Journal of Tekirdag Agricultural Faculty
Tekirdağ Ziraat Fakültesi Dergisi

Aralık/December 2023, 20(4)
Başvuru/Received: 22/12/22
Kabul/Accepted: 04/02/23
DOI: 10.33462/jotaf.1222792

http://dergipark.gov.tr/jotaf
http://jotaf.nku.edu.tr/

ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Evaluation of Wild Annual Sunflower Species for Some Morphological, Phenological, and Agronomic Characters under Field Conditions*

Tek Yıllık Yabani Ayçiçeği Türlerinin Tarla Koşullarında Bazı Morfolojik, Fenolojik ve Agronomik Karakterleri Açısından Değerlendirilmesi*

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Abstract

New gene sources are needed for adaptation to climatic changes, resistance to the regeneration of diseases and pests, and achieving high heterosis in sunflower breeding. Wild species are the most important gene sources for sunflower breeding studies. For breeding studies, it is necessary to know the morphological, Phenological, and agronomic characteristics of these genotypes in field conditions. The aim of this research was to determine these components of annual wild sunflower (*Helianthus*) species under field conditions in the 2012 and 2013 growing seasons for new gene sources. In this research, *H. agrestis, H. annuus* (4 different genotypes), *H. anomalus, H. argophyllus*, *H. bolanderi*, *H. debilis* (*ssp. debilis, ssp. cucumerifolius, ssp. silvestris, ssp. tardiflorus* and *ssp. vestitus subspecies), H. deserticola, H. exilis, H. neglectus, H. niveus (ssp. niveus, ssp. canescens and ssp. tephrodes subspecies) H. petiolaris (ssp. petiolaris* (2 different genotypes) and *ssp. fallax subspecies), H. porteri*, and *H. praecox (ssp. praecox* (2 different genotypes), *ssp. hirtus, and ssp. runyani subspecies)* were used as material. In this study, determined characters on annual wild sunflower genotypes were plant height, primary branches number, secondary branches number per primary branches, plant spreading diameter, the number of days from planting to first flowering, the number of days from planting to 50 % flowering, the number of days from planting to the end of flowering, the number of days of the flowering period, main stem diameter, head diameter, 1000 seeds weight, and seed yield. Year factor had a significant effect on these characters except plant height. Genotype had a significant effect on all characters in both years except seed width in 2013. In both years, the highest values for seed yield, 100 seed weight, head diameter, and main stem diameter were obtained in wild *H. annuus* genotypes while *H. argophyllus* had the highest values for plant height and primary branches number, and the highest days numbers from planting to first and 50% flowering. In the first and second growing seasons; values of the genotypes changed between 61.33 and 325.67 cm for plant height, between 0.73 and 101.20 g for thousand seed weight, between 97 and 223 days for the time from planting to 50% flowering, between 50 and 171 days for the flowering period, between 5.0 and 800.70 units for the number of plant heads, between 1.57 and 233.20 g for plant grain yields.

Keywords: *Helianthus*, Flowering period, Plant height, Seed yield, Seed weight

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Atıf/Citation: Önemli, F., Önemli, G. (2023). Evaluation of wild annual sunflower species for some morphological, physiological, and agronomic characters under field conditions. *Journal of Tekirdağ Agricultural Faculty,* 20(4): 857-870.

*This study cited from Master thesis of Gürkan ÖNEMLİ under Fadul ÖNEMLI supervision titled as "The Determination of Plant Characters of Some Annual Wild Sunflower Species (*Helianthus* L.) in Field Condition" at Graduate School of Natural and Applied Science, Tekirdağ Namık Kemal University.

Öz

Ayçiçeği ıslahında; iklim değişikliklerine uyum, yenilenen hastalık ve zararlılara dayanıklılık ve yüksek heterosisi yakalamak için yeni gen kaynaklarına gereksinim duyulmaktadır. Yabani türler ayçiçeği ıslahı çalışmaları için en önemli gen kaynaklarıdır. Islah çalışmaları için bu genotiplerin tarla koşullarındaki morfolojik, Fenolojik ve agronomik özelliklerinin bilinmesi gereklidir. Bu araştırmanın amacı; tek yıllık yabani ayçiçeği (*Helianthus*) türlerinin bu komponentlerini 2012 ve 2013 yetiştirme sezonlarında tarla koşullarında yeni genetik kaynağı olarak belirlemektir. Araştırmada; *H. agrestis*, *H. annuus* (4 farklı genotip), *H. anomalus*, *H. argophyllus*, *H. bolanderi*, *H. debilis (ssp. debilis, ssp. cucumerifolius, ssp. silvestris, ssp. tardiflorus ve ssp. vestitus alttürleri)*, *H. deserticola*, *H. exilis*, *H. neglectus*, *H. niveus (ssp. niveus, ssp. canescens ve ssp. tephrodes* alt türleri) *H. petiolaris* (*ssp. petiolaris* (2 farklı genotip) ve *ssp. fallax* alt türleri), *H. porteri*, ve *H. praecox* (*ssp. praecox* (2 farklı genotip), *ssp. hirtus*, ve *ssp. runyani* alttürleri) materyal olarak kullanılmıştır. Çalışmada tek yıllık yabani ayçiçeği genotipleri üzerinde incelenen karakterler; bitki boyu, birincil yan dal sayısı, birincil yan dala düşen ikincil dal sayısı, bitki yayılma çapı, ekimden ilk çiçeklenmeye kadar olan gün sayısı, ekimden %50 çiçeklenmeye kadar olan gün sayısı, ekimden çiçeklenme sonuna kadar olan gün sayısı, çiçeklenme periyodu gün sayısı, ana sap çapı, tabla çapı, bin dane ağırlığı ve tane verimi unsurlarıdır. Yıl faktörü, bitki boyu haricinde incelenen tüm karakterler üzerinde önemli etkiye sahip olmuştur. Genotip, 2013 yılındaki tohum haricinde her iki yılda incelenen tüm karakterler üzerinde istatistiki önemli etkiye sahip olmuştur. Her iki yılda, *H. argophyllus* genotipinde en yüksek bitki boyu, en fazla birincil dal sayısı ve en yüksek ekimden % 50 çiçeklenmeye kadar olan gün sayısı değerleri elde edilirken, *H. annuus* genotiplerinde en yüksek tohum verimleri, en yüksek 1000 tane ağırlıkları, en yüksek tabla çapları ve en yüksek sap çapı değerleri belirlenmiştir. Yabani tek yıllık ayçiçeği türlerine ait genotiplerin morfolojik ve agronomik karakterlerine ait her iki yetiştirme sezonundaki değerlerde; bitki boyları 61.33 ve 325.67 cm, bin tane ağırlığı 0.73 ve 101.20 g, ekimden % 50 çiçeklenmeye kadar olan süre 97 ve 223 gün, çiçeklenme periyodu 50 ve 171 gün, bitki tabla sayısı 5.0 ve 800.70 adet ve bitki tane verimleri 1.57 ve 233.20 g arasında değişmiştir.

