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YIELD TRAITS OF SUNFLOWER (*HELIANTHUS ANNUUS* L.) HYBRIDS ACCORDING TO THE DIFFERENCE IN THEIR GROWTH STAGES

ISMAIL DEMIR

Kırşehir Ahi Evran University, Faculty of Agriculture, Department of Field Crops, Kırşehir, Turkey.
Corresponding author's email: ismail.demir@ahievran.edu.tr

Abstract

The responses of sunflower hybrids to environmental conditions during vegetative and generative growth periods are different; these differences play an important role in seed yield. In this study, dry matter accumulation, stem diameter, number of leaves and plant height data of seven commonly used sunflower hybrids grown under irrigated conditions were regularly collected during growth periods uptill the harvest season. The effects of growth stage differences on yield traits were investigated. Dry matter accumulation of hybrids continued till the back of head yellowing period and the highest dry matter accumulation was obtained in seed filling period (R6) as 47.24 g m^{-2} day^{-1}. Dry matter losses of hybrids were at the highest level following the R7 period due to the fall of leaves which lost their functions, and dry matter content in R7 period was 17.04 t ha^{-1}, while it was decreased to 11.38 t ha^{-1} at harvest. Approximately, 5.66 t ha^{-1} dry matter loss was added to soil as organic matter. To conclude, LG 5585 hybrid had the biggest head diameter, highest number of seeds in a head, plant seed weight and 1000-seed weight, seed yield (3957.8 kg ha^{-1}), harvest index (45.75%) and, consequently, the highest oil yield (1820.6 kg ha^{-1}), suggesting that this hybrid could be used in irrigated lands for seed and oil production.

Key words: Sunflower, Growth stage, Dry matter, Yield, Oil

Introduction

Sunflower (*Helianthus annuus* L.) is an important oilseed crop to sustain the requirements of people for vegetable oil in Turkey. Sunflower has been considered as an important crop among oilseed plants due to its tolerance to dry conditions and sufficient yield under non-irrigated lands (Kaya *et al.*, 2007). Recent use of sunflower hybrid seeds has increased the yield and oil production in per unit area. Seed yield and price increases of sunflower positively affected farmers to preference of sunflower cultivation, while plays an important role in meeting the vegetable oil demand of Turkey. Despite all these positive developments, vegetable oil demand of Turkey is not met by the current production. Only 25% of the annual demand is met by domestic production, and the remaining 75% are imported either as oilseed or crude vegetable oil (Anon., 2019). Due to lack of enough domestic oilseed production, established vegetable oil industry processes imported oilseeds. Not only the vegetable oil demand but also the future of oil industry depends on oilseed crops. Breeding the efficient varieties with high crude oil content in addition to increasing the total cultivation area is an important way to overcome the vegetable oil problem of country.

Hybrid sunflowers with wider adaptability may react differently to environmental conditions during growth, development and maturity periods. Separation of different cultivars from each due to their reactions to the environmental conditions during their growth periods is a result of breeding processes. Determination of critical periods and the adequacy of the genetic potential in these periods are important in determining the productive varieties. Growth development periods in sunflower as in many other crops have been suggested by different researchers. A detailed classification under vegetative and generative parts of plants has been proposed by Schneiter & Miller (1981). Determination of critical periods during growth and developments of sunflower is very important both for productivity and disease and pest managements. High success has been achieved in productivity and resistance with the increase of hybrid varieties. The progress in genetic competence during growth and development periods is important in yield potential of varieties. The aims of this study were to determine the performances of the most commonly used sunflower varieties during growth, development and maturation periods, and compare the differences of varieties for yield and yield criteria.

Materials and Methods

The experimental soil was clay loam intexture, alkaline, calcareous, non-saline and had certain amount of available phosphorus concentration, rich in potassium content, poor in organic matter and nitrogen (Table 1).

