WATER STRESS EFFECT ON CONFECTIONERY HYBRID SUNFLOWER (*HELIANTHUS ANNUUS* L.) CULTIVARS IN DIFFERENT GROWTH PERIODS

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ABSTRACT

Drought is one of the factors that cause serious yield losses in agricultural production. Severe drought events from global warming seriously affect plants and cause yield losses. Confectionary sunflower is involved in the production as a very important plant for in Turkey. However, the drought stress that may occur periodically causes this product to lose efficiency. In this study, water stress was applied in different development periods (head formation, flowering, seed-filling periods) of two hybrid confectionery sunflowers. The trial was conducted as split-plot design based on 3 replications between 2018-2019 years. According to the results obtained, many characteristics were affected by water stress during the flowering period. Particularly, seed yield, head diameter, 1000 seed weight, seed length, and hull ratio characteristics show significant differences. To seed filling period, water stress adversely affected the oil content. However, the water stress in the head formation period weren't affect the plant properties compared to the control parcel. As a result; seed yield, seed length, and oil ratio characteristics, flowering, and seed-filling period were determined as an important step for confectionery hybrid sunflower.

KEYWORDS:
Confectionery hybrid sunflower, Cultivar, Development periods, Drought stress, Yield

INTRODUCTION

Sunflower (Helianthus annuus L.) is grown in mild and subtropical climates in 72 countries and is one of the most produced seed plants in the world after soybean, rapeseed, and peanut [1]. Climate change and rainfall shortages limit agricultural production. The effects of climate change on drought's production of agriculture under rain have a significant impact on the production of rain-fed crops. Small and medium-sized rain-fed farms are highly vulnerable to climate change, and to a greater extent, small and medium-sized rain-fed farms have adopted greater coping mechanisms for climate change compared to large farms [2]. In addition, it has a significant number of uses as confectıonery, ornamental, silage, animal, and bird feed. Although it is the most important oil plant in Turkey, it is consumed extensively as a confectionery [3]. Sunflower is affected by many abiotic and biotic stress factors such as yield and product quality during growth and development periods [4]. Today, drought is caused by the decrease in the amount of precipitation, increasing temperatures, evaporation, loss of water, and the amount of water available in the soil. Drought is among the common abiotic stresses in plants [5, 6]. The negative effects of drought on plants along with global climate change have made it necessary to produce resistant and drought tolerant plant varieties that can complete their life cycle in the presence of limited water in the soil [7-9]. In order to ensure sustainable water management in agriculture, on-site development work such as leveling, consolidation, and drainage must be undertaken in conjunction with irrigation systems. It should be noted that the success of irrigation projects depends on the regulation of soil water-human relations in the field of a physical infrastructure project. The agricultural water user sector is ranked first as the most water usage sector in Turkey. Therefore, the use of tools and techniques that provide effective water use in agriculture should be among the primary targets of Turkey. Completion of work to ensure that surface storage facility and groundwater reservoirs are kept at the highest level with maximum feeding, proper water collection application methods, and effective water use methods must be developed according to land use types [10]. On the other hand, determining the non-critical stages, especially during plant growth periods, prevents unnecessary irrigation. In this context, water resources and soil fertility increase. The response of plants to drought stress varies significantly depending on the intensity and duration of the stress, the plant variety, and the growth stage [11, 12]. In studies on water stress during the development period of plants, Human et al. [13] applied water stress, taking into account the water potential in the leaf during the sunflower heading, pollination, and seed setting periods. Patil and Gangavane [14] performed the water stress with water evaporation test in three different periods 0-30, 30-60, 60-90 after planting. Subramanian and Maheswari [15] applied water stress based solely on the flowering period. The study aim is to determine the effect of water stress on yield and yield components in some stages of the vegetation period in some hybrid sunflower varieties.

MATERIALS AND METHODS

This research was conducted in Eskişehir Çifteler district (altitude 875 m) during to periods of 2018 and 2019. The study was conducted on Palancı and Ahmetbey hybrid confectıonery sunflower varieties. The trial was conducted as a split-plot design based on 3 replications. The trial establishment dates for 2018 and 2019 were in the first week of May, and the harvest was carried out in the first week of September. In the experiment, water stress (control, head formation, flowering, and seed formation period) was applied in four different plant growth stages. In the study, development periods were located in main plots and varieties in subplots. According to the soil analysis results of the experimental area, it is seen that the soil has a slightly alkaline reaction and a clayey-loam structure. Phosphorus content is high, organic matter is medium and potassium is sufficient (Table 1). Each parcel is 5 m long and consists of 4 rows. The row spacing is 70 cm and the row top is 26 cm. After planting, maintenance (hoe, etc.) operations were carried out at the four-leaf level and in different periods. Half of the nitrogenous fertilizer applications were applied at planting and the other half at four-leaf levels. In all parcels, the first irrigation was carried out with planting. In 10 plants randomly selected by applying edge effect on plots; plant height, head diameter in the plant, hull ratio, seed width, seed length, 1000 seed weight, seed yield, and oil rate were investigated. The research consists of four main plots. Water stress applications were applied to the varieties in three main plots during heading formation, flowering, and seed formation periods. The fourth main plot is the control group and is not exposed to water stress. In the examination of the meteorological data of the experimental area, no precipitation was observed during the water stress periods (Table 1). The data obtained as a result of the research were subjected to the MSTAT-C statistical analysis method according to the Two Factor Randomized Complete Block Design with Split Plot Combined over years and variance analysis was performed. Differences between applications were determined with the Duncan test [16].