Anahtar kelimeler: *Helianthus*, Çiçeklenme periyodu, Bitki boyu, Tane verimi, Tane ağırlığı

1. Introduction

Sunflower (*Helianthus annuus* L.) is the fourth crop for contributes to world vegetable oil production after palm, soybean, and rapeseed. It is grown in many regions of the world and adapted to different agroecological conditions due to its genetic structure with high adaptability. Cultivated sunflower belongs to the genus *Helianthus*, a member of the Asteraceae family consisting of 53 species and 19 subspecies, including 14 annual and 39 perennials (Seiler et al., 2017). Sunflower is thought to have been domesticated 3000–5000 years ago by Native Americans who primarily used it as a source of edible seed (Heiser, 1951). It was introduced to Europe in the early 16th century. The first oilseed cultivars were developed and grown at an industrial scale in Russia (Gavrilova and Anisimova, 2017). The later, breeding efforts have transitioned sunflower from primarily open-pollinated varieties into hybrid cultivars. Hybrid production refers to the establishment of novel cultivars that are reproductively isolated from their parental species and genetically stabilized (Rieseberg, 2006; Rauf, 2019).

Interspecific hybridization has been extensively applied in sunflower breeding. Wild species are adapted to a wide range of habitats and possess considerable variability for most biotic and abiotic traits (Seiler et al., 2017). Wild genotypes have been undeniably beneficial to modern agriculture dating back 100 yr, providing plant breeders with a broad pool of potentially useful genetic resources (Hajjar and Hodgkin, 2007). Wild sunflower species have been used as sources of desirable genes for a number of characteristics. With hybrid cultivar breeding, the importance of wild sunflower species has increased even more to capture heterosis and resistance to disease, pests, stress, and herbicide. Many traits dealing with morphology, architecture, and disease resistance have been transferred from *Helianthus* species to sunflower (Onemli and Gucer, 2010c: Qi et al., 2019). The genetic research on the development of new CMS - restorers of fertility have contributed to enriching diversity and increasing heterosis in sunflower (Atlagić et al., 2006; Seiler, 2007; Nooryazdan et al., 2010; Onemli and Gucer, 2010b; Whitney et al., 2010; Seiler et al., 2017). Wild species are a potentially important source of abiotic tolerance; therefore, it may be desirable to introgress drought, heat, and salinity tolerant genes from wild relatives (Onemli and Gucer, 2010a; Seiler et al., 2017; Hernández et al., 2018). They also contain considerable variability for biotic stress such as disease, orobanche, and insect pest resistance (Vear, 2016; Seiler et al., 2017; Talukder et al., 2019; Fernández-Aparicio, 2022). The increase in sunflower production has been largely connected to the inclusion of wild Helianthus species in the improvement work on sunflower (De Haro, 1991; Perez et al., 2007; Nooryazdan et al., 2010; Onemli, 2012a; 2012b; Seiler et al., 2017). Although interest in using wild species in breeding programs has increased, the limited genetic variability in cultivated sunflower has slowed the future improvement of the crop, and has placed the crop in a vulnerable position should any major shifts of disease races or pests occur.

Evaluations of wild species have provided information about useful genes for future sunflower improvement. However, there are still numerous genes in wild sunflower species yet to be identified and introgressed into cultivated sunflower. Plant breeders need more detailed information about wild genotypes. The understanding of wild *Helianthus* species will increase the number of useful genes available from wild *Helianthus* species, making it possible to transfer cultivated sunflower (Hernández et al., 2019). In addition, it is also important for the arrangement of hybridization programs such as flowering calendars. In the present study, we focus on the evaluation of wild annual *Helianthus* species for their morphological, phenological, and agronomic characteristics in field conditions to determine useful features for future sunflower breeding.

2. Materials and Methods

2.1. Plant materials

In this research, twenty-seven wild annual *Helianthus* species and subspecies listed in *Table 1* getting from the USDA-ARS North Central Regional Plant Introduction Station-Iowa State University were used as materials. In this research annual wild sunflower (*Helianthus*) species; *H. agrestis*, *H. annuus* (4 different genotypes), *H. anomalus, H. argophyllus, H. bolanderi, H. debilis* (*ssp. debilis, ssp. cucumerifolius, ssp. silvestris, ssp. tardiflorus* and *ssp. vestitus subspecies), H. deserticola, H. exilis, H. neglectus, H. niveus (ssp. niveus, ssp. canescens and ssp. tephrodes subspecies) H. petiolaris (ssp. petiolaris* (2 different genotype) and *ssp. fallax subspecies), H. porteri*, and *H. praecox (ssp. praecox* (2 different genotypes), *ssp. hirtus, and ssp. runyani subspecies)* were planted under field conditions in the 2012 and 2013 sunflower growing seasons. Wild sunflower genotypes are origins of USA except *H. annuus* Ames 29348 and *H. niveus subsp. tephrodes*.

