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Determining the Relationships between Yield and Yield Attributes in Sunflower

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Abstract: Relationships between seed yield and agronomic characters in sunflower were investigated without considering genetic effects. Sunflower hybrids were evaluated in 3 categories: constant hybrids, control hybrids (mostly the same in each year), and test hybrids (changing each year). Seed yield was positively correlated with oil content, plant height, and 1000-seed weight, but flowering and physiological maturity period correlated negatively with yield based on the analyses in this research. A diverse relationship was determined between the seed yield of the hybrids and oil content. Results of the regression analysis indicated that, up to 40%-45% oil content, there was a negative correlation between yield and oil content, but both values increased equivalently after this point. Up to 70 g 1000-seed weight, sunflower seed yield increased, but hybrids would sacrifice yield performance to get larger size seeds after this point. Seed yield gradually increased with increasing plant height and earlier maturing hybrids demonstrated higher yield performance in this research. The relationships between seed yield and other components gave similar results in the same climatic conditions, except Tarsan-1018 and Sanbro hybrids with respect to each characteristic observed.

Key Words: Sunflower, hybrid, seed yield, yield traits, regression analysis

Ayçiçeğinde Verim ve Verim Öğeleri Arasındaki İlişkilerin Belirlenmesi

Özet: Araştırmada; ayçiçeğinde tane verimi ve verim öğeleri arasında ilişkiler, genetik katkı dikkate alınmaksızın incelenmiştir. Bu çerçevede ayçiçeği hibritleri, en çok ekilen iki hibrit, genelde her yıl denemelerde yer alan kontrol çeşitleri ve her yıl değişen aday hibritler olmak üzere üç kategoride değerlendirilmiştir. Yapılan korelasyon analizleri sonucunda, ayçiçeğinde bitki boyu, yağ oranı ve 1000 tane ağırlığı tane verimine olumlu katkı yaparken, çiçeklenme ve fizyolojik olgunlaşma süresi ise, negatif yönde etkilemişlerdir. Yapılan regresyon analizleri sonucunda, % 40-45 yağ oranına kadar, tane verimiyle arasında negatif bir ilişki mevcut iken, bu orandan sonra, her iki öğede pozitif bir artış görülmüştür. Yine bin tane ağırlığında 70 g ağırlığa kadar tohum veriminde pozitif bir artış gözlemlenirken, bu miktardan sonraki düşüş eğilimi; hem iri taneli, hem de yüksek verim için, hibritlerin genelde tane veriminden daha fazla taviz vermesi gerektiğini ortaya koymaktadır. Araştırma süresince erkenci hibritlerin genelde daha yüksek verim verdiği belirlenirken, Tarsan-1018 ve Sanbro hibritleri hariç, aday hibritler ve kontrollerin, incelenen her bir karakter açısından benzer sonuçlar verdiği gözlemlenmiştir.

Anahtar Sözcükler: Ayçiçeği, hibrit, tane verimi, verim öğeleri, regresyon analizi

Introduction

Sunflower is one of the most important oil crops in Turkey as well as in the rest of the world. Because it offers advantages in crop rotation systems, such as high adaptation capability, suitability to mechanization, and low labor needs, and because it is the oil preferred by Turkish people, the importance of sunflower in this country has increased in the last 30 years. Sunflower is grown mainly in dry conditions in Turkey. As a summer crop, sunflower is greatly affected by environmental conditions; therefore, seed yield changes dramatically year to year depending on climatic conditions (Kaya, 2003). Sunflower hybrids with high yield capacity and stability are preferred by producers in many areas. Turkish farmers evaluate sunflower hybrids only in terms of yield potential, earliness, and yield fluctuations by location and year. Buyers usually ignore the quality of the sunflower seed oil content because, for them, seed yield is more important and also it is the most important characteristic of sunflowers in breeding programs.

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Plant breeders commonly prefer yield components that indirectly increase yield. Indirect selection of yield components such as 1000-seed weight, plant height, and head diameter can increase grain yield. Therefore, it is important to know the relationships among yield traits in sunflower to get higher yields. Although relationships between seed yield and other traits were investigated in many studies using correlation, path analysis, combining ability, and similar statistical techniques (Marinkovic, 1992; Badwal et al., 1993; Gangappa et al., 1997; Miller and Fick, 1997; Petakov, 1998; Chikkadevaiah and Nandini, 2002; Kaya and Atakişi, 2003, Dusanic et al., 2004; Joksimovic et. al., 2004 and 2006; Ortis et al., 2005; Hladni et al., 2006), no research using regression analysis for this purpose was conducted in sunflower. In the current research, these relationships will be examined by detailed regression analyses using data collected over a long period of time. Using a large data set and average values without considering genetic effects will help plant breeders interpret results.

