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Determination of Yield and Quality Characteristics of *Tribenuron Methyl* Group Sunflower Genotypes Newly Developed

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HIGHLIGHTS

- Sunflower is the most important oil plant for Türkiye.
- Improving sunflowers is an agricultural study and development process to enhance the genetic characteristics of the sunflower plant and to develop new varieties with desired characteristics.

Abstract

The present study was conducted to determine the yield and quality characteristics of oil sunflower genotypes as candidates for registration under Konya and Karaman conditions, in 4 replications according to the "Random Blocks Trial Design". The differences between the cultivars used in both locations of the study in terms of the number of days to bloom, the number of days to physiological maturity, the diameter of the tray, the thousand seed weight, seed moisture, seed yield, oil content, and oil yield were found to be statistically significant. The number of flowering days of the genotypes was found to be 64.5-60.8 days (H412; P63LLE113), the number of days to physiological maturity was 113.9-110.3 days (H412; P63LLE113), plant height 169.0-164.6 cm (M94S35; P63LE113), head diameter 20.9-17.3 cm (H412; P63LLE113), thousand-seed weight 60.3-47.4 g (H408; P64LE119), seed moisture 7.8-5.9 % (H408; P63LE113), seed yield 43.6-43.2 t ha^{-1} (H412; P64LE119), oil content 44.2-41.8 (H412; M94S35), and oil yield 19.2-17.0 t ha^{-1} (H412; P63LE113). The study showed that high yields could be achieved by using newly-developed hybrid sunflower genotypes in the conditions in the region. According to the averages of the location, it can be argued that the H412 hybrid that has high seed and oil yield can be successfully grown in regional conditions.

Keywords: Sunflower; breeding; yield; hybrid

1. Introduction

The consumption of foodstuffs, and for this reason, vegetable oil consumption is increasing with the increasing world population. Vegetable oils have become the raw material of the energy sector in recent years because they have been used extensively in biodiesel production in some countries other than the food sector. In this way, vegetable oils are considered a strategic product used extensively in the food, energy, and chemistry sectors. The main problem of the Turkish vegetable oil industry is not the vegetable oil production, but the 60-70% foreign-dependent sector of raw material supply. Although it changes according to years, oilseed plants and their derivatives are the only agricultural product group included in the top 10 in Turkey's import items (Anonymous 2021). Oilseed plants cultivated in Turkey are sunflowers, cottonseed, soybean,

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peanut, poppy, sesame, rapeseed, and safflower. Among these plants, sunflower is an important oil plant in terms of vegetable crude oil production, which can be grown in many regions of our country because of its high adaptability, and contains a high percentage of seeds (22-55%) and quality oil [69% unsaturated fat (Linoleic acid 50-65%, Oleic acid 25-35%)]. It takes the first place among the oilseed plants produced in our country because of its characteristics such as being resistant to drought and low temperatures, and adapting to several soil types and very different environments, (Arıoğlu et al. 2010).

According to the 2022 data from the Turkish Statistical Institute (TUIK), the oil sunflower cultivation area was 900.517 hectares, the production was 2.350.000 tons and the average yield was 2.610 t ha^{-1}.

It is essential to prevent the decrease in yield and quality and the most important factors in this decrease are diseases, pests, and weeds. In this context, the chemical control method is among the most preferred control methods in the fight against diseases and pests as a problem in plant production. One of the most important agricultural struggles against diseases, pests, and weeds is chemical control in our country (Yücel 2011). In terms of chemical applications, the response of today's sunflower cultivars to herbicides applied to the soil has varied widely. The sensitivity and tolerance levels of the sunflower plant can change with several molecular studies, and the tolerance levels can also vary according to the growth periods, the herbicide dose, and environmental conditions such as temperature and relative humidity (Gillespie and Miller 1983).