RESULTS AND DISCUSSION

Drought is the most serious environmental factor affecting almost all living organisms as a result of global warming. The average Duncan test results obtained in the study are significant at 1% and 5% level and are given in tables 3, 4, 5, 6, 7, 8, 9, 10. Many features examined by Radic et al. [17]; head diameter, hull ratio, seed width, seed length, 1000 seed weight, and seed yield characteristics in the plant are affected by water stress during the flowering period.

Plant Height (cm). Plant height is an important parameter in determining the vegetative growth level. In the study, a significant difference at $p < 0.01$ level was determined as a result of the combined analysis of variance for confectionery sunflower hybrid varieties for two years. In terms of plant height, the Palancı1 variety (191.85 cm) has a longer height than the Ahmetbey variety (183.90 cm) (Table 3). The interaction of water stress in different periods applied to the cultivars and water stress, which is the main factor, was not found to be significant. Water stress applied during the specified periods did not cause any interaction with the plant height (Table 3). Water stress haven't affect the growth of the stem in the last stage of plant height, head formation in sunflower, and the final stage of growth until the flowering stage [18]. Goksoy et al. [19] limited irrigation reduces plant height in sunflower. Vilalobos et al. [20] and Osborne et al. [21] observed during their research that the plant height of sunflower increased with increasing irrigation water and decreased when stress was applied. In our research, water stress; there was no significant difference in plant height as it was applied in the last stage of plant growth during the table formation, flowering, and seed filling periods (Table 3). It can be concluded that sunflower maintains that feature of growing vegetatively until the beginning of the blooming period.

TABLE 1
Trial area climate characteristics*

Climate Factors	Years	Months					Total/Mean
		May	June	July	August	September	
Precipitation (mm)	2018	67.4	49.4	8.2	6.4	8.6	140.0
	2019	27.4	102.6	16.4	18.2	3.4	168.0
	Long Years	50.1	42.8	19.5	14.1	11.4	137.9
Temperature (°C)	2018	16.5	19.9	22.5	22.6	17.8	19.9
	2019	16.0	20.4	20.6	21.4	17.6	19.2
	Long Years	15.2	19.4	22.3	22.5	17.7	19.4

*: General Directorate of Meteorology

TABLE 2
Soil analysis results of the trial site for 2018 and 2019**

Years	N (%)	P (kg/da)	K (kg/da)	pH	Organic Matter (%)	Lime (%)	EC (dS/m)	Structure
2018	0.12	9.68	203.19	7.78	2.52	38.32	0.52	Clay-loam
2019	0.11	8.32	198.20	7.68	2.36	38.50	0.55	Clay-loam

**: Professional Environmental Analysis Laboratory Food Agriculture and Quality.

TABLE 3
Data on plant height (cm) of hybrid sunflower varieties affected by water stress in different growth periods

	Plant Height (cm)								
	Control		Head Formation		Flowering		Seed-Filling Periods		Mean
	Palancı1	Ahmetbey	Palancı1	Ahmetbey	Palancı1	Ahmetbey	Palancı1	Ahmetbey	
2018	192.67	183.33	189.67	182.67	191.67	184.00	192.00	184.02	187.42
2019	193.48	184.91	190.31	184.52	191.59	185.29	193.41	182.39	188.24
Variety×DDP	193.08	184.12	189.99	183.60	191.63	184.65	192.71	183.21	
Mean DDP	188.60		186.79		188.14		187.96		
Mean Variety	191.85 **A**	183.90 **B**							

DDP; Different development period

TABLE 4
Data on the head diameter (mm) of the cookie hybrid sunflower varieties affected by water stress in different growth periods

	Head Diameter (cm)								
	Control		Head Formation		Flowering		Seed-Filling Periods		Mean
	Palancı1	Ahmetbey	Palancı1	Ahmetbey	Palancı1	Ahmetbey	Palancı1	Ahmetbey	
2018	20.67	21.00	19.83	18.83	16.50	16.83	18.67	19.17	18.93
2019	20.42	21.43	19.98	19.28	16.42	17.98	18.49	18.92	19.12
Variety×DDP	20.55	21.22	19.91	19.06	16.46	17.41	18.58	19.05	
Mean DDP	20.88	**A**	19.48	**B**	16.93	**C**	18.81	**B**	
Mean Variety	18.87	19.18							

DDP; Different development period

Head Diameter (cm). In water stress applications during the development period, the average of varieties is 16.93 cm minimum head flowering period, and it is 20.88 cm less than the control group. The difference between the averages was found to be statistically significant (Table 4). There was no statistical difference between the cultivars and the interaction of water stress. The water stress applied according to the results obtained haven't create significant differences between the varieties in the diameter of head. The water stress applied during the flowering period in terms of the variety averages of different growth periods negatively affected the head diameter (Figure 1), and the interaction between different growth periods and the cultivar averages was found to be statistically insignificant (Table 4). Consequently, the main reason for the sensitivity of the head diameter to stress during the flowering and pollination period can be attributed to the gradual growth of flowers on the head during this period. Thus, at the beginning of the flowering stage, the flower head is relatively small.

The flower head and the increase in the number of flowers occur together. The water stress applied during the flowering period negatively affected the flowering amount and the diameter of the head. In this context, generative period water stress can cause negative situations in sunflower head development [19, 22, 23].