The limits and directions of yield trait relationships are very important for sunflower breeders in developing desirable hybrids. Among yield components, 1000-seed weight and plant height are important yield related characters in sunflower (Miller and Fick, 1997; Kaya et al., 2003; Dusanic, et al., 2004; Hladni et al., 2006).

This research was conducted to determine the effects of important agronomic traits on sunflower yield and the level of relationship by regression analysis under conditions in Edirne, which is the second largest province for sunflower production in Turkey, and so the results represent both the Trakya region and Turkey.

Materials and Methods

Experiments were conducted without irrigation between 1999 and 2004 growing seasons at the Trakya Agricultural Research Institute fields in Edirne. The institute is at 41° 40' North latitude, 26 ° 34' East longitude, and 41 m altitude. Research field soils were sandy clay loam and the planting time during the experiments varied from mid-March to mid-May and the harvesting time was from mid-August to mid-September. The experiments were planted and harvested by hand.

The tested hybrids in this study were developed by crossing female cytoplasmic male-sterile (CMS) and restorer lines in the Turkish National Sunflower Research Project. Within this project, 26 yield trials in 1999, 23 trials in 2000, 17 trials in 2001, 15 trials in 2002, 8 trials in 2003, and 13 yield trials in 2004 were conducted, and a total of 2116 sunflower hybrids were tested in a randomized complete blocks design with 3 replications.

Out of 13 hybrids, preferred mostly by sunflower producers in Turkey, various combinations of 5 hybrids were used as controls in all experiments in each year to get a better evaluation of new test hybrids. In controls, Sanbro and Tarsan-1018 hybrids existed in the experiments constantly for 6 years. The control hybrids were Sanbro, Tarsan-1018, AS-508, Turkuaz, and P-64-A-52 in 1999; Sanbro, Tarsan-1018, S-288, P-64-A-83, and AS-615 in 2000 and 2001; Sanbro, Tarsan-1018, TR-3080, Coban, and Isera in 2002; Sanbro, Tarsan-1018, P-4223, Coban, and Isera in 2003; and Sanbro, P-4223, Coban, Isera, and Meriç F1 in 2004. They were evaluated separately for yield relationships between yield traits, ignoring genetic effects. To analyze these relationships in detail by regression analysis, control hybrids were represented in each experiment and test hybrids were represented once each, but in large numbers. Regression and correlation analysis were carried out using all data collected in 6 years.

Hybrids were planted in 3-row plots 6-m long with 70 x 35 cm plant spacing; the middle row was harvested and the border rows were discarded. Plot size was 3.78 m^2 at harvest. Seed and oil yield (kg ha^{-1}), flowering and physiological maturity period (day), plant height (cm), and oil content (%) were determined. JMP 5.01 and SPPS 11 statistical packages were used to run regression and correlation analyses.

Results and Discussion

Seed yield in cultivated plants is the most important character influenced by genetic and environmental factors. Correlation analysis showed that most of the yield related characters had a significant effect on seed yield. Excluding physiological maturity and flowering period, all characters studied contributed positively to seed yield in sunflower (Table 1). According to the correlation results of test hybrids, the highest positive values were observed for oil content, plant height, and 1000-seed weight. In the control hybrids and in detailed evaluation of each constant hybrid (Sanbro and Tarsan

Table 1. Correlation values of test hybrids.

Yield Traits	Seed Yield	1000-seed weight	Oil content	Flowering period	Physiological maturity	Plant height
Seed Yield	1.000					
1000-seed weight	0.193**	1.000				
Oil content	0.380**	-0.041ns	1.000			
Flowering period	-0.303**	-0.239**	-0.120**	1.000		
Physiol. maturity	0.034ns	-0.050*	-0.015ns	0.634**	1.000	
Plant height	0.235**	-0.094**	0.443**	0.294**	0.275**	1.000

** = Significant at 1% level. * = Significant at 5% level. ns = Non-Significant

1018), flowering period affected seed yield negatively similar to test hybrids (Tables 2-4). Similar results were obtained in almost all relationships between seed yield and other traits, except 1000-seed weight in the control hybrids.