Hybrid seeds are employed in sunflower production in Turkey, and producers prefer hybrid varieties are preferred by producers because of their high yield performance, superior quality characteristics, homogeneous appearance, and resistance to some diseases and Orobanche. For this reason, cultivation programs in our country and the world are generally aimed at the hybrid cultivation of sunflowers (Kaya et al. 2009).

Also, increasing crop yields necessitates the development of novel, more productive genotypes, and the advancement of growing technology. Plant cultivation for tolerance to herbicides covers both these aspects. Although it is possible to develop plants tolerant to any herbicide theoretically, a real commercial application has been made only for combinations of economically important plants and herbicides with favorable properties (glyphosate, glufosinate ammonium, sulfonylurea, imidazolinones, etc.) (Malidža et. al. 1999).

The early stages of plant cultivation for herbicide resistance did not involve any study on the sunflower plant. Plant species for which herbicide-tolerant genotypes were developed started to be grown more widely with their improved production and high economic returns, and as a result, sunflower production decreased in South and North America, where new technologies were accepted without any legal restrictions. The herbicides used in sunflowers are less developed than the rest of the field crop species produced. Because of the studies conducted on broad-leaved weeds and the lack of post-emergence herbicides, weeds caused large yield losses in sunflowers. Although the present chemical precautions are ineffective against large-seeded broad-leaved weeds, existing soil herbicides are generally not adequately effective in suppressing small-seeded weed species, especially in years when rainfall is scarce after herbicide application (Malidža et al. 2004). On the other hand, sunflower (*Helianthus*) is among the most important oilseed crops on a global scale, cultivated on a total area of 22 million hectares worldwide (Škorić et al. 2008). All of this had effects in having sunflower researchers start working on the plant's tolerance to herbicides. In the first breakthrough, Al-Khatib et al. (1998) used a wild population of *Helianthus annuus* L. (ANN-PUR) that originated in Rossville, Kansas (USA) as resistant to imidazolinone-based herbicides. After the genetics of resistance were studied and understood (Miller and Al-Khatib 2000; Jocić et al. 2001), this population was used to develop the first sunflower hybrids tolerant to Imidazolinone Herbicides. These hybrids were developed in the USA in 2003 and in 2004 in Serbia and Turkey (Jocić et al. 2004).

The discovery of a wild population of *Helianthus annuus* L. (ANN-KAN) resistant to a Sulfonylurea Herbicide (Tribenuronmethyl) in the USA (Al-Khatib et al. 1999) opened up the possibility of expanding sunflower cultivation for tolerance to herbicides. In this study, the purpose was to develop sunflower hybrids with Tribenuronmethyl tolerance. The introduction of such hybrids brings with them many benefits, including reducing or avoiding the high-cost applications used to suppress some annual broadleaf weeds after sunflower emergence, and providing a wide range of herbicides in sunflowers and more effective control of Canadian Thistle (*Cirsium arvense*) (Zollinger 2003; Malidža et al. 2006).

However, as well as chemical control, new approaches such as cultural, mechanical, biological, genetic, integrated, and biotechnological control are required in this respect. Alternative methods are sought in weed control in the world and our country to minimize chemical contamination, reduce input costs, and increase the amount and quality of the product taken from the unit area. Many studies are conducted on hoeing plants such as sugar beet, sunflower, cotton, corn, and hoeing, and its combinations are preferred for weed control, especially in these plants where hoeing is very important (Yücel 2011).

There is the resistance of commercial varieties to herbicide groups, which provide significant advantages in combating weeds at the forefront of hybrid cultivation issues in sunflowers. An important issue in this respect is the development of fast and effective solutions by considering the economic conditions while fighting against foreigners. Resistance to herbicides with Tribenuronmethyl active ingredient, one of the herbicides called SU group (Sulfonyl Urea), comes to the forefront for the development of new varieties of sunflower. The use of this herbicide is increasing in Turkey because of its broad spectrum, cost-effective status, and easy accessibility. Cultivation studies for SU group sunflower varieties have gained momentum in the cultivation studies conducted in Turkey in recent years.