Table 1: Genotypes and origins of annual wild Helianthus species and subspecies

Genotype	*Helianthus species and subspecies*	Origins
1	*H. agrestis*	USA, Florida
2	*H. annuus* Ames 4114	USA, North Dakota
3	*H. annuus* Ames 7111	USA, California
4	*H. annuus* Ames 29273	USA, Texas
5	*H. annuus* Ames 29348	Australia, South Australia
6	*H. anomalus* S.F. Blake	USA, Utah
7	*H. argophyllus* Torr.& A. Gray	USA, Texas
8	*H. bolanderi* A. Gray	USA, California
9	*H. debilis* Nutt. subsp. *cucumerifolius* (Torr. & A.Gray)Heiser	USA, Texas
10	*H. debilis* Nutt. subsp. *debilis*	USA, Florida
11	*H. debilis* Nutt. subsp. *silvestris* Heiser	USA, Texas
12	*H. debilis* Nutt. subsp. *tardiflorus* Heiser	USA, Florida
13	*H. debilis* Nutt. subsp. *vestitus* (E. Watson) Heiser	USA, Florida
14	*H. deserticola* Heiser	USA, Nevada
15	*H. exilis* A. Gray	USA, California
16	*H. neglectus* Heiser	USA, New Mexico
17	*H. niveus* (Benth.) Brandegee	USA, Arizona
18	*H. niveus* (Benth.) Brandegee subsp. *canescens* (A. Gray) Heiser	USA, Utah
19	*H. niveus* (Benth.) Brandegee subsp. *tephrodes* (A. Gray) Heiser	Mexico
20	*H. petiolaris* Nutt.	USA, South Dakota
21	*H. petiolaris* Nutt. subsp. *fallax* Heiser	USA, New Mexico
22	*H. petiolaris* Nutt. subsp. *petiolaris*	USA, Oklahoma
23	*H. porteri* (A. Gray) Pruski	USA, Georgia
24	*H. praecox* Engelm. & A. Gray	USA, Texas
25	*H. praecox* Engelm. & A. Gray subsp. *hirtus* (Heiser) Heiser	USA, Texas
26	*H. praecox* Engelm. & A. Gray subsp. *praecox*	USA, Texas
27	*H. praecox* Engelm. & A. Gray subsp. *runyonii* (Heiser) Heiser	USA, Texas

2.2. Meteorological data and field soil properties in the Experimental location

The experiments were carried out in the Research area of the Field Crops Department of the Faculty of Agriculture at Namık Kemal University in Süleymanpaşa, Tekirdağ, Turkey (40º59´N, 27º33´E, elevation 3 m) on soil with clay loam and low organic matter content (*Table 2*).

Table 2. Soil properties of the experimental field

Soil Depth cm	**PH (Sat)**	**Salt EC µS/cm (Sat)**	**SOM %**	**SW (Sat) %**	**P_2O_5 kg/ha**	**Lime %**	**Cu ppm**	**Fe ppm**	**Mn ppm**	**Ca ppm**	**K ppm**	**Mg ppm**	**Zn ppm**
0-20	7.78	866	1.37	42	108.3	1.82	0.75	3.81	8.83	6076	210	241	0.15
30-60	7.82	720	1.18	43	72.6	3.71	0.67	3.62	6.60	6055	151	247	0.10
60-90	7.85	631	0.92	43	55.9	8.06	0.62	3.62	7.08	5911	125	263	0.09

SOM: Soil Organic matter, SW: Soil Water Content, Sat: Saturation

Climatic data during growing periods of wild *Helianthus* ssp. in 2012 and 2013 are given in *Table 3*. Generally, the values of rainfall, relative humidity, and temperature in the vegetative growth period and flowering duration of wild sunflower genotypes in the first year of field conditions were higher than in 2013 except for June rainfall and May temperature.

Table 3. Climatic data during growing periods of wild annual Helianthus genotypes in 2012 and 2013

Month	Year	Total Precip (mm)	Rainy day (day)	Sun. per day (hour)	Relat. Humi. (%)	Humi of Soil (%)	Aver. Air Temp. (^{0}C)	Max. Air Temp. (^{0}C)	Min. Air Temp. (^{0}C)	Aver.Soil Temp. (^{0}C)
March	2012	18.0	8	6.3	81.8	22.0	7.9	12.3	3.6	1.6
	2013	52.8	8	4.5	98.5	24.1	9.6	13.5	5.9	4.8
April	2012	61.4	10	7.4	82.4	24.4	14.1	19.3	9.6	8.7
	2013	16.0	6	6.7	84.8	23.5	13.5	17.7	9.4	8.0
May	2012	62.4	13	7.1	91.2	25.6	18.1	22.5	14.2	13.5
	2013	8.0	2	9.4	69.7	20.7	19.5	23.8	15.1	14.6
June	2012	0.2	1	10.9	78.2	23.6	24.1	28.4	18.9	18.4
	2013	35.0	10	8.4	68.7	18.5	22.4	26.7	18.1	17.5
July	2012	6.0	2	10.6	68.7	16.1	27.0	31.5	22.1	21.2
	2013	0.0	0	10.5	61.4	15.5	24.7	28.8	20.0	19.5
August	2012	7.8	2	10.3	62.7	13.8	26.0	31.1	20.9	19.9
	2013	0.2	1	9.6	62.3	13.3	25.9	30.1	21.7	20.7
September	2012	8.4	3	8.1	73.6	12.9	22.2	26.6	18.1	17.3
	2013	10.2	3	8.4	61.4	12.4	21.6	25.6	16.9	15.8
October	2012	51.0	7	6.5	87.3	17.6	19.2	23.5	15.1	14..0
	2013	96.4	5	6.5	76.2	21.2	14.3	17.9	10.4	9.3
November	2012	24.8	5	3.4	97.0	24.3	13.7	16.9	10.7	10.0
	2013	36.6	6	3.6	79.0	21.3	12.6	15.9	9.6	7.9
December	2012	184.6	17	2.6	97.3	25.1	6.4	9.7	3.1	2.6
	2013	2.4	3	2.7	74.1	20.6	6.2	9.7	3.0	1.7