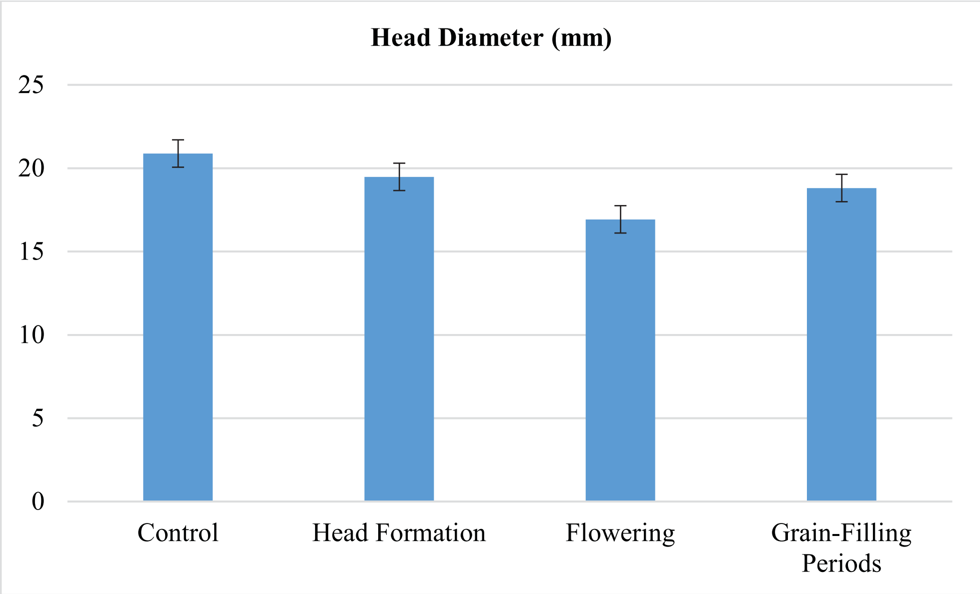

FIGURE 1
Average of different growth periods of confectionery hybrid sunflower varieties in terms of head diameter (mm)

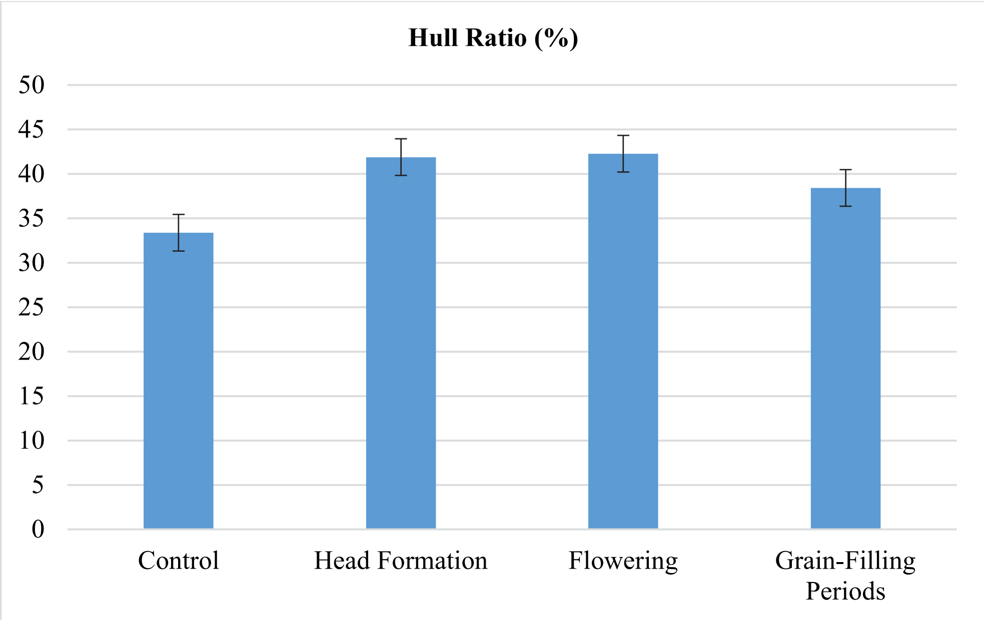

FIGURE 2
Average of different growth periods of confectionery hybrid sunflower varieties in terms of hull ratio (%)

Hull Rate (%). According to the results obtained in the study, the highest hull rate was found in the Ahmetbey variety with 43.72% during the flowering period and at least in the Palancı1 variety with 32.99% in the control application (Table 5). Considering that there is an inverse proportion between the hull ratio and the seed length, the most sensitive development process according to the average Duncan table (Table 5) in terms of hull ratio was determined as the flowering period (Figure 2). In terms of the interaction between the variety averages and the different growth period, the highest value was obtained with 43.72% in the water stress application of the Ahmetbey variety during the flowering period, while the lowest hull rate was found in the control application to the Palancı1 variety with 33.38% (Figure 3, Table 5). The hull ratio is the stage where the seed length is determined, and the water stress applied in the specified periods causes an increase in the hull ratio and small seed. Besides the hull ratio of large seeds is low, the particle ratio of small seeds is high. Kaya [24] found that different irrigation practices differ in the hull ratio of hybrid sunflower varieties.