The performance of SU group hybrids obtained by sunflower cultivation studies conducted in Selcuk University Faculty of Agriculture, in different locations is emphasized in the present study.

2. Materials and Methods

The present study was conducted in two separate trials in Konya and Karaman in 2022. Commercial hybrid sunflower varieties (P63LE113, P64LE119, and M94S35), which are resistant to SU group (Tribenuronmethyl) herbicides and the H408 and H412 hybrids developed by Assoc. Prof. Rahim ADA in Selcuk University Faculty of Agriculture was used in the study. The 75% Tribenuronmethyl active ingredient (Granstar) herbicide was applied with a licensed dose of 30 g ha^{-1} + Spreading Adhesive in the trial areas. The study was conducted when the plants in the plots had 4-6 leaves.

The study was conducted in four replications according to the "Randomized Blocks Trial Design" at each location (Düzgüneş et al. 1987).

The trial fields, where the front crop was wheat, were plowed deeply with a socket in the autumn following the preliminary crop harvest and left for the winter. The disc harrow and the field were raked several times and made ready for planting Before planting in the spring.

The study plots were 2.8 mx 7.5 m = 21.0 m^2 and each plot was arranged in a way that there were 70 cm in 4 rows in the row spacing and 120 kg ha^{-1} N and 80 kg ha^{-1} P_2O_5 were applied to all trial plots, all together with sowing.

3. Results and Discussion

The results of the analysis of variance of the characteristics examined in the sunflower genotypes of the SU group included in the trial are given in Table 1, and the average values of the Karaman and Konya are given in Table 2.

Konya, where the number of flowering days (%) values were evaluated, was ahead of Karaman (61.5 days) with 63.4 days. In terms of genotypes, the H412 hybrid took the lead with 64.5 days, although the P63LE113 variety (60.8 days) took the lowest place. Genetic factors and environmental conditions are effective in flowering time. Especially air temperatures are an environmental factor in flowering, and the difference between locations has ecologically determinative effects on the flowering time in climate and soil conditions (Poyraz 2012).

Physiological maturity values paralleled the study number of flowering days. Although it was 112.9 days in Konya, it was 111.5 days in Karaman. After the accumulation of nutrients in the seed is over, the maturation of the accumulated materials continues. During this period, called physiological maturity, plants reach their maximum dry weight. Although the harvest time in sunflowers varies among regions, it starts from mid-August and lasts until the end of September. Knowing the appropriate harvest time for the preferred variety is essential. Early harvest causes the seeds not to ripen, the oil content to decrease and the seed yield to decrease; On the other hand, late harvest causes yield loss in the form of seed shedding in the plant (Kolsarıcı et al., 1987). Earliness in Turkey is an important characteristic in areas with a short growing season in sunflower agriculture. Also, late planting for reasons such as second crop or hail damage brings advantages in terms of harvest time (Süzer, 1991). These results are consistent with the findings of Jocić et al. (2011), who conducted a study on Tribenuron tolerant sunflower hybrids, which they found to vary between 109.9 -127.5 days.

The plant height values were insignificant in the present study in terms of location, genotype, and location x genotype. Plant height values varied between 177.3 and 164.6 cm. Genetic structure is one of the determining factors of plant height (Önder et al. 2001; Akkaya 2006; Ceyhan et al. 2008; Öztürk et al. 2008; Day 2011; Tan 2014).

Statistical differences were detected between genotypes when the head diameter values were evaluated. The highest head diameter value of 20.9 cm was obtained in the H412 hybrid, although the lowest was obtained in the commercial variety P63LE113 (17.3 cm). the results were supported by Gürbüz et al. (2003), who reported that the diameter of the head diameter in sunflowers varied greatly depending on ecological conditions, soil structure, cultivation techniques, irrigation status, and a variety of factors. The heritability of the head size is quite low in sunflowers (Turan and Göksoy 1998). Also, the diameter of the head is an important indicator of seed yield in sunflowers (Özkahraman 2021).