The meteorological data for the growth period of experimental crop were collected from the Turkish State Meteorological Service. Climate data of 2014 and 2015 were significantly different from long term averages. The highest temperatures were recorded in July and August. In 2015, temperature was less than that of 2014, except September. The total precipitation was higher than long term in both 2014 and 2105. The highest rainfall in April 2015 was 161.4 mm. Short-term high-intensity precipitation events and low temperature were observed in 2015, and most of the precipitation moved as surface runoff. Relative humidity was below the long-term average in 2014 (Table 2).

Experiment was conducted under field conditions in 2014 and 2015 at Mucur District of Kırşehir province (39.08 N and 34.36 E). Seven sunflower hybrids (Transol, Bosfora, LG 5580, LG 5585, Cadix, Hornet, and Sirena) usually preferred in the region, were used, and the experiment was laid out in a randomized complete block design with three replicates. Sunflower hybrids were planted in the second week of April in both years and in triple irrigation water was applied at heading (R1), flowering (R5) and seed filling stages (R6) (Kaya & Kolsarıcı 2011). Seeds were planted at 50x25 cm interrow and intra-row spacings. Based on soil analysis, 120 kg ha^{-1} N and 80 kg ha^{-1} P_2O_5 were applied to each plot. Total phosphorus and half of nitrogen doses were applied to trial areas before the seeding time. Rest 50% of nitrogen (60 kg N ha^{-1}) was applied 30-35 days after sowing (DAS). The sizes of plots were kept larger than the regular sizes to provide sufficient sample size in each period and the size of each plot was 10x5 m. The growing stages defined by Schneiter & Miller (1981) were considered as reference study.

Ten plant samples were collected considering the growth stages from the emergence to harvest. Plant sampling was started from appearance of the first cotyledonary leaf and continued in every 20 days after emergence (DAE). The fresh weights of plant samples were weighed in the field, and the dry weights were weighed after one week in open air and for 48 hours in 60ºC drying oven. Dry matter accumulation, stem diameter, plant height and number of leaves per plant were recorded until the harvest. In the harvest, head diameter, number of seeds per head, seed weight per head, 1000-seed weight, harvest index, yield, crude oil ratio and oil yield values were obtained. Seed samples were collected from each plot and ground with an electric coffee mill. A small portion of ground seeds (5 g) was transferred to a disposable filter column and seed oil content was determined by the Soxhlet extraction technique. Oil yield was calculated as a function of seed yield and oil content. The data were subjected to analysis of variance in MSTAT-C software according to the randomized block design and presented as a two-year average (Russell 1986). LSD ($p<0.05$) Multiple Comparison Test was used to compare the means.

Results and Discussion

Dry matter accumulation: Dry matter accumulation at different periods of cultivars was statistically significant ($p<0.01$), except for 20th and 60th days after emergence. The differences in dry matter accumulation of cultivars under the same environmental conditions might be attributed to the genetic characteristics of the cultivars.

The dry matter accumulation of cultivars reached the highest level in the back of the head started to turn a pale yellow (R7) and amount of dry matter was decreased after this stage. The reduction of dry matter after R7 stage is generally attributed to the reduction of plant viability, fallen dried leaf and ray and disc florets. The number of leaves, which were approximately 20 at R7 stage, fell down to 6 at the harvest stage (Table 5). Similarly, Andrade (1995) reported that dry matter accumulation of sunflower was the highest during flowering stage, and the decline in dry matter accumulation after flowering was related to leaf falling and the loss of leaf viability. The loss of dry matter in this period meant that the organic matter was added to soil in sunflower culture. Average dry matter content of the cultivars was, approximately, 17.04 t ha^{-1} (R7 stage) which was decreased to 11.38 t ha^{-1} at the harvest period (Table 3). In average, 5.66 t ha^{-1} which was 33.22% of the total dry matter of sunflower at R7 stage was returned to soil as organic matter.