TABLE 5
Data on the hull ratio (%) of confectionery hybrid sunflower varieties affected by water stress in different growth periods

	Hull Rate (%)								
	Control		Head Formation		Flowering		Seed-Filling Periods		Mean
	Palancı1	Ahmetbey	Palancı1	Ahmetbey	Palancı1	Ahmetbey	Palancı1	Ahmetbey	
2018	32.67	34.33	39.50	43.67	41.00	44.00	36.33	41.00	39.06
2019	33.32	33.18	40.25	44.12	40.65	43.44	35.98	40.35	38.91
Variety×DDP	32.99 **f**	33.75 **e**	39.87 **c**	43.89 **a**	40.82 **b**	43.72 **a**	36.15 **d**	40.67 **b**	
Mean DDP	33.38	**C**	41.89	**A**	42.27	**A**	38.42	**B**	
Mean Variety	37.46 **B**	40.51 **A**							

DDP; Different development period

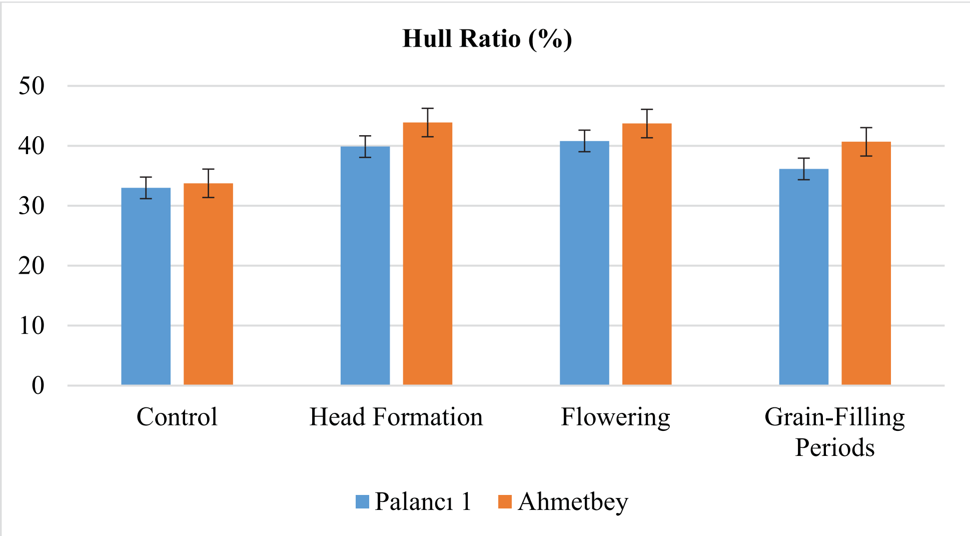

FIGURE 3
Variety × DDP (different development periods) interaction data in terms of hull ratio (%)

TABLE 6
Data on the seed width (mm) of confectionery hybrid sunflower varieties affected by water stress in different growth periods

	Seed Width (mm)								
	Control		Head Formation		Flowering		Seed-Filling Periods		Mean
	Palancı1	Ahmetbey	Palancı1	Ahmetbey	Palancı1	Ahmetbey	Palancı1	Ahmetbey	
2018	7.83	7.20	7.77	6.93	5.67	5.73	6.57	6.63	6.79
2019	7.87	7.35	7.74	6.89	5.75	5.60	6.66	6.81	6.83
Variety×DDP	7.85 **a**	7.27 **b**	7.76 **a**	6.91 **b**	5.71 **d**	5.66 **d**	6.62 **c**	6.72 **c**	
Mean DDP	7.56	**A**	7.34	**A**	5.69	**C**	6.67	**B**	
Mean Variety	6.86	6.67							

DDP; Different development period

Seed Width (mm). The average water stress applications in different growth periods was the lowest with 5.69 mm during the flowering period, while the highest value was obtained with 7.56 mm in the control group (Figure 4, Table 6). In the control application of the cultivar averages and the interaction of different growth periods, the Palancı1 variety was the highest with 7.85 mm, and the Ahmetbey variety was found to be the lowest with 5.66 mm in the flowering period water stress application (Figure 5, Table 6). Kaya et al. [25] extreme temperatures in sunflower, especially during the seed filling period, cause rapid moisture loss in the seeds in the sunflower heads, stated situation decreases the seed length and leads to the formation of thin seeds.

Seed Length (mm). Although the seed length is a feature of the variety, it is closely related to the head diameter and the number of seeds in the head. Also, it is one of the most important features in confectionery sunflower. As the length of the confectionery sunflower increases, there is an increase in the product prices. In the research, in the water stress applied during the flowering period of the Palancı1 variety in 2018-2019. While the shortest seed length was obtained with 15.40 mm and 15.44 mm, the longest seed length was obtained in the control application of 19.23 mm Ahmetbey variety (Table 7). Different growth period averages are the lowest in the flowering period 15.59 mm and the highest in the control group with 18.74 mm (Figure 6, Table 7). Interaction of cultivar average and different growth periods Palancı1 and Ahmetbey varieties had the lowest values with 15.44 mm and 15.75 mm in the flowering period, while Palancı1 and Ahmetbey varieties were in the higher groups with 18.25 mm and 19.22 mm in the control group (Figure 7, Table 7). Pekcan [26] reported that the seed length increased 4.3% approximately with irrigation during flowering and 5.8% with two irrigation applications at the end of flowering and flowering period.

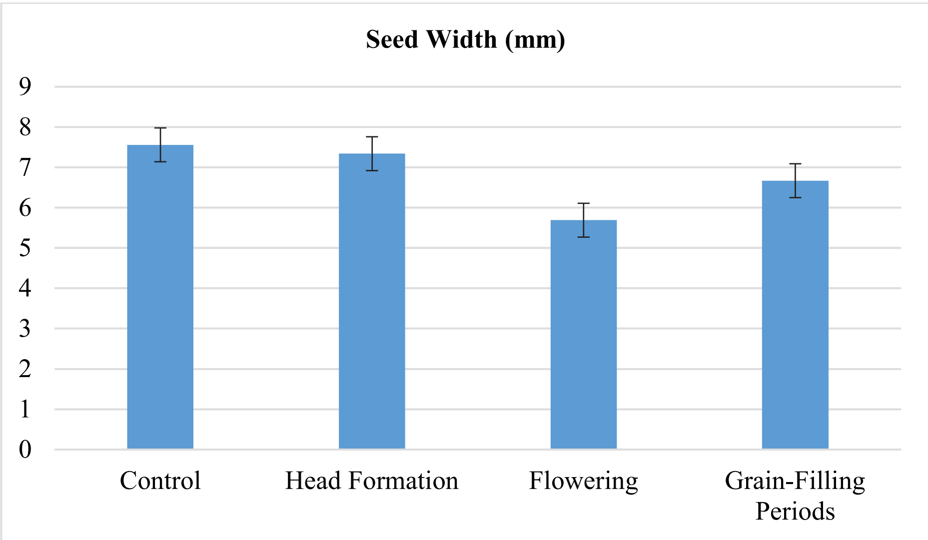

FIGURE 4
Average of different growth periods of confectionery hybrid sunflower varieties in terms of seed width (mm)