Although a statistical difference was detected between genotypes in terms of thousand seed weights, no difference was detected in terms of locations and location x genotype interaction. In the present study, the highest 1000-seed weight was obtained in the H408 hybrid, although the lowest was obtained in the P64LE119 variety. One thousand seed weight, which is one of the most important yield factors in sunflowers, varies according to the variety and growing conditions (Ilbaş et al., 1996). However, it can also be argued that the differences between varieties in terms of thousand seed weight occur mostly because of genotypic differences (Yılmaz and Bayraktar 1996, Özer et al. 2003).

When the seed moisture values were evaluated in the study, it was found that the highest value was obtained in the H408 hybrid (7.8%), and the lowest value was obtained in the commercial variety P63LE113 with 5.9%. Seed moisture is an important indicator of physiological maturity and harvest period in sunflowers.

When Table 1 is evaluated in terms of seed yields, although the genotypes were statistically significant at the 1% level, the interaction of location and location x genotype was insignificant. When the average data were evaluated, the highest seed yield was obtained in the (A) P64LE119 (4.32 t ha^{-1}), M94S35 (4.10 t ha^{-1}), and H412 (4.36 t ha^{-1}) genotypes, which were in the same statistical group followed by P63LE113 (4.02 t ha^{-1}) and H408 (3.54 t ha^{-1}) genotypes, respectively. Besides genetic structure, yield is affected by many elements in sunflowers along with ecological, morphological, physiological, and agronomic factors (Bange et al, 1997). On other words, the different results of the cultivars in terms of seed yield stem from their genotypic structures being different and reacting differently to ecological variables associated with years (Kıllı 1997). Because of the great influence of environmental factors, the heritability of seed yield is quite low (Turan and Göksoy 1998). For this reason, when evaluating the study results, it should not be forgotten that the cultural treatments (e.g., rotation, planting time, irrigation) will significantly change the yield performance of the varieties. As in other cultivated plants, the using of varieties that are suitable for the area is one of the main factors that increase yield and quality in sunflower cultivation. Several seed yield results were obtained in previous studies conducted by many researchers in different varieties and different ecologies (Öztürk et al. 2008).

Table 1. Results of variance analysis in the experiment conducted in Konya-Altinekin and Karaman Locations

Source of Variation	df	Means square				
		Flowering days	**Physiological maturity days (day)**	**Plant height (cm)**	**Head diameter (cm)**	**Thousand seed weight (g),**
Location	1	36,10**	21,03**	1849,60**	4,23	193,60*
Replication [L]	6	2,25	0,93	23,12	2,19	14,20
Genotypes	4	17,65**	17,98**	30,10	16,29**	199,90**
L x G	4	2,60	12,65**	10,98	4,41	15,85
Error	24	2,38	2,61	24,72	1,73	13,66
Source of Variation	**df**	**Seed moisture (%)**	**Seed yield (t ha^{-1})**	**Oil content (%)**	**Oil yield (t ha^{-1})**	
Location	1	0,41	396,90	2,50	189,23	
Replication [L]	6	0,21	701,57	0,80	83,69	
Genotypes	4	4,08**	8566,96**	6,10*	2057,77**	
L x G	4	0,11	986,96	5,89*	120,12	
Error	24	0,12	1540,46	1,67	334,98	

[1] Tables may have a footer.