Although the daily dry matter accumulation rate continued to increase until the end of R7 stage, the highest daily dry matter increment was obtained at the 80 DAE and this period was called flowering complete, ray flowers wilting stage (R6) (Fig 1). At this stage, the daily dry matter accumulations of hybrids was 47.24 g m^{-1}. The highest dry matter loss (35.14 g m^{-1}) of the varieties was recorded at the 120 DAE called back of the head yellow and bracts remained green (R8). Accumulation of dry matter as well as water loss continued in this period despite of the yellowing of back of head in the R7 stage. The availability of water in soil until this period also, had a positive effect on dry matter accumulation and yield.

Stem diameter: The difference in stem diameter among the varieties was statistically significant ($p<0.01$), except at emergence stage. Stem development of varieties reached the highest values in R6 period and after this period, stem thickness decreased with the start of drying period. The LG5580 and the Hornet varieties had the higher stem thickness in the R6 stage, while the Bosfora variety had the highest stem thickness during the harvest period. The highest stem thickness change was observed in the Cadix variety and the stem thickness of 22 mm at the R6 stage decreased by 15.70 mm in the harvest period (Table 4). The reduction in stem thickness might be resulted from the loss of water in pith and the decrease of available water in soil (Silva *et al.*, 2007; Gomes *et al.*, 2010). The head weight could not be hold up due to rapid decline in stem thickness during the maturation period, therefore the excessive bending and fractures in stem occurred at a distance of 20-25 cm to the head.

Table 1. The results of soil analysis in trial areas.

Texture	Ph	Ec (mmhos/cm)	Salinity (%)	Available P_2O_5 (kg ha^{-1})	Caco$_3$ %	Available K_2O (kg ha^{-1})	Om (%)
Clayed-loamy	7.69	0.59	0.02	27.4	28.10	846.2	1.71

Table 2. Meteorological data in Kırşehir Province during the period of 1970-2015.

	Total precipitation (mm)			Mean temperature (°C)			Relative humidity (%)		
	1970-2015	2014	2015	1970-2015	2014	2015	1970-2015	2014	2015
April	45.3	20.0	26.8	13.8	13.2	8.8	63.7	54.8	66.2
May	45	46.6	39.2	14.9	16.3	16	60.8	61.3	58.1
June	36.4	36.0	161.4	21	19.9	18.4	54	54.1	66.9
July	9.1	13.0	20.6	24.2	25.5	23	48.1	39.2	47
August	6.9	17.0	11.8	25.7	25.9	24.8	48.4	39.7	47.5
September	14	29.8	1.0	18.4	19.9	23	53.1	50.9	40.8
Total/mean	**156.7**	**162.4**	**260.8**	**19.67**	**20.12**	**19.00**	**54.68**	**50.00**	**54.42**