In the Sanbro and Tarsan 1018 results, correlations could be evaluated as an environmental effect and genotype x environment interactions, because the genetic factor was constant. Conversely, oil content was non-significant in Sanbro, which had the highest yield performance among sunflower hybrids in the experiment. These results were probably because Sanbro had a smaller seed size and lower oil content than other control sunflower hybrids in this research.

In correlation results, among other yield traits, highly negative correlations were found between flowering period and other yield traits, and non-significant relationships were detected between physiological maturity and other traits in test, constant, and control hybrids. However, the highest positive relationship was observed between physiological maturity and flowering period in Tarsan 1018.

Regression and determination coefficients of test hybrids, constant hybrids, and controls are given in Table 5. Regression coefficients obtained from regression analysis were subjected to analysis of variance to see the effect of seed yield and other yield traits. The results revealed that seed yield and other characteristics have significant effects on regression coefficients in almost all sunflower hybrids in the experiment.

Seed yield of all test hybrids, controls, and Sanbro and Tarsan 1018 showed a quadratic relationship with oil content, but in different directions (Figures 1 and 2). Tarsan 1018 showed an almost linear positive relationship between seed yield and oil content, but the rate of seed yields of Sanbro and the control hybrids decreased with increasing oil content up to 45% oil content rate and then increased beyond this point. The test hybrids had a similar pattern, but with the inflexion point closer to 40% oil content.

Table 2. Correlation values of control hybrids.

Yield Traits	Seed Yield	1000-seed weight	Oil content	Flowering period	Physiological maturity	Plant height
Seed Yield	1.000					
1000-seed weight	0.003ns	1.000				
Oil content	0.364**	0.017ns	1.000			
Flowering period	-0.237**	-0.395**	-0.040ns	1.000		
Physiol. maturity	-0.013ns	-0.249**	-0.042ns	0.588**	1.000	
Plant height	0.358**	-0.028ns	0.590**	0.228**	0.060ns	1.000

** = Significant at 1% level. * = Significant at 5% level. ns = Non-Significant

Table 3. Correlation values of Sanbro hybrid.

Yield Traits	Seed Yield	1000-seed weight	Oil content	Flowering period	Physiological maturity	Plant height
Seed Yield	1.000					
1000-seed weight	0.259**	1.000				
Oil content	-0.119ns	-0.431**	1.000			
Flowering period	-0.489**	0.021ns	-0.189ns	1.000		
Physiol. maturity	-0.089ns	-0.220*	-0.165ns	0.520**	1.000	
Plant height	0.100ns	0.602**	-0.368**	0.106ns	-0.040ns	1.000

** = Significant at 1 % level. * = Significant at 5 % level. ns = Non-Significant

Table 4. Correlation values of Tarsan 1018 hybrid.

Yield Traits	Seed Yield	1000-seed weight	Oil content	Flowering period	Physiological maturity	Plant height
Seed Yield	1.000					
1000-seed weight	0.257*	1.000				
Oil content	0.447**	0.332**	1.000			
Flowering period	-0.426**	-0.226*	-0.400**	1.000		
Physiol. maturity	-0.062ns	-0.047ns	-0.232ns	0.847**	1.000	
Plant height	0.249*	0.515**	0.104ns	0.189ns	0.389**	1.000

** = Significant at 1 % level. * = Significant at 5 % level. ns = Non-Significant

The 1000-seed weight was positively correlated with sunflower yield up to 68 g in controls and 73 g in test hybrids (Figure 3). Based on average values, sunflower seed yield was influenced positively by seed weight up to 45 g in Sanbro and 58 g in Tarsan 1018 (Figure 4). These results indicate that the degree of positive relationship between seed yield and 1000-seed weight, which is in agreement with previous studies, reached certain upper limits. To get a higher 1000-seed weight in sunflower, hybrids would sacrifice seed yield potential after 60-70 g.

Plant height correlated positively and almost linearly with seed yield based on average values of controls and test hybrids. However, seed yield correlated positively with plant height only up to 130 cm in Tarsan 1018, the shortest of the hybrids, and up to 145 cm in Sanbro. Both constant hybrids showed a quadratic relationship with seed yield (Figures 5 and 6).