Precip: Precipitation, Sun: Sunshine, Temp: Temperature Humi: Humidity Aver.: Average

2.3. Experimental design and treatments

In the first year, seeds of wild sunflower were sown into multiple pots in the glasshouse on March 13, 2012, and their seedlings were planted into fields on April 25, 2012. In the second year, the sowing time of seeds into multiple pots and planting time of seedlings on the field were March 12, 2013, and May 17, 2013, respectively. Each experiment was laid out in a Randomized Complete Block Design (RCBD) having four replications and genotypes belonging to different wild annual *Helianthus* species and subspecies. Plot length was kept at 5m in both years. The distance between the rows and between the plants in the rows was 1 m for each. Irrigation was applied for the seedlings to stay alive and hold on the soil during the planting time of seedlings in both years. Weeds were cleaned by mechanical hoeing.

Morphological, agronomic, and Phenological characters such as plant height, primary branches number, secondary branches number per primary branches, plant spreading diameter, the number of days from planting to first flowering, the number of days from planting to 50 % flowering, the number of days from planting to the end of flowering, the number of days of the flowering period, main stem diameter, head diameter, 1000 seeds weight, and seed yield were determined on wild genotypes.

The beginning and ending dates of seed harvest of annual *Helianthus* species are given in *Table 4*. Seed harvest dates of wild annual sunflower genotypes. Harvest times of annual *Helianthus* species were changed from July 15 to December 10 depending on year and genotype.

We could not get enough seeds to calculate yield during harvest from *H. agrestis, H. anomalus*, H. *deserticola, H. niveus, H. niveus subsp. canescens, H. niveus subsp. tephrodes, H. petiolaris subsp. fallax, H. petiolaris subsp. petiolaris, H. porteri* in both years, and *H. exilis* in the second year due to plant drying and pollination problems depending on climatic conditions although they had plant emergence, plant development, and flowering. Therefore, some agronomic characters were not evaluated for these genotypes.

2.4. Statistical analysis

Statistical analysis was performed according to standard procedures for a randomized complete block design (RCBD) including replication, year, and genotype factors. The SAS System was used to generate the analysis of variance (ANOVA) for determining treatment effects on the dependent variables (SAS Institute, 1997). Mean comparisons in each year were based on F-Protected Least Significance Differences (LSD) at $P \leq 0.05$.

Table 4. Seed harvest dates of annual Helianthus species in 2012 and 2013

Helianthus species and subspecies	**Harvest duration 2012 Start-End**	**Harvest duration 2013 Start-End**
H. annuus Ames 4114	July 20 - August 31	July 30 - August 01
H. annuus Ames 7111	August 05 – October 31	August 25 – November 20
H. annuus Ames 29273	August 05 – October 31	September 05 – November 30
H. annuus Ames 29348	August 01 – October 31	August 20 – October 31
H. argophyllus	November 05 - November 20	November 05 - November 20
H. bolanderi	August 1 – October 31	August 20 – November 20
H. debilis ssp. *cucumerifolius*	July 15 - November 08	August 20 - November 20
H. debilis ssp. *debilis*	August 05 – November 30	September 01 – December 10
H. debilis ssp. *silvestris*	August 05 – September 30	August 20 – November 30
H. debilis ssp. *tardiflorus*	August 01 – September 30	August 20 – November 25
H. debilis ssp. *vestitus*	August 05 – November 30	August 10 – December 10
H. exilis	August 25 – September 30	-
H. neglectus	July 20 - September 30	August 10 - November 30
H. petiolaris	August 05 – November 08	August 15 - November 05
H. praecox	July 15 – October 31	August 01 – December 10
H. praecox ssp. *hirtus*	July 15 – October 31	August 01 – December 10
H. praecox ssp. *praecox*	July 15 – October 31	August 01 – December 10
H. praecox ssp. *runyonii*	July 25 – October 20	August 01 – December 10

3. Results and Discussion

According to the analysis of variance in Table 5, year, genotype and year x genotype interaction factors for seed yield, 1000 seeds weight, head diameter, primary branches number, plant spreading diameter, main stem diameter, number of days from planting to first flowering, number of days from planting to 50% flowering, number of days from planting to the end of flowering and number of days of the flowering period were statistically significant at $P < 0.01$. Plant height was affected significantly by genotype and year x genotype interaction factors. The reason for the CV values higher than 10 % was due to the inhomogeneity of the genetic material. The mean comparisons for genotypes were analyzed separately on the basis of years.