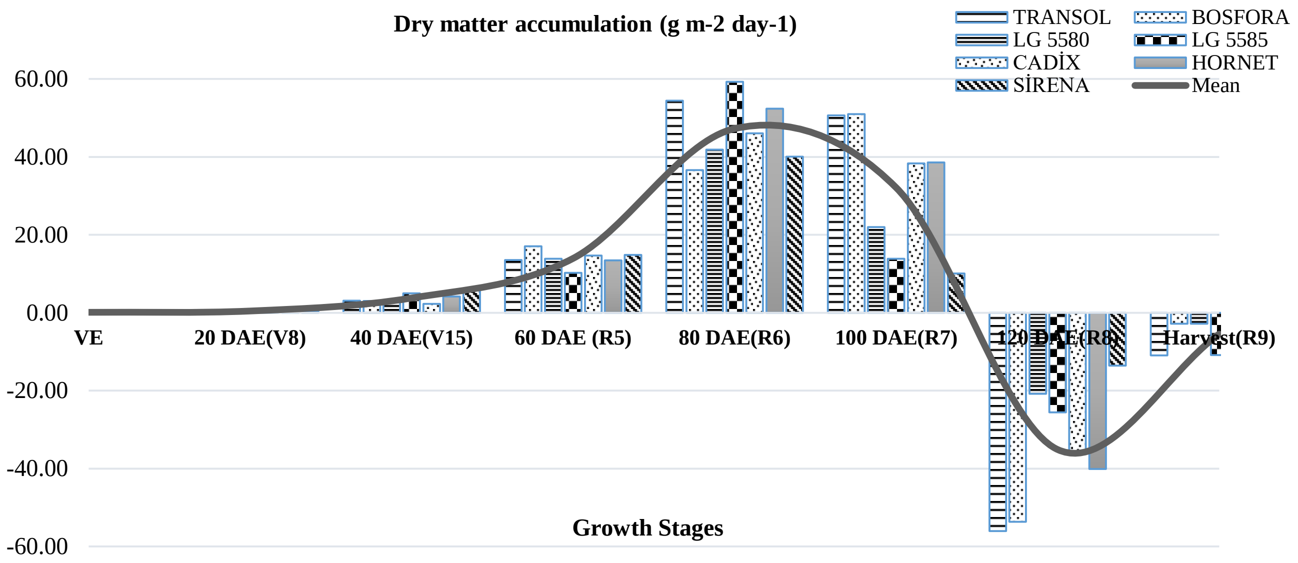

Fig. 1. Daily dry matter accumulation for 7 sunflower hybrids from emergence to physiological maturity. DAE: days after emergence.

Table 3. Result of variance analysis of dry matter accumulation for 7 sunflower hybrids from emergence to physiological maturity.

	df	Dry matter accumulation (g plant^{-1})							
		VE	20 DAE (V8)	40 DAE (V15)	60DAE (R5)	80DAE (R6)	100DAE (R7)	120DAE (R8)	Harvest (R9)
Year	1	1.87	0.00	1.61	0.21	0.53	0.05	0.78	1.51
Error	4	0.00	0.09	4.03	60.58	202.83	71.03	87.85	277.46
Factor	6	9.67**	1.80	86.38**	1.52	9.23**	63.01**	8.05**	9.70**
*Y*F*	6	0.85**	0.27	4.56**	1.38	1.09	1.83	1.69	0.54
Error	24	0.00	0.07	0.74	97.24	190.29	187.64	120.49	110.54
CV (%)	15.24	16.24	8.24	16.23	8.43	5.62	7.04	7.39	
Cultivar									
Transol	0.26a	1.01	8.66d	42.43	178.54a	305.26a	165.06ab	137.71bc	
Bosfora	0.15bc	1.34	8.80d	51.38	142.90b	270.42bc	136.25e	129.14c	
Lg 5580	0.10c	1.32	8.55d	43.22	147.83b	202.84e	150.91cd	143.88b	
Lg 5585	0.15bc	1.41	13.86b	39.47	187.63a	222.37d	158.41bc	131.14c	
Cadix	0.16b	1.29	7.07e	43.70	158.90b	254.85c	164.56ab	156.52a	
Hornet	0.19b	1.08	11.52c	45.07	175.98a	272.52b	172.17a	163.88a	
Sirena	0.16b	1.17	15.94a	53.15	153.41b	178.58f	144.54de	133.20bc	
Mean (t ha^{-1})	0.01	0.10	0.85	3.64	13.09	17.04	12.48	11.38	
LSD (p>0.05)	0.053		1.023		16.44	16.32	13.08	12.53	

*, ** Significant at the 0.05 and 0.01 level, respectively. For each main effect, values within columns followed by the same letter are not significant. ns, Non-significant. DAE: days after emergence

Table 4. Result of variance analysis of Steam diameter for 7 sunflower hybrids from emergence to physiological maturity.