There was a linear relationship between flowering period and seed yield, suggesting that early flowering sunflower hybrids would have higher yields under Edirne conditions (Figures 7 and 8). However, physiological maturity (PM) results show that this earliness is limited. Control and test hybrids gave higher yield potentials (up to 110 days to PM), but Sanbro and Tarsan 1018, which are the earliest sunflower hybrids in Turkey, had the highest yield performance on days 103 and 107, respectively (Figures 9 and 10). These results showed that earlier hybrids give higher yields under Edirne conditions, contrary to the expectation that later maturing hybrids would have greater yield potential. Because earlier plants avoided drought stress, later hybrids were influenced greatly by dry conditions due to limited rain and very hot seasons experienced during the experiments.

Table 5. Regression analysis coefficients between seed yield and other yield traits.

Cultivars	R^2	DF	F Value	Significance Level	b0	B1	b2
			1000-seed weight				
Sanbro	0.089	107	5.2	0.007	-162.9	14.1	-0.1
Tarsan-1018	0.183	92	10.3	0.000	-220.6	19.3	-0.2
Test Hybrids	0.160	2115	201.1	0.000	34.1	5.3	0.0
Controls	0.143	556	46.5	0.000	11.0	6.7	0.0
			Plant height				
Sanbro	0.061	108	3.5	0.033	-587.9	11.1	0.0
Tarsan-1018	0.235	93	14.3	0.000	-1403.8	25.2	-0.1
Test Hybrids	0.063	2113	70.7	0.000	-26.8	2.8	0.0
Controls	0.136	556	43.6	0.000	-86.1	3.5	0.0
			Flowering period				
Sanbro	0.323	108	25.8	0.000	-1870.1	64.9	-0.5
Tarsan-1018	0.184	93	10.5	0.000	668.2	-10.1	0.1
Test Hybrids	0.096	2113	112.6	0.000	-10.4	7.9	-0.1
Controls	0.059	555	17.5	0.000	64.9	6.0	-0.1
			Physiological maturity				
Sanbro	0.058	108	3.4	0.039	-2546.7	53.7	-0.3
Tarsan-1018	0.045	93	2.2	0.119	-1572.2	33.3	-0.2
Test Hybrids	0.022	2116	23.5	0.000	-1006.5	22.0	-0.1
Controls	0.021	553	6.0	0.003	-845.2	19.4	-0.1
			Oil content				
Sanbro	0.019	82	0.8	0.449	961.8	-33.3	0.4
Tarsan-1018	0.207	68	8.9	0.000	-585.6	28.9	-0.3
Test Hybrids	0.049	1602	41.3	0.000	502.5	-16.2	0.2
Controls	0.027	423	5.9	0.003	1013.8	-36.3	0.4

R^2 = The determination coefficient, b0, b1 and b2 = Regression coefficients, DF = Degree of Freedom.

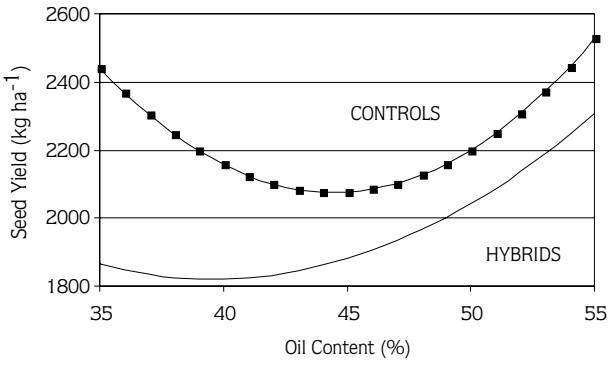

Figure 1. Relationships between seed yield and oil content in controls and hybrids.

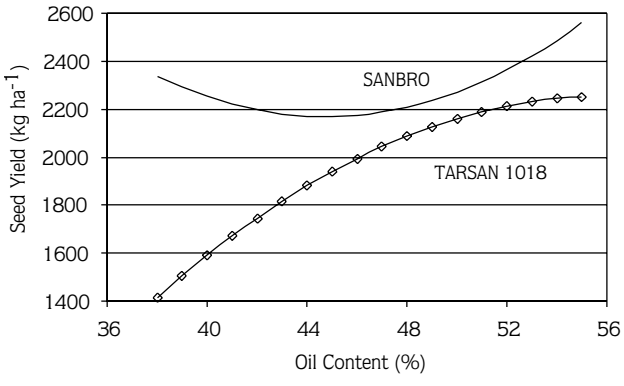

Figure 2. Relationships between seed yield and oil content in 2 hybrids.

