEĞIRMENCI, H., HATIPOĞLU, M., TAŞ, H., ARSLAN, A., ÇIKMAN, A. ŞAKAK (2016): Effects of irrigation on yield and yield components at safflower plant in Harran plain. Journal of Central Research Institute For Field Crops, *25:*149-154.

OAD, F.C., M.A., SAMO, S.M., QAYYUM, N.L., OAD (2002): Inter and intra row spacing effect on the growth, seed yield and oil content of safflower (Carthamus tinctorius L.). Asian J. Plant Sci., *1*: 18-19.

ÖZTÜRK, Ö., R., ADA, F., AKINERDEM (2009): Determination of yield and yield components of some safflower cultivars under irrigated and dried conditions. Selçuk Tarım ve Gıda Bilimleri Dergisi, *23*: 16-27.

POURDAD, S.S., M.J., MOGHADDAM (2013): Study on seed yield stability of sunflower inbred lines through GGE biplot. Helia, *36*: 19-28.

ROBBELEN, G., R.K., DOWNEY, A., ASHRI (1989): Oilcrops of the world. McGraw Hill Books, USA.

SAINI, H.S., M.E., WESTGATE (2000): Reproductive development in grain crops during drought. Advances in Agronomy, *68*: 59-96.

UYSAL, N., H., BAYDAR, S., ERBAŞ (2006): Determination of Agricultural and Technological Properties of Safflower (Carthamus tinctorus L.) Lines Developed from Isparta Population. SDÜ Ziraat Fakültesi Dergisi, *11*: 52-63.

WEISS, E.A. (2000): Safflower. In*:* Oilseed Crops. Blackwell Sci. Ltd., Victoria, Australia, pp: 93-129.

YAN, W., L.A., HUNT, Q., SHENG, Z., SZLAVNICS (2000): Cultivar evaluation and mega-environment investigation based on the GGE biplot. Crop Sci., *40*: 597-605.

YAN, W., N.A., TINKER (2006): Biplot analysis of multi-environment trial data: Principles and applications. Canadian J. Plant Sci., *86*: 623-645.

INTERAKCIJA GENOTIPA I ŽIVOTNE SREDINE ZA PRINOS SEMENA I SADRŽAJ ULJA U GENOTIPIMA ŠAFRANIKE (*Carthamus tinctorius* L.)

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Izvod

Ovo istraživanje je sprovedeno radi utvrđivanja interakcije genotipa sa okolinom genotipova šafranike testiranih od 2014. do 2017. godine). Konija, gde je sprovedeno istraživanje, je mesto sa najviše neregularnih i najmanje padavina u Turskoj. U ovom istraživanju, analiza varijanse godina i genotipova pokazala je da su glavni efekti na genotipove ostvareni po godinama i interakciji genotipa i godine bili statistički značajni ($p < 0{,}01$) za sve ispitivane karakteristike. Klimatski uslovi, posebno količina i raspored padavina, tokom godina omogućavali su genotipovima šafranike da se značajno drugačije ponašaju u prinosu semena i sadržaju ulja. Biplot analiza pružila je značajne prednosti u identifikovanju obećavajućih genotipova. Genotipovi su pokazivali slične performanse tokom godina, dok su količina i raspored padavina pokazivali slične obrasce. Eksperimentalni rezultati su otkrili da postoje poželjeni genotipovi u pogledu stabilnosti i visokog prinosa, kao što su Göktürk, G7 i Dinçer, G5 i G9 i sadržaj ulja, kao što su Göktürk, Balcı i Linas. U odnosu na sadržaj ulja, prinos semena bio je osetljiviji na faktore okoline.

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