	df	Steam diameter (mm)							
		VE	20 DAE (V8)	40 DAE (V15)	60DAE (R5)	80DAE (R6)	100DAE (R7)	120DAE (R8)	Harvest (R9)
Year	1	1.56	0.24	0.08	0.30	12.64	0.06	1.38	1.01
Error	4	0.01	0.03	0.16	0.03	0.20	0.18	0.13	0.54
Factor	6	1.98ns	21.08**	43.46**	77.04**	22.57**	25.96**	25.12**	10.20**
*Y*F*	6	0.92ns	6.76**	2.21ns	4.57**	22.93**	1.75ns	2.28ns	2.41ns
Error	24	0.03	0.04	0.12	0.14	0.04	0.21	0.13	0.33
CV(%)		6.62	3.65	3.37	2.15	0.93	2.34	1.95	3.37
Cultivar									
Transol		2.66	4.84d	8.81e	14.90f	22.14c	19.08c	17.90c	16.52c
Bosfora		2.63	5.60bc	10.21c	17.77bc	22.66b	20.96a	19.51a	17.87a
Lg 5580		2.67	5.82ab	9.61d	17.22cd	23.15a	20.78a	19.20a	17.42ab
Lg 5585		2.66	6.02a	10.94b	15.84e	22.63b	19.67b	18.51b	17.15bc
Cadix		2.64	5.52c	11.40a	16.97d	22.00c	18.85c	17.38d	15.70d
Hornet		2.83	5.88a	11.31ab	18.65a	22.94a	18.87c	18.26bc	17.45ab
Sirena		2.89	5.64bc	10.43c	18.15ab	22.61b	18.67c	18.25bc	17.63ab
Mean (mm)		2.71	5.62	10.39	17.07	22.59	19.55	18.43	17.11
LSD (p>0.05)			0,244	0.418	0.669	0.250	0,544	0.428	0,687

*, ** Significant at the 0.05 and 0.01 level, respectively. For each main effect, values within columns followed by the same letter are not significant. ns, Non-significant

Table 5. Result of variance analysis of Plant hight for 7 sunflower hybrids from emergence to physiological maturity.

	df	Plant height (cm)							
		VE	20 DAE (V8)	40 DAE (V15)	60DAE (R5)	80DAE (R6)	100DAE (R7)	120DAE (R8)	Harvest (R9)
Year	1	4.25	37.83	44.02	60.39	0.46	1.47	2.84	6.06
Error	4	0.055	0.02	0.315	0.252	1.694	4.431	3.577	2.638
Factor	6	20.54**	9.79**	37.22**	43.78**	60.30**	164.73**	99.38**	66.92**
*Y*F*	6	23.21**	2.11	1.66	8.24**	4.61**	5.21**	2.58*	1.40
Error	24	0.022	0.311	0.898	4.623	2.028	1.462	2.238	3.204
CV(%)		5.46	6.06	3.12	3.04	1.2	0.92	1.15	1.39
Cultivar									
Transol		2.73b	9.94a	32.79a	79.57a	117.48c	129.29c	127.38c	126.70c
Bosfora		2.69b	10.17a	29.22cd	74.98b	113.92d	144.58a	141.86a	140.37a
Lg 5580		3.10a	9.62ab	28.90d	63.73e	111.97e	129.63c	127.55c	126.72c
Lg 5585		2.33c	9.00bc	31.41b	63.65e	121.56b	129.39c	128.24c	127.53c
Cadix		2.36c	8.35c	26.71e	70.73cd	117.42c	136.84b	133.72b	131.84b
Hornet		2.82b	8.77c	30.05c	73.00bc	123.27a	128.28cd	125.37d	123.70d
Sirena		2.85b	8.54c	33.45a	69.32d	123.43a	126.95d	124.45d	122.86d
Mean (cm)		2.70	9.20	30.36	70.71	118.43	132.14	129.80	128.53
LSD (p>0.05)		0.177	0.664	1.129	2.562	1.697	1.441	1.783	2.133

*, ** Significant at the 0.05 and 0.01 level, respectively. For each main effect, values within columns followed by the same letter are not significant. ns, Non-significant