Table 2. Means of two locations for Number of days to bloom (day), Physiological maturity days (day), Plant height (cm), Head diameter (cm), Thousand seed weight (g), Hectoliter weight (kg) of 9 sunflower genotypes evaluated in Konya and Karaman Locations

	Number of days to bloom (day)			Number of days to physiological maturity (day)			Plant height (cm)		
Genotypes	**Altinekin**	**Karaman**	**Mean**	**Altinekin**	**Karaman**	**Mean**	**Altinekin**	**Karaman**	**Mean**
H194	65,0	66,3	65,6 A	117,0	114,8	115,9 A	120,0 I	171,8 A	145,9 DE
H249	62,3	63,8	63,0 BC	113,3	113,8	113,5 BC	145,0 FG	141,5 GH	143,3 E
H250	62,3	63,0	62,6 BC	113,3	113,8	113,5 BC	142,5 G	152,8 C-E	147,6 C-E
H253	63,0	65,0	64,0 AB	115,0	115,8	115,4 AB	160,3 B	161,0 B	160,6 B
H5	62,5	64,8	63,6 B	116,3	115,3	115,8 A	148,5 D-G	144,5 FG	146,5 C-E
H55	60,3	63,0	61,6 CD	110,5	112,3	111,4 C	144,3 FG	158,3 BC	151,3 C
P63MM54	59,0	62,3	60,6 D	108,3	109,8	109,0 D	134,3 H	155,8 B-D	145,0 DE
Tunca	63,8	67,3	65,5 A	116,8	117,0	116,9 A	172,3 A	173,0 A	172,6 A
Gibraltar	61,3	63,5	62,4 BC	112,8	113,8	113,3 BC	146,3 E-G	151,5 C-F	148,9 CD
Mean	62,1 B	64,3 A	63,2	113,7	114,0	113,8	145,9 B	156,7 A	151,3
		Lsd $_{genotype\ (0.01)}$ = 1,78			Lsd $_{genotype\ (0.01)}$ = 2,16			Lsd $_{genotype\ (0.01)}$ = 5,25	
								Lsd $_{locationx\ genotype\ (0.01)}$ = 7,42	
Genotypes		**Head diameter (cm)**			**Thousand-seed weight (g)**			**Hectoliter weight (kg)**	
H194	15,8 EF	19,8 A	17,8 A-C	46,8	50,8	48,8 A-C	30,3	30,2	30,3
H249	16,5 D-F	16,8 C-F	16,6 BC	51,5	53,1	52,3 AB	32,0	29,3	30,6
H250	19,0 AB	18,5 A-D	18,8 A	56,9	51,6	54,2 A	30,5	31,5	31,0
H253	17,8 A-E	18,8 A-C	18,3 AB	50,8	53,6	52,2 AB	31,1	31,0	31,0
H5	19,0 AB	17,3 B-E	18,1 AB	51,1	49,9	50,5 AB	31,6	30,6	31,1
H55	19,0 AB	17,0 B-F	18,0 AB	45,5	47,0	46,3 BC	29,9	31,9	30,9
P63MM54	15,0 F	16,8 C-F	15,9 C	46,1	54,1	50,1 AB	32,7	31,9	32,3
Tunca	17,5 B-E	18,5 A-D	18,0 AB	52,9	52,1	52,5 AB	31,5	31,6	31,6
Gibraltar	15,8 EF	16,8 C-F	16,3 BC	44,9	41,8	43,4 C	30,8	30,4	30,6
Mean	17,3	17,8	17,5	49,6	50,4	50,0	31,2	30,9	31,0
		Lsd $_{genotype\ (0.01)}$ = 2,07			Lsd $_{genotype\ (0.01)}$ = 6,70				
		Lsd $_{locationx\ genotype\ (0.05)}$ = 2,19							

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Table 3. Means of two locations Seed moisture (%), Seed yield (t ha^{-1}), Oil content (%), Oil yield (t ha^{-1}) of 9 sunflower genotypes evaluated in Konya and Karaman Locations