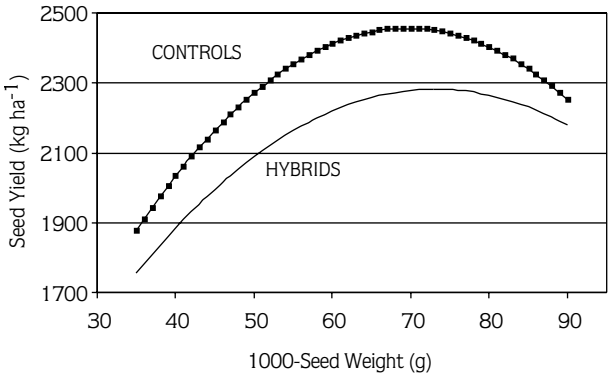

Figure 3. Relationships between seed yield and 1000-seed weight in controls and hybrids.

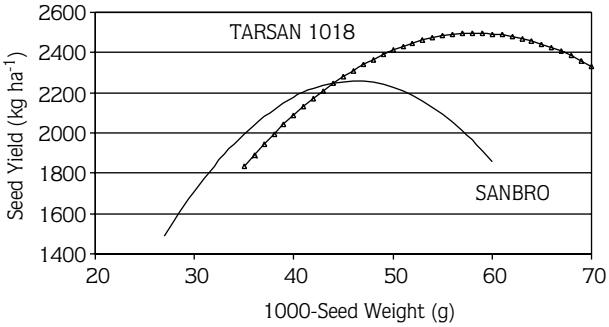

Figure 4. Relationships between seed yield and 1000-seed weight in 2 hybrids.

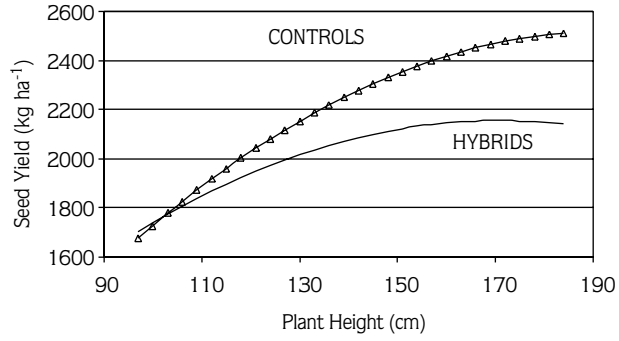

Figure 5. Relationships between seed yield and plant height in controls and hybrids.

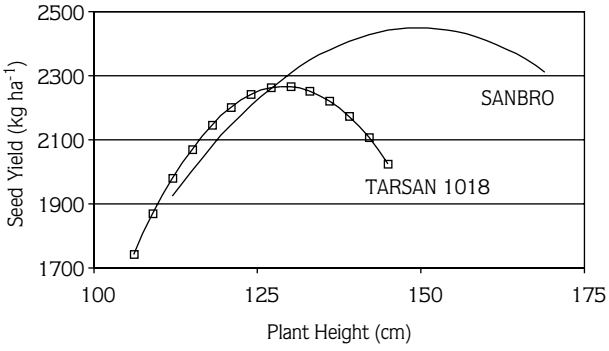

Figure 6. Relationships between seed yield and plant height in 2 hybrids.

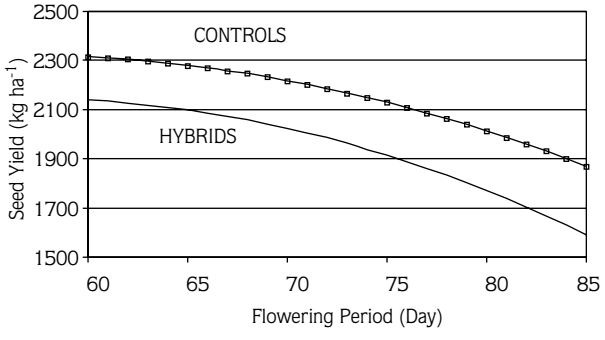

Figure 7. Relationships between seed yield and flowering period in controls and hybrids.