Table 6, shows mean comparisons for seed yield, 1000 seed weight, and head diameter of wild annual *Helianthus* species and years. Seed yield per decare of wild sunflower genotypes in 2012 and 2013 ranged between 3.00 and 32.00 kg, and between 1.68 and 249.75 kg, respectively. In the first year, the seed yield of genotypes was very low. We think that the reason for the low yield was the fertility problems experienced in pollination and forming seeds in flowers due to the high air temperature. Hernández et al. (2018) also indicated negative effects of heat stress on seed setting of wild sunflower germplasm. Pollen development has been shown to be highly sensitive to elevated temperatures while the development of the female gametophyte as well as sporophytic tissues might also be disturbed under mild or severe heat stress conditions (Mesihovic et al., 2016). The material was brought from Iowa State, USA. Genotypes grown there at low temperatures were more affected by the high-temperature conditions in the Thrace region of Turkey. In the second year, this effect decreased with the decrease in regional temperatures. *H. annuus* Ames 4114 had the highest seed yield in the first year. This genotype was followed by *H. argophyllus*. In 2013, H. annuus Ames 29348 had the highest seed yield while *H. annuus* Ames 29273, *H.debilis* ssp.*cucumerifolius*, *H. bolanderi*, *H. neglectus*, *H. annuus* Ames 7111 and *H. praecox* ssp. *Runyonii* were in the second-highest seed yield group.

Table 5. Analysis of variance of some seed yield and yield components

Variation sources	Seed yield	1000 seeds weight	Head diameter	Plant height	1. branches number	Spreading diameter
Replication	1084.00	8.94	1.21	111.11	6.22	653.95
Y (Year)	47175.65**	116.48**	33.67**	978.98	657.66**	17368.25**
G (Genotype)	5837.03**	2409.99**	45.43**	26543.64**	384.13**	5910.17**
Y*G	5050.21**	92.71**	13.57**	1920.42**	36.49**	3166.62**
C.V. (%)	94.10	36.52	37.13	16.53	19.19	17.81
Variation sources	**Main stem diameter**	**NDFP+ to first flowering**	**NDFP to 50% flowering**	**NDFP to the end of flowering**	**Flowering period days**	
Replication	0.88	32.91	100.70	163.12	135.46	
Y (Year)	10.94**	10360.63**	40480.63**	19298.13**	1400.82**	
G (Genotype)	5.51**	3275.71**	4879.93**	3643.19**	5612.44**	
Y*G	2.27**	125.56**	645.04**	1032.44**	1060.68**	
C.V. (%)	22.00	4.77	4.71	3.63	9.21	
Variation sources	**2. stem diameter 2012**	**Head number 2013**	**Seed number per head 2013**	**Seed yield per plant 2013**	**Seed length 2013**	**Seed width 2013**
Replication	0.26	156295.43	5588.88	1937.05	0.30	0.32
G (Genotype)	1.14**	127995.46**	23260.77**	9305.93**	13.08**	3.41

* and ** : Significant differences are shown at P < 0.05 and P < 0.01, respectively, NDFP+: Number of days from planting

Table 6. Mean comparisons for seed yield, 1000 seed weight, and head diameter

Genotype number	*Helianthus species / subspecies*	Seed yield (kg da^{-1}) 2012	Seed yield (kg da^{-1}) 2013	1000 seeds weight (g.) 2012	1000 seeds weight (g.) 2013	Head diameter (cm) 2012	Head diameter (cm) 2013
2	*H. annuus* Ames 4114	32.00a	17.21c	101.20a	69.20a	18.33a	6.40a
3	*H. annuus* Ames 7111	8.00fg	55.34bc	12.50b	10.13b	6.47b	3.23c
4	*H. annuus* Ames 29273	12.00de	112.28b	4.40d	6.50bcd	5.77b	4.10b
5	*H. annuus* Ames 29348	22.00c	249.75a	12.80b	9.20bc	7.57b	4.40b
7	*H. argophyllus*	24.00b	16.60c	9.00c	6.53bcd	2.30c	3.20b
8	*H. bolanderi*	13.00d	61.03bc	3.20e	5.60bcd	2.23c	2.33d
9	*H.debilis* ssp.*cucumerifolius*	7.00gh	109.65b	1.30ij	2.86bcd	1.90c	2.23de
10	*H. debilis* ssp. *debilis*	6.00h	1.68c	1.40hij	0.73d	1.13e	1.13h
11	*H. debilis* ssp. *silvestris*	3.00i	16.50c	1.60ghi	1.03d	1.70c	1.77efg
12	*H. debilis* ssp. *tardiflorus*	7.00gh	13.77c	1.10j	1.33d	1.37c	1.63fgh
13	*H. debilis* ssp. *vestitus*	3.00i	17.40c	1.20ij	0.90d	1.37c	1.30gh
15	*H. exilis*	9.00f	-	1.90fg	-	1.83c	-
16	*H. neglectus*	3.00i	60.29bc	1.40hij	2.93bcd	2.20c	2.10def
20	*H. petiolaris*	11.00e	35.17c	4.60d	3.77bcd	2.50c	2.30de
24	*H. praecox*	11.00e	25.43c	1.80gh	1.90cd	2.30c	1.83defg
25	*H. praecox* ssp. *hirtus*	3.00i	31.99c	1.40hij	1.37d	1.63c	1.87def
26	*H. praecox* ssp. *praecox*	3.00i	34.18c	1.80gh	1.43d	1.90c	1.60fgh
27	*H. praecox* ssp. *runyonii*	3.00i	44.10bc	2.30f	1.23d	2.17c	1.87def
	Means for year	10.07B	53.08A	9.59A	7.45B	3.70A	2.55B
	LSD (p<0.05) for genotype	1.61	69.55	0.47	7.32	2.56	0.54
	LSD (p<0.05) for years	11.75		1.23		0.46	

*: Within each column for genotype and line for the year in each character, means followed by the same letters are not significantly different at P ≤ 0.05.