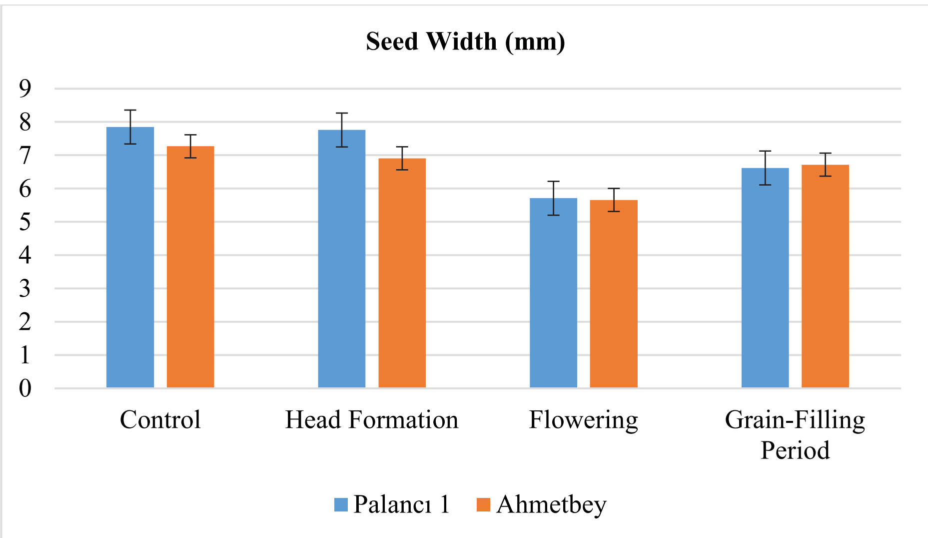

FIGURE 5
Variety × DDP (different development periods) interaction data in terms of seed width (mm)

TABLE 7
Data on the seed length (mm) of confectionery hybrid sunflower varieties affected by water stress in different growth periods

	Seed Length (mm)								
	Control		Head Formation		Flowering		Seed-Filling Periods		Mean
	Palancı1	Ahmetbey	Palancı1	Ahmetbey	Palancı1	Ahmetbey	Palancı1	Ahmetbey	
2018	18.23	19.23	17.90	18.30	15.40	15.77	16.63	16.67	17.26
2019	18.27	19.21	17.82	18.22	15.44	15.75	16.55	16.72	17.24
Variety×DDP	18.25 **b**	19.22 **a**	17.86 **b**	18.26 **b**	15.42 **d**	15.76 **d**	16.59 **c**	16.69 **c**	
Mean DDP	18.74 **A**		18.06 **B**		15.59 **D**		16.64 **C**		
Mean Variety	17.03 **B**	17.48 **A**							

DDP; Different development period

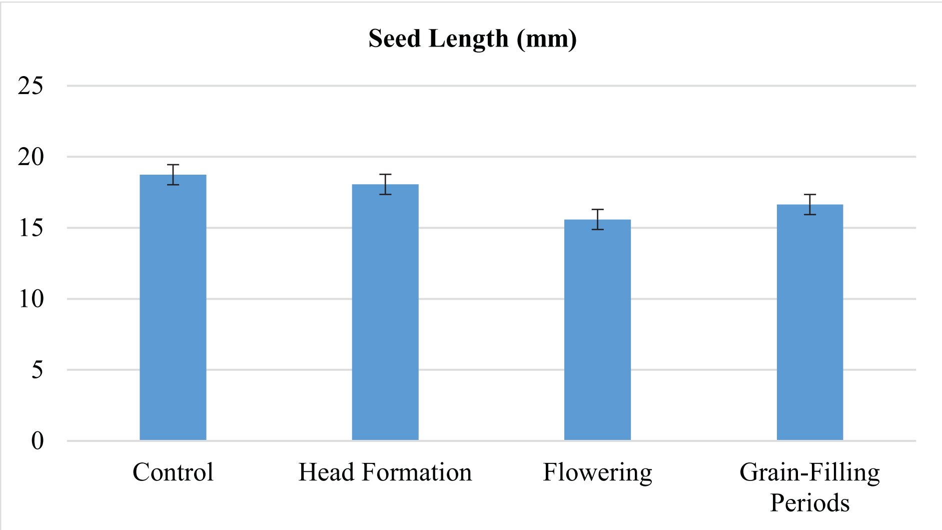

FIGURE 6
Average of different growth periods of confectionery hybrid sunflower varieties in terms of seed length (mm)