	Seed moisture (%)			**Seed yield (t ha^{-1})**		
Genotypes	**Altinekin**	**Karaman**	**Mean**	**Altinekin**	**Karaman**	**Mean**
H194	8,4	7,4	7,9	4,40	4,34	4,37 A
H249	7,9	8,1	8,0	3,85	3,78	3,82 B
H250	7,8	8,4	8,1	4,33	4,22	4,27 AB
H253	8,7	7,6	8,1	3,93	3,87	3,90B
H5	7,9	7,6	7,7	4,18	4,13	4,16AB
H55	7,8	7,5	7,7	4,25	4,15	4,20AB
P63MM54	7,5	7,1	7,3	4,10	4,24	4,17 AB
Tunca	8,3	7,7	8,0	4,01	3,94	3,98AB
Gibraltar	7,5	7,1	7,3	4,26	4,04	4,15AB
Mean	8,0	7,6	7,8	415,0	4,08	4.11
					$Lsd_{genotype (0.05)} = 4.6$	

Genotypes		**Oil rate (%)**			**Oil yield (t ha^{-1})**	
H194	44,4	45,8	45,1 BC	1,95	1,99	1,97 AB
H249	41,9	44,0	43,0 C	1,61	1,67	1,64 D
H250	47,8	47,9	47,8 A	2,07	2,02	2,04 A
H253	46,1	45,3	45,7 AB	1,81	1,75	1,78 B-D
H5	44,9	45,4	45,2 BC	1,88	1,88	1,88 A-C
H55	43,2	42,5	42,9 C	1,83	1,76	1,79 B-D
P63MM54	43,5	43,0	43,2 C	1,78	1,82	1,80 B-D
Tunca	43,8	43,6	43,7 BC	1,75	1,72	1,73 CD
Gibraltar	44,7	43,1	43,9 BC	1,90	1,74	1,82 A-D
Mean	44,5	44,5	44,5	184,6	1,82	1,83
		$Lsd_{genotype (0.01)} = 2,31$			$Lsd_{genotype (0.01)} = 2,3$	

[1] Tables may have a footer.

In the present study, conducted in Konya and Karaman in 2022, genotype and location x genotype interaction were found to be statistically different at a 1% significance level in terms of oil content values. In terms of genotype averages, the highest oil content was obtained in the H412 sunflower hybrid with 44.2%, followed by P64LE119 (42.6 %), H408 (42.5%), and P63LE113 (42.4%). The results of the present study confirmed that the oil content is affected by environmental factors, cultural practices, and sunflower genotypes (Esechie et al. 1996, Özer et al. 2003). The effects of the cultivars on the oil content are very important, and the oil content is around 38-50% in commercial hybrid cultivars. For this reason, care should be taken to ensure that this ratio in sunflower varieties consumed as oil is 40% or more (Coşge and Ulukan 2005). Also, the oil content is a quantitative character significantly affected by environmental conditions (temperatures, day lengths, and precipitation rates) because of cultural processes (Zürrer and Bachofen 1985; Karasu et al. 2006).

When the study results were evaluated in terms of oil yield, the differences between the genotypes were found to be statistically significant. The highest oil yield was obtained in H412 (1.92 t ha^{-1}) followed by P64LE119 (1.84 t ha^{-1}), M94S35 (1.71 t ha^{-1}), P63LE113 (1.70 t ha^{-1}), and H408 (1.50 t ha^{-1}) genotypes, respectively. Oil yield, a combination of seed yield and oil content, is influenced by all growing conditions and ecological factors affecting seed yield and oil content, as well as variety characteristics.

The most economically important yield criterion is the oil yield in all oil crops (Öztürk et al. 2008). In the present study, oil yield showed variability under the influence of ecological and growing conditions and various characteristics.

4. Conclusions

As a result of the present study which was conducted to determine the yield and quality characteristics of SU group (Tribenuronmethyl) hybrid oil sunflower genotypes as candidates for registration in Konya and Karaman, it can be argued that the H412 hybrid and P64LE119 commercial hybrid variety used in both locations are suitable for the ecology of the region in which the study was conducted, in terms of crude oil yield and the characteristics investigated.

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