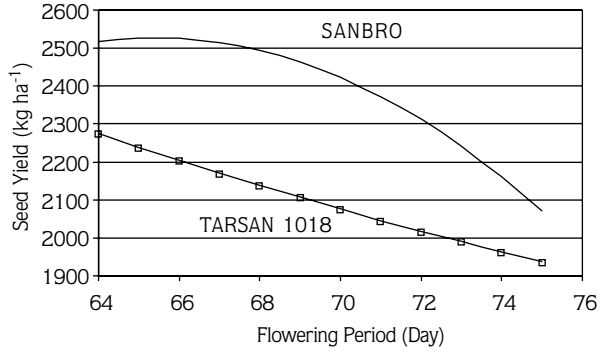

Figure 8. Relationships between seed yield and flowering period in 2 hybrids.

There were no significant differences among sunflower hybrids regarding the correlations between seed yield and other trait components except in constant hybrids. Tarsan 1018 and Sanbro sunflower hybrids showed different performances than the controls with respect to some traits. It could be concluded that sunflower hybrids generally exhibit the same relationships in the same climatic conditions, and that examinations of relationships among average values could give reasonable and satisfactory results.

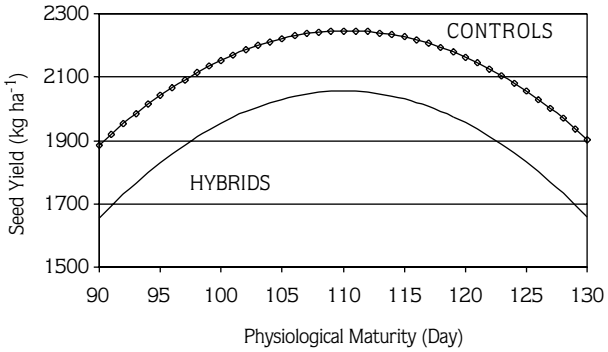

Figure 9. Relationships between seed yield and physiological maturity in controls and hybrids.

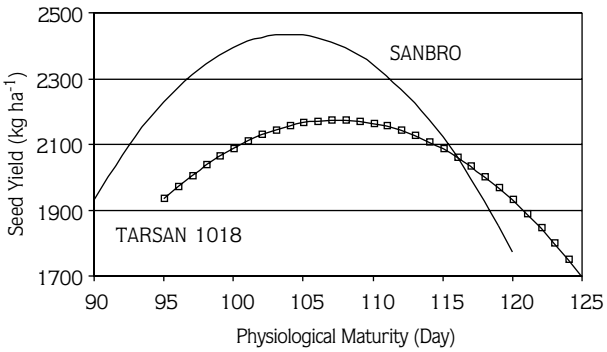

Figure 10. Relationships between seed yield and physiological maturity in 2 hybrids.

The main finding of this research, positive contributions of oil content, plant height, and 1000-seed weight on seed yield, agreed with the previous studies (Marinkovic, 1992; Miller and Fick, 1997; Chikkadevaiah and Nandini, 2002; Kaya et al., 2003; Dusanic et al., 2004; Ortis et al., 2005, Hladni et al., 2006). Additionally, the other finding of the study, negative effect of flowering period and physiological maturity on seed yield (i.e. earlier maturity contributes to higher yielding hybrids) was similarly reported by Kaya and Atakişi (2003), Kaya et al. (2003), and Joksimovic et al. (2004). Although all these studies investigated only the importance of relationships among yield traits, regression analysis in this study was able to reveal these important relationships with limits and shapes.

Conclusions

Correlation analyses showed that physiological maturity period is a less important factor on seed yield. According to the quadratic relationships in regression analysis, sunflower seed yield had an increase up to 70 g seed weight; however, in Sanbro and Tarsan 1018 hybrids, which have a relatively small seed size, this maximum was lowered to 50-60 g. Therefore, to get larger size seeds in sunflower breeding, hybrids would have to sacrifice the seed yield potential beyond these 1000-seed weights. Although sunflower seed yield decreased as oil content rose to 40%-45%, there was a gradual increase in seed yield as oil content was further augmented.

The average seed yield increased with increasing plant height. However, Tarsan 1018 seed yields augmented up to 125 cm and Sanbro up to 145 cm height, after which yield began to decline. Phenological results of the study showed that early flowering sunflower hybrids had higher yields under Edirne conditions. Similar conclusions could be drawn based on PM values, e.g., sunflower hybrids exhibited higher yields up to 110 days to PM, indicating that earlier hybrids give greater seed yield.

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