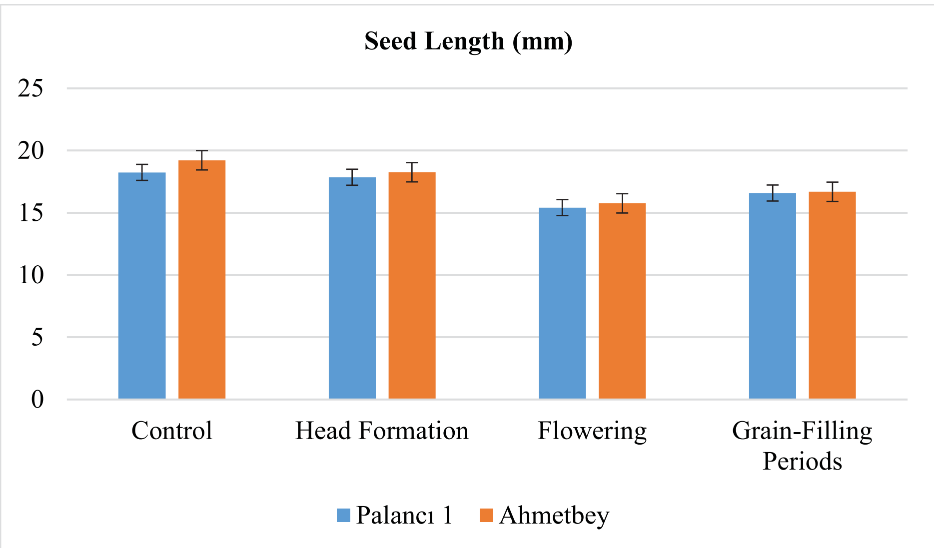

FIGURE 7
Variety × DDP (different development periods) interaction data in terms of seed length (mm)

TABLE 8
Data on the 1000 seed weight (g) of confectionery hybrid sunflower varieties affected by water stress in different growth periods

	1000 Seed Weight (g)								
	Control		Head Formation		Flowering		Seed-Filling Periods		Mean
	Palancı1	Ahmetbey	Palancı1	Ahmetbey	Palancı1	Ahmetbey	Palancı1	Ahmetbey	
2018	126.00	111.00	124.67	110.33	106.00	101.00	112.67	106.17	112.22
2019	126.41	112.22	123.97	110.83	105.88	100.97	112.91	106.97	112.52
Variety×DDP	126.20 **a**	111.61 **d**	124.32 **b**	110.58 **d**	105.94 **e**	100.98 **f**	112.79 **c**	106.57 **e**	
Mean DDP	118.91 **A**		117.45 **A**		103.46 **C**		109.68 **B**		
Mean Variety	117.31 **A**	107.44 **B**							

DDP; Different development period

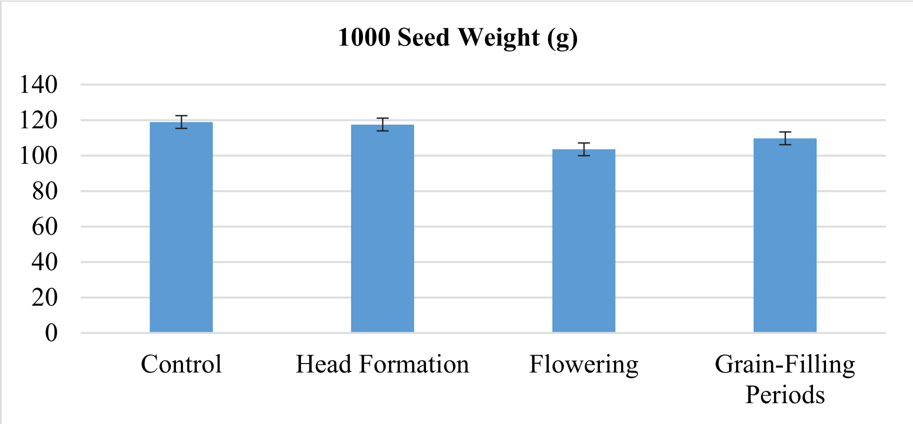

FIGURE 8
Average of different growth periods of confectionery hybrid sunflower varieties in terms of 1000 seed weight (g)

1000 Seed Weight (g). Varieties and water stress applications in different periods were found statistically significant to $p < 0.01$ level in terms of thousand-seed weight. While the highest thousand-seed weight was observed in the control application of 126.20 g Palancı1 variety, the lowest thousand-seed weight was observed in the Ahmetbey cultivar with 100.98 g in the flowering period water stress application (Table 8). According to the different growth period averages, the control group (118.91 g) and the head formation (117.45 g) were among the high groups, while the flowering period (103.46 g) was in the low groups (Figure 8, Table 8).

In terms of the interaction between the cultivar average and the different growth periods, the maximum value was obtained from the Palancı1 variety with 126.20 g in the control group and the minimum value from the Ahmetbey variety with 100.98 g in the flowering period (Figure 9, Table 8). Thousand-seed weight is a feature that directly affects the yield. The plant exposed to water stress during the flowering period physiologically shows a decrease in the number of seeds as a result of the decrease in the number of flowers in the head. Subramanian et al. [15] water stress decreased in the number of flowers in the head before and during the flowering period. In some studies, the findings we obtained regarding a thousand-seed weight are that the shortening of the irrigation interval increases the weight of a thousand seeds [27, 28].

Seed Yield (kg/da). In the study, as a result of the analysis of variance regarding confectionery hybrid sunflower varieties to water stress in different periods, a significant difference was found at the level of $p < 0.01$ in the water stress application periods. Variety averages of different growth periods were obtained in the control group and seed formation period, and the minimum value was obtained with 323.16 kg/da in the flowering period (Figure 10, Table 9). The water stress applied on the yield components causes the final performance of the product to decrease. According to the results, water stress seen before the generative period haven't affect the seed yield negatively [29, 30].