1000 seed weight of wild annual sunflower genotypes ranged from 1.10 to 101.20 g in 2012 although it was between 0.73 and 69.20 g in the second growing season. In the first year, the seed weight was higher than in the second year. Despite the fertilization and seed setting problems due to high temperature, the development of the formed grains was better in the first year. *H. annuus* Ames 4114 gave the highest seed weights in both years. This genotype was followed by *H. annuus* Ames 29348 and *H. annuus* Ames 7111 in 2012, and by *H. annuus* Ames 7111, *H. annuus* Ames 29348, *H. argophyllus*, *H. annuus* Ames 29273, *H. bolanderi*, *H. petiolaris*, *H. neglectus* and *H. debilis ssp. cucumerifolius* in 2013.

Head diameter according to genotypes ranged between 1.13 and 18.33 cm in 2012, and between 1.13 and 6.40 in 2013. In the first year, the head diameter was measured higher than in the second year. In this result, it is thought that the fact that the precipitation in April and May in the first year was much higher than in the second year had a positive effect on the head development. *H. annuus* Ames 4114 had the highest head diameter in both growing seasons. The second highest head diameter group was created by *H. annuus* Ames 29348, H. annuus Ames 7111and *H. annuus* Ames 29273 in 2012, and by *H. annuus* Ames 29348, *H. annuus* Ames 29273, and *H. argophyllus*.

Mean comparisons for plant height, primary branches number, plant spreading diameter, and main stem diameter are given in *Table 7*.

Table 7. Mean comparisons for plant height, primary branches number, plant spreading diameter, and main stem diameter

Geno. No.	Plant height (cm)		Primary branches number (No)		Plant spreading diameter (cm)		Main stem diameter (cm)	
	2012	2013	2012	2013	2012	2013	2012	2013
2+	138.33ef	79.33j	5.00i	5.00h	100.67gh	37.67g	4.17b	1.27 fg
3	187.67ed	165.33efg	20.67cd	21.33defg	210.00bc	143.67bcde	4.03b	2.29cde
4	251.00b	234.67b	27.33b	27.67bcd	274.00a	157.33abc	6.00a	3.17ab
5	166.33cde	228.00bc	19.67cde	27.00bcd	123.33efgh	129.00cdef	3.47bc	3.86a
7	325.67a	305.00a	45.67a	39.33a	156.00de	125.67cdef	3.73bc	2.90c
8	194.33c	198.67cd	22.00bcd	28.00bc	175.00cd	159.67abc	2.50def	3.15abc
9	118.67fgh	192.67de	14.00efgh	27.33bcd	152.67def	192.33a	1.90efgh	2.81bc
10	80.33hi	61.33j	8.33hi	17.33fg	147.00def	95.67f	1.30gh	0.95g
11	145.00def	89.67ij	17.00def	19.33efg	155.00de	112.33def	1.90efgh	1.58efg
12	108.00fghi	136.67gh	25.33bc	31.00b	150.00def	156.0 abcd	2.17defg	2.30bcde
13	71.00i	78.33j	13.67efgh	15.00g	143.33defg	151.7abcde	1.00h	1.39fg
15	105.67fghi	-	25.00bc	-	93.67h	-	1.77fgh	-
16	188.00cd	171.67def	18.00de	26.67bcd	150.00def	183.00ab	5.30a	2.42bcde
20	197.67c	155.67fg	20.00cde	25.33bcde	220.00b	112.00ef	2.80cde	1.79efg
24	102.33fghi	91.0ij	11.33fghi	22.67cdef	176.00bcd	126.33cdef	2.00efg	1.86def
25	84.00ghi	89.0ij	10.00ghi	19.33efg	110.00fgh	135.33cdef	1.60fgh	1.75efg
26	81.67hi	62.67j	15.67defg	19.67efg	139.0defgh	133.33cdef	2.00efg	1.57efg
27	130.67efg	121.0hi	16.0defg	24.00cde	170.0cd	157.33abc	3.00cd	2.68bcd
Means	151.22A	145.02A	18.22 B	23.29A	161.88A	135.78B	2.88A	2.22B
LSD1	46.88	32.18	6.64	6.66	44.54	43.69	0.94	0.88
LSD2	9.68		1.58		10.48		0.22	

+: *Helianthus* species, subspecies, and genotype names in Table 1

Mean: Mean for two growing seasons LSD1: LSD for genotype at p<0.05 LSD2: LSD for the year at p<0.05, Geno.: Genotype

*: Within each column for genotype and line for the year in each character, means followed by the same letters are not significantly different at P ≤ 0.05.

Plant height for the genotype ranged between 71.0 and 325.67 cm in 2012, and between 61.33 and 305.00 cm in 2013. There was no difference between years for plant height. *H. argophyllus* had the highest plant heights in both years. This genotype was followed by *H. annuus* Ames 29273 in the first year, by *H. annuus* Ames 29273 and *H. annuus* Ames 29348 in the second year. *H. debilis ssp. debilis*, *H. debilis* ssp. *vestitus*, *H. praecox*, *H. praecox ssp. hirtus* and *H. praecox ssp. praecox* were in the shortest plant height group in both years. In addition, *H. exilis* and *H. debilis* ssp. *tardiflorus* were in the shortest plant height group in the first growing season while in the second year, *H. debilis* ssp. *silvestris* and *H. annuus* Ames 4114 in this shortest plant height group.

Primary branches number of wild sunflower genotypes ranged between 5.00 and 45.67 cm in 2012, and between 5.00 and 39.33 cm in 2013. In both years, *H. argophyllus* had the highest primary branches number while *H. annuus* Ames 4114 created the lowest primary branches number group. The means of primary branches number of genotypes in the second year was significantly higher than in the first year. We think that this was due to the very low rainfall in the first year in June when branching was at its peak.