Plant height: The difference in plant height among hybrid sunflowers was significant (*p*<0.01) for each period. Plant height of varieties was in the highest group in one period, while it was in the middle or highest group in another period. The LG5580 variety during the emergence period, the Transol variety during the flowering period and the Bosfora variety during the harvest period had the highest plant height. The differences in height among varieties showed the different response and adaptation of varieties against environmental conditions. The highest plant was obtained during the R7 stage for all hybrids. Harvest stage was obtained by a shortening of 3.6 cm along with drying. The highest increase in plant height was observed in R6 and R5 periods with an increase of 47.7 cm and 40.4 cm respectively (Table 5). Plant height is generally considered a genetically determined trait; however, it is significantly affected by soil and climatic conditions (Pillai *et al.*, 1995). The presence of available water in soil caused a significant increase in plant height, and plants with no water stress had approximately 20.8% higher plant height (Silva *et al.*, 2007; Nobre *et al.*, 2010; de Freitas *et al.*, 2012; de Andrade Barbosa *et al.*, 2015). The results on plant height changes in this study were in consistent with the results of others who linked the variation in plant height to the genetic differences and environmental effects (Bakht *et al.*, 2006; Kaya *et al.*, 2009; Ali *et al.*, 2011; Demir 2016; Ahmad *et al.*, 2017).

Number of leaves: No difference was observed in the number of leaves among the varieties until the 40 DAE, whereas the changes in the number of leaves after this stage were significant (*p*<0.01). Number of leaves and growth continued until the R6 stage. The functions of leaves decreased after R5 stage and started to fall down. The average number of leaves was 20.69 in the R5 period and 19.93 in R6 and R7 growth periods, the leaves lost their functions following this period and decreased to 6.05 in the harvest (Table 6).

The highest leaf loss occurred after R7 period. In a similar study carried out under arid conditions, the aging and drying of leaves were started after 75 DAE (Papatheohari *et al.*, 2016). Leaf loss in this study was decreased rapidly from 100 DAE. In this study, leaf loss occurred late due to the irrigated conditions and, therefore, photosynthesis continued longer. Cadix variety had the highest number of leaves (7.83) during the harvest period while LG5585 had the lowest number of leaves (4.83). Bosfora varieties had the highest number of leaves during seed filling period while Transol and Cadix varieties had the higher number of leaves in R8 period. The increase in the number of leaves had a positive effect on dry matter accumulation and significant positive correlation (r = 0.55**, *p*<0.01) was obtained. In addition, the number of leaves in the harvest period had a significant negative correlation with the harvest index (r = -0.59**) indicating that the presence of leaves increased the biological yield and decreased the economic efficiency rate. The number of leaves and changes in number of leaves obtained in this study were in accordance with those reported by (Canavar *et al.*, 2010; de Andrade Barbosa *et al.*, 2015).

Yield and yield components: Head diameters, number of seeds per head, seed yield per plant, 1000-seed weight, seed yield, harvest index, change in crude oil ratio and oil yield showed statistically significant differences among varieties (*p*<0.01). The biggest head diameter was obtained in LG5585 variety as 21.22 cm while the smallest head diameter values was found in Transol, Sirena and LG5580 varieties as 16.78 cm and 17.00 cm and 17.27 cm, respectively (Table 7).

The number of seeds per head ranged from 1311.31 to 800.12 and the highest seed number was obtained in LG5585 and the lowest was found in LG5580 variety (Table 7). A positive relationship was observed between head diameter and seeds number.

The highest seed yield per plant (87.39 g) was obtained from LG5585 while the lowest (62.91 g) was obtained in LG5580 variety (Table 7). Head diameter, number seeds per head and seed yield per plant had significant positive correlations between each other. Stress conditions, temperature and the presence of available water in soil are considered as important environmental factors during the head formation and seed production periods. Presence of sufficient green leaves on plant supports seed filling with photosynthesis resulting a decrease in the number of empty seeds (Muro *et al.*, 2001; Nezamia *et al.*, 2007).