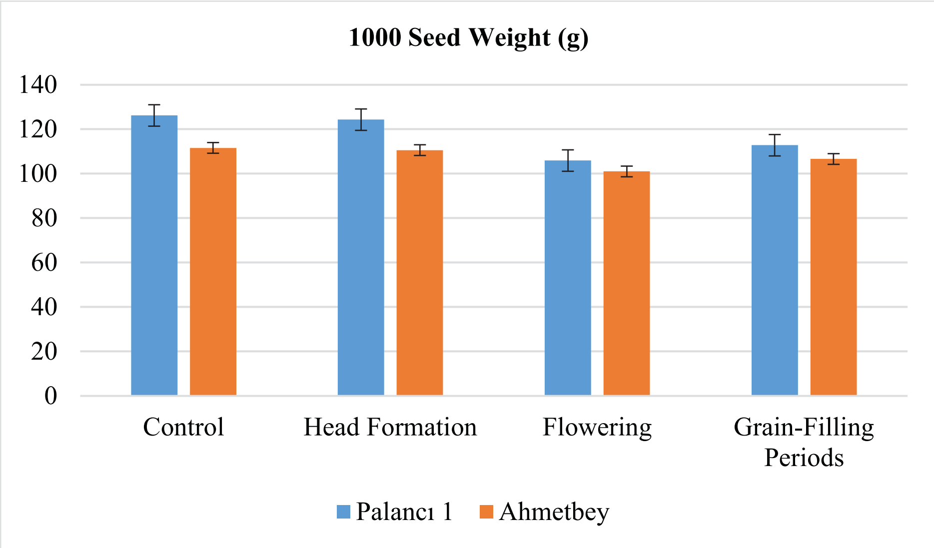

FIGURE 9
Variety × DDP (different development periods) interaction data in terms of 1000 seed weight (g)

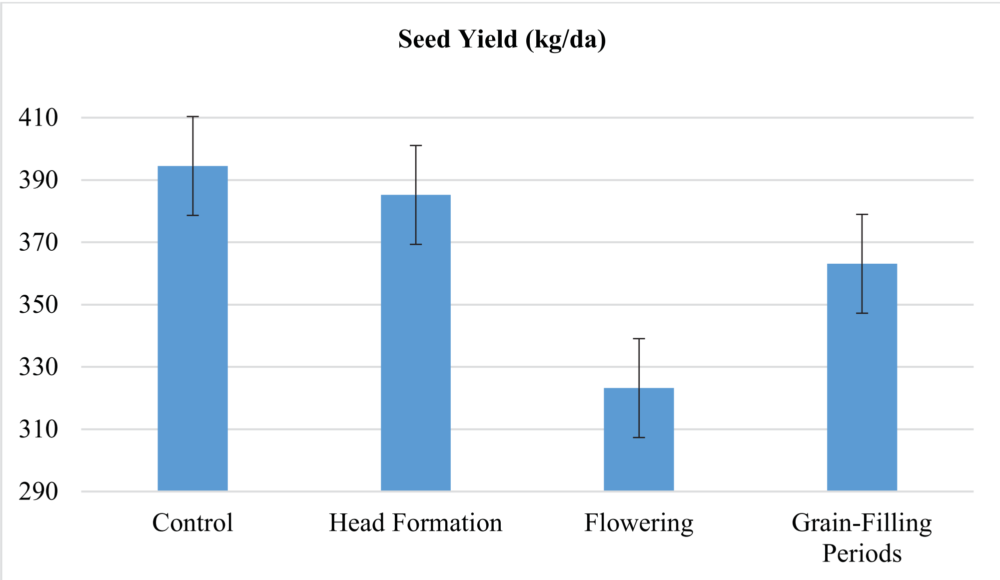

FIGURE 10
Average of different growth periods of confectionery hybrid sunflower varieties in terms of seed yield (kg/da)

TABLE 9
Data on the seed yield (kg/da) of confectionery hybrid sunflower varieties affected by water stress in different growth periods

	Seed Yield (kg/da)								
	Control		**Head Formation**		**Flowering**		**Seed-Filling Periods**		**Mean**
	Palancı1	**Ahmetbey**	**Palancı1**	**Ahmetbey**	**Palancı1**	**Ahmetbey**	**Palancı1**	**Ahmetbey**	
2018	379.00	390.00	377.33	388.00	321.00	330.67	354.00	362.00	362.75
2019	395.75	413.35	380.15	395.23	315.75	325.22	361.84	374.55	370.23
Variety×DDP	387.38	401.68	378.74	391.62	318.38	327.95	357.92	368.28	
Mean DDP	394.53	**A**	385.18	**A**	323.16	**C**	363.10	**B**	
Mean Variety	360.60 **B**	372.38 **A**							

DDP; Different development period

TABLE 10
Data on the oil ratio (%) of confectionery hybrid sunflower varieties affected by water stress in different growth periods

	Oil Ratio (%)								
	Control		Head Formation		Flowering		Seed-Filling Periods		Mean
	Palancı1	Ahmetbey	Palancı1	Ahmetbey	Palancı1	Ahmetbey	Palancı1	Ahmetbey	
2018	24.33	20.57	23.67	19.33	22.00	18.17	19.33	15.50	20.36
2019	25.34	19.58	23.88	19.89	22.45	17.98	19.26	15.59	20.50
Variety×DDP	24.84 **a**	20.08 **bc**	23.78 **ab**	19.61 **c**	22.23 **ab**	18.08 **cd**	19.30 **c**	15.55 **d**	
Mean DDP	22.46 **A**		21.69 **B**		20.15 **C**		17.42 **D**		
Mean Variety	22.53 **A**	18.33 **B**							