Plant spreading diameter of wild annual sunflower genotypes ranged between 93.67 and 274.00 cm in the first year, and between 95.67 and 192.33 cm in the second year. The highest plant spreading diameter was measured in *H. annuus* Ames 29273 in 2012 while the highest plant spreading group had *H.debilis* ssp.*cucumerifolius*, *H. neglectus*, *H. bolanderi*, *H. praecox* ssp. *runyonii*, *H. debilis ssp. tardiflorus*,. *H debilis ssp. vestitus* genotypes. The mean of the first-year plant spreading diameter was statistically higher than the second year.

The main stem diameter of genotypes ranged from 1.00 to 6.00 cm in 2012, and from 0.95 to 3.86 in 2013. In the first year, the highest main stem diameter was measured in *H. annuus* Ames 29273 and *H. neglectus* while it was obtained in *H. annuus* Ames 29348, *H. annuus* Ames 29273 and *H. bolanderi* in the second year. There was a statistically significant difference between years for this character, and the main stem diameter in 2012 was higher than in 2013.

Table 8. Mean comparisons for the number of days from planting to first flowering, number of days from planting to 50% flowering and number of days from planting to the end of flowering, number of days of the flowering period

	Number of days from planting to first flowering (No)		Number of days from planting to 50% flowering (No)		Number of days from planting to the end of flowering (No)		Number of days of the flowering period (No)	
Geno.	2012	2013	2012	2013	2012	2013	2012	2013
2+	95.00h	105.33g	107.00j	122.00f	173.33k	146.00f	78.33m	40.67g
3	109.33cd	129.67cd	113.33gh	160.67cde	232.00fg	250.00cde	121.67i	120.33ef
4	108.00d	138.00bc	112.33b	161.67cde	236.67d	264.00abc	128.33gh	126.00ef
5	103.00e	126.00cd	114.00g	164.67cd	230.67gh	237.67e	127.67h	116.67f
7	202.00a	202.33a	221.00a	223.00a	252.00b	254.00cde	50.00o	51.67g
8	102.00ef	122.67de	107.00j	162.67cde	232.33fg	256.00bcde	130.33g	133.33def
9	91.00i	125.67cd	97.00l	158.00cde	241.67c	258.3abcde	150.67c	132.67def
10	108.33d	144.00b	158.00c	216.33a	265.00a	278.33a	156.67b	134.33def
11	111.00c	128.00cd	151.00d	169.67bc	202.00j	265.67abcd	91.00l	137.67cdef
12	101.67ef	130.00cd	141.67f	150.33de	203.00j	260.67abcd	101.33k	130.67def
13	103.00e	121.00def	144.00e	216.33a	266.67a	278.67a	162.67a	157.67abcd
15	129.00b	-	159.33c	-	202.00j	-	73.00n	-
16	98.00g	122.67de	143.33e	165.00cd	202.00j	265.33abc	104.00j	142.67bcde
20	108.00d	126.33cd	164.67b	185.67b	242.67c	239.33de	134.67f	113.00f
24	91.00i	112.00efg	97.00l	149.33de	233.67ef	276.33ab	142.67d	164.33abc
25	91.67i	110.00efg	97.33l	146.67e	229.67h	278.33a	138.00e	168.33ab
26	94.00h	108.00fg	101.67k	151.67de	235.33de	279.00a	141.33d	171.00a
27	101.00f	109.33fg	110.00i	154.00cde	221.00i	278.67a	120.00i	169.33ab
Mean	106.96B	127.12A	128.26B	168.10A	229.33B	256.84A	122.31B	129.73A
LSD1	1.93	13.09	1.52	16.06	2.26	22.24	2.63	27.09
LSD2	2.21		2.76		3.78		4.59	

+: Helianthus species, subspecies, and genotype names in *Table 1*
Mean: Mean for two growing seasons, Geno.: Genotype
LSD1: LSD for genotype at p<0.05 LSD2: LSD for year at p<0.05

Mean comparisons for the number of days from planting to first flowering, number of days from planting to 50% flowering, and number of days from planting to the end of flowering, number of days of the flowering period are given in *Table 8*.

The beginning of flowering, the end of flowering, and the flowering period are the most important Phenological characters for sunflower breeding studies with wild sunflowers. Because in hybridization studies, sowing time should be arranged between the parents in order to obtain pollen from the wild at the appropriate time.

The number of days from planting to first flowering ranged from 91.00 to 202.00 in 2012, and from 105.33 to 202.33 in 2013. In the first year, the earliest flowering was observed in *H.debilis* ssp.*cucumerifolius*, *H. praecox*, and *H. praecox ssp. hirtus* while *H. annuus* Ames 4114 and four H. praecox subspecies had the earliest flowering I the second year. In both years, *H. argophyllus* had the latest first flowering. The beginning of this wild annual sunflower species was later than the nearest genotype about 2.5 months in 2012 and 2 months in 2013. In the second year, the beginning of the flowering of genotypes was delayed as statistically significant due to climatic conditions.

The results of the number of days from planting to 50% flowering was similar to beginning of flower. H. *debilis* ssp. *cucumerifolius*, *H. praecox*, and *H. praecox ssp. hirtus* reached earliest to 50% flowering in 2012 while *H. annuus* Ames 4114 had earliest 50% flowering in 2013. *H. argophyllus* had the latest 50% flowering in both years while *H. debilis* ssp. *silvestris* and *H. debilis* ssp. *vestitus* were in the same latest 50% flowering group in 2013. The number of days from planting to 50% flowering in the second year was higher than in the first year.

The number of days from planting to the end of flowering ranged from 173.33 to 266.67 in 2012, and from 146.00 to 278.67 in 2013. The flowering of the first year was completed earlier than the second year. In both years, *H. annuus* Ames 4114 reached the earliest to the end of flowering.

The flowering period of wild sunflower genotypes ranged from 50.0 to 162.67 days in 2012, and from 40.67 to 171.0 days in 2013. In the first year, *H. argophyllus* had the shortest flowering period while *H. debilis ssp. vestitus* had the highest days number for flowering period. In the second year, *H. argophyllus* and *H. annuus* Ames 4114 had the shortest flowering period while the longest flowering was observed in *H. debilis ssp. vestitus* and all *H. praecox* subspecies. Four *H. praecox* genotypes had longer flowering in 2013 according to the first year.

Mean comparisons for the secondary stem diameter, head number per plant, seed number per head, seed yield per plant, seed length, and seed width are given in *Table 9*. Stem diameter was observed in the first year while head number per plant, seed number per head, seed yield per plant, seed length, and seed width were taken in the second year. The main stem diameter of genotypes ranged from 0.60 to 2.33 cm. The highest main stem diameters were measured in *H. annuus* Ames 4114, *H. annuus* Ames 29273, *H. neglectus*, *H. annuus* Ames 29348, *H. argophyllus* and *H. praecox ssp. runyonii*. Head number per plant ranged between 5.0 and 800.70. *H.debilis ssp.cucumerifolius*, *H. neglectus*, *H. praecox ssp. praecox, H. praecox*, *H. bolanderi*, *H. debilis ssp. tardiflorus* and *H. praecox ssp. runyonii* were in the highest head number per plant group while *H. annuus* Ames 4114 had the lowest head number per plant. Seed number per head ranged from 48.67 to 401.00. *H. annuus* Ames 29348 had the highest seed number per plant. Seed yield per plant was observed between 16.07 and 233.20 g. *H. annuus* Ames 29348 had the highest seed yield per plant while the lowest seed yield per plant was observed in *H. annuus* Ames 4114. Seed length ranged from 2.98 to 12.25 mm while seed width was between 1.35 to 5.80 mm. *H. annuus* Ames 4114 highest seed sizes.

It was not possible to measure some features in some species not included in previous results. The characters measured in these species are given in *Table 10*. But, statistical analyzes were not made on these data. It was not possible to obtain grains because these genotypes (*H. agrestis*, H. *anomalus*, *H. deserticola*, *H. debilis subsp. tardiflorus,* all *H. niveus species*, *H. porteri* and two *H. petiolaris* species) had bad germination, growth problems or drying out due to climatic conditions.

Table 9. Mean comparisons for the secondary stem diameter, head number per plant, seed number per head, seed yield per plant, seed length, and seed width

Helianthus* *species/subspecies	**Secondary stem diameter (cm) 2012**	**Head number per plant (No) 2013**	**Seed number per head (No) 2013**	**Seed yield per plant (g.) 2013**	**Seed length (mm) 2013**	**Seed width (mm) 2013**
H. annuus Ames 4114	2.33a	5.00e	48.67e	16.07e	12.25a	5.80a
H. annuus Ames 7111	1.50bc	117.00cde	177.33c	51.67bc	5.72bc	2.73bc
H. annuus Ames 29273	2.27a	203.70bcde	286.33b	104.84b	4.64cdefg	2.26bc
H. annuus Ames 29348	1.93ab	223.70bcde	401.00a	233.20a	6.44b	3.13bc
H. argophyllus	1.93ab	228.00bcde	177.00c	15.50c	5.10bcde	1.71c
H. bolanderi	1.10cd	479.00abcd	107.67cde	56.99bc	4.97cdef	2.16bc
H.debilis ssp.*cucumerifolius*	0.83d	800.70a	140.00cde	102.38b	3.64fgh	2.10bc
H. debilis ssp. *debilis*	0.73d	83.70de	54.67e	15.57c	4.14defgh	1.83bc
H. debilis ssp. *silvestris*	0.80d	221.30bcde	130.00cde	15.41c	2.98h	1.35c
H. debilis ssp. *tardiflorus*	0.90d	417.00abcde	68.00e	12.85c	4.32defg	3.76b
H. debilis ssp. *vestitus*	0.63d	217.70bcde	78.00de	16.25c	3.75efgh	3.05bc
H. exilis	0.90d	-	-	-	-	-
H. neglectus	2.20a	593.30ab	86.67cde	56.30bc	4.21defgh	2.14bc
H. petiolaris	1.60bc	245.00bcde	117.67cde	32.84c	5.30bcd	2.65bc
H. praecox	0.60d	501.70abc	98.67cde	23.75c	4.00defgh	2.27bc
H. praecox ssp. *hirtus*	0.87d	297.70bcde	133.00cde	28.93c	3.90efgh	1.53c
H. praecox ssp. *praecox*	0.97d	536.70ab	122.00cde	32.00c	3.53gh	1.63c
H. praecox ssp. *runyonii*	1.90ab	418.30abcde	163.33cd	41.18bc	4.02defgh	1.92bc
LSD ($p<0.05$) for genotype	0.53	413.35	94.50	64.97	1.38	1.94

The phylogenetic classification studies on annual wild sunflower species showed that *H. annuus*, *H. argophyllus*, *H. bolanderi* and *H. exilis* were in one of the branches while *H. niveus subsp niveus*, *H. niveus subsp. tephrodes*, *H. niveus subsp. canescens*, *H. praecox*, *H. debilis*, *H. neglectus* and *H. petiolaris* were in the second other branches. In these studies, *H anomalous*, *H. deserticola* and *H. paradoxus* were stated between *H. annuus* and *H. petiolaris* (Rieseberg, 2006). Jocković et al. (2020) studied the pericarp features of wild *Helianthus* L. species