Table 6. Result of variance analysis of leaf number for 7 sunflower hybrids from emergence to physiological maturity.

	df	Leaf Number							
		VE	20 DAE (V8)	40 DAE (V15)	60DAE (R5)	80DAE (R6)	100DAE (R7)	120DAE (R8)	Harvest (R9)
Year	1	0.14	0.82	2.27	0.10	1.47	1.47	0.14	0.021
Error	4	0.167	0.262	0.262	0.238	0.405	0.405	0.667	0.762
Factor	6	0.86ns	0.93ns	8.64**	5.05**	13.55**	13.55**	3.23*	12.014**
*Y*F*	6	0.71ns	0.16ns	0.17ns	2.60*	2.87*	2.87*	1.14ns	0.685ns
Error	24	0.111	0.29	0.234	0.544	0.266	0.266	0.472	0.567
CV(%)		5.73	6.4	3.3	3.56	2.59	2.59	8.8	9.46
Cultivar									
Transol		2.33	8.00	14.33cd	19.50d	20.33b	20.33b	9.50a	5.33de
Bosfora		2.17	8.50	14.83bc	21.33ab	21.33a	21.33a	8.33bc	5.17de
Lg 5580		2.00	8.33	14.17d	20.50bc	19.17c	19.17c	8.83ac	5,83cd
Lg 5585		2.17	8.50	15.33ab	20.33cd	19.33c	19.33c	9.00ab	4.83e
Cadix		2.00	8.50	14.17d	20.67ac	20.33b	20.33b	9.33a	7.83a
Hornet		2.17	8.33	14.17d	21.00ac	19.50c	19.50c	8.50bc	6.83b
Sirena		2.00	8.67	15.50a	21.50a	19.50c	19.50c	8.17c	6.50 bc
Mean		2.12	8.40	14.64	20.69	19.93	19.93	8.81	6.05
LSD (p>0.05)				0.576	0.879	0.608	0.614	0.819	0.897

*, ** Significant at the 0.05 and 0.01 level, respectively. For each main effect, values within columns followed by the same letter are not significant. ns, Non-significant

Table 7. Result of variance analysis of Head diameter (HD), number of seeds in a head (NSH), seed yield per plant (SYP), thousand seed weight (TSW), seed yield (SY), harvest index (HI), crude oil rate (and oil yield (OY) for 7 sunflower hybrids at physiological maturity.

	Df	HD	SN	SYP	TSW	SY	HI	Oil	OY
Year	1	1.76	0.08	1.292	1.26	1.9631	1.6526	15.50	5.9341
Error	4	0.00	1856.63	9.115	0.00	474.756	5.344	0.00	74.704
Factor	6	40.61**	48.43**	54.579**	18.98**	30.3885	15.2296	3.87**	28.664**
*Y*F*	6	2.35	0.36	0.342ns	1.77ns	0.3923ns	1.1727ns	1.24ns	0.363ns
Error	24	0.001	3729.74	7.308	0.00	444.641	7.093	0.00	99.273
CV(%)		3.26	5.86	3.84	4.32	6.89	7.16	1.87	7.02
Cultivar									
Transol		16.78d	1023.70c	72.10b	63.49cd	326.82b	39.20b	47.36a	154.81b
Bosfora		18.59b	949.90d	70.44b	62.54cd	313.54b	36.75bc	46.15b	144.72bc
Lg 5580		17.27d	800.12e	62.91d	65.21bc	253.27d	36.56bc	45.98b	116.45f
Lg 5585		21.22a	1311.31a	87.39a	69.02a	395.78a	45.78a	46.01b	182.06a
Cadix		18.05bc	939.46d	66.19c	67.14ab	279.54c	33.70 c	46.01b	128.58de
Hornet		17.42cd	1050.51c	69.44b	61.84d	305.56b	34.56c	45.72b	139.61cd
Sirena		17.00d	1215.76b	64.69cd	56.31e	267.53cd	33.94c	47.39a	126.82ef
Mean		18.05	1041.54	70.45	63.65	306.01	37.21	46.37	141.87
LSD (p>0.05)		0.71	72.77	3.22	2.76	25.13	3.17	1.03	11.87

*, ** Significant at the 0.05 and 0.01 level, respectively. For each main effect, values within columns followed by the same letter are not significant. ns, Non-significant

The 1000-seed weight of LG5585 was the highest (69.02 g) while it was the lowest (56.31 g) in Sirena variety (Table 7). The highest number of seeds per head and the lowest 1000-seed weight of Sirena variety indicate insufficient seed filling and significant effects of environmental conditions. Many environmental factors during flowering and seed filling periods can significantly affect seed yield of sunflower (Petcu *et al.*, 2001; Ali *et al.*, 2011).

The seed yield of varieties ranged from 3957.8 kg/ha (LG 5585) to 2532.7 kg/ha (LG 5580). Yield positively correlated with the head diameter in a plant, the number of seeds per head and 1000-seed weight (Table 7). Stress conditions, which started from flowering to the end of seed filling period, had a significant effect on yield. In addition, dry matter accumulation was continued in the period including the R7 period (100 DAE). Therefore, the highest dry matter accumulation was observed in the R6 and R7 periods is important in determining the yield potential of varieties, and genetic potentials against the stress conditions causing the yield differences of varieties in this period. LG5585 variety was placed in the highest group in terms head diameter, the number of seeds per head, seed yield per plant and 1000-seed weight. Thus, LG5585 variety showed the best adaptation to environmental conditions and placed in the highest group in terms of yield.

The LG 5585 was placed in the highest harvest index group with 45.78% while the Cadix, Sirena and Hornet varieties were placed in the lowest harvest index group with 33.70%, 33.94% and 34.56% respectively (Table 7). Harvest index is defined as the ratio of economic efficiency to biological yield. Cadix and Hornet varieties had the highest dry matter during harvesting period. However, they had lower harvest index due to the low yield. Negative relationship was, also, obtained between the variation in the number of leaves during the harvest period and the harvest index. The harvest index showed a positive correlation with yield, and negative impact of stress conditions on the harvest index has been reported by Flenet *et al.*, (1996) and Chimenti *et al.*, (2002).

The highest crude oil content was obtained for Sirena with 47.39% and for Transol with 47.36%. All other sunflower varieties placed in the same group in terms of crude oil content (Table 7). Placing the varieties into three groups in terms of crude oil contents and differences in crude oil contents of varieties showed the importance of genetic ability of crude oil content under the same environmental conditions. The crude oil content of sunflower seed is controlled by many genes (Mozaffari *et al.*, 1996) and it is a quantitative trait that is, also, affected by important environmental conditions. Crude oil yield varied from 1820.6 kg/ha to 1164.5 kg/ha. The oil yield of the high-yield LG5585 variety was naturally high. Oil yield has a significant positive relationship with head diameter, number of seeds per head, yield and 1000-seed weight. Positive correlation between yield and oil yield indicates that the yield is a coefficient in oil yield.

Conclusion

In this study, the responses of commonly used varieties of sunflower, grown under irrigated conditions to the yield and yield criteria in different growing periods were determined. In order to eliminate the irregularities of variations in rainfall, irrigation in critical periods reduced the variation in yield criteria related to water stress, hence eliminated the difference between years. Varieties showed statistically significant differences in dry matter accumulation, stem diameter, plant height and number of leaves in different development stages, and head diameter, number of seeds per head, seed weight per head, seed yield, harvest index and crude oil content in the harvest period. LG 5585 has been identified as the most efficient variety due to the bigger head diameter, number of seeds per head and 1000-seed weight compared to the other varieties. Although the increase of dry matter accumulation and length increase of the varieties continued in the R7 period, the R5 and R6 growth periods were considered as the most critical periods for the yield. Dry matter loss was related to drying process starting with R7 period until maturation, especially increased number of falling of dead leaves. The presence of available water in soil during flowering and R7 periods is highly important for high yield and has a significant positive effect on the head diameter, number of seeds per head, plant seed yield, 1000-seed weight and oil yield. Approximately, 33.22% of the dry matter produced during the vegetation period of about 126-138 days was added to soil surface in the form of leaves, ray and disc florets drying in the natural process.

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