DDP; Different development period

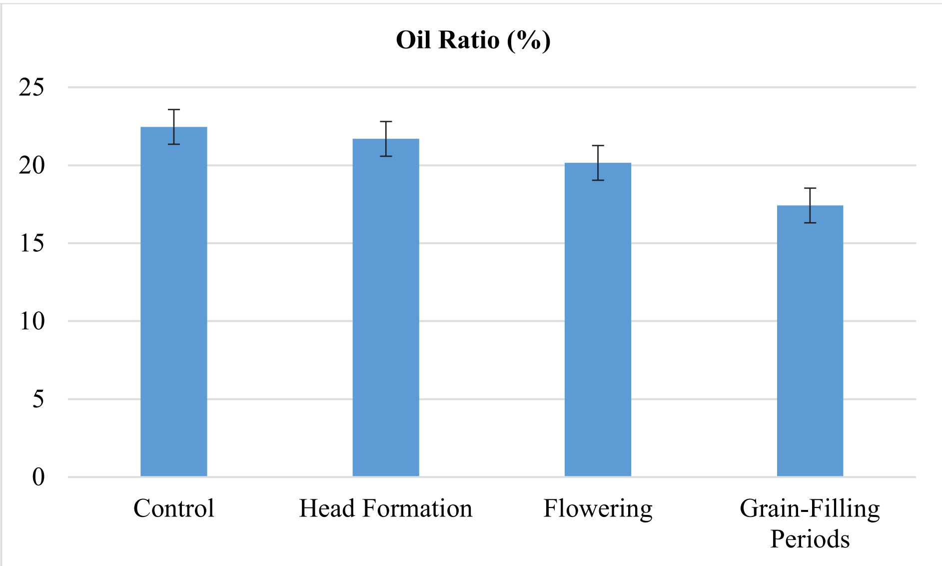

FIGURE 11
Average of different growth periods of confectionery hybrid sunflower varieties in terms of oil ratio (%)

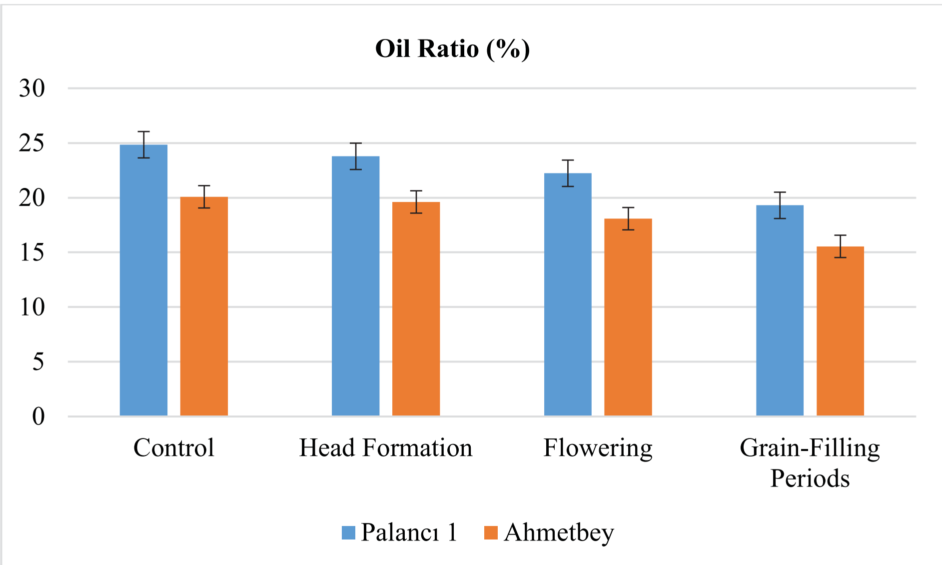

FIGURE 12
Variety × DDP (different development periods) interaction data in terms of oil ratio (%)

Oil ratio (%). There was a statistically significant difference at p <0.01 between the cultivars and the application periods in the water stress application applied in different growth periods with the confectionary hybrid sunflower varieties. In water stress applications to different periods, the highest oil ratio was found in the control application with 22.46%, and the lowest oil ratio was found in the seed-filling period with 17.42% (Figure 11, Table 10). Palancı1 variety had the highest oil rate with 24.84% in the control group, and the Ahmetbey variety had the lowest oil rate with 15.55% in the seed-filling period to the interaction of the variety average and different growth periods (Figure 12, Table 10). The decrease in the seed oil ratio in the plant subjected to water stress application in the generative period emphasizes the importance of the specified period in terms of oil ratio compared to the vegetative period. Tabatabaei et al. [31] reported that the oil rate they obtained under water stress conditions was 17.61% lower than the irrigation conditions.

CONCLUSIONS

This study was carried out with applying water stress in hybrid sunflower for two confectionery varieties in different vegetative and generative periods of the plant to irrigate the plant in certain periods when the plant is affected to water stress, to make an economic contribution to the companies that sell as confectionery and to offer a high quality standard product to the consumer. Significant differences were observed in the statistical analysis and average values of the examined properties. With the water stress applied during the flowering period significant reductions were determined on head diameter, hull ratio, seed width, seed length, 1000 seed weight, and seed yield characteristics. For the oil ratio feature, the seed filling period has been determined as the most sensitive period in water stress application. According to the two-year results obtained from the research, one of the most important factors that producers should pay attention to during the cultivation of sunflowers for confectionery is not to expose the plant to water stress during the flowering period.

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Received: **11.01.2021**
Accepted: **10.02.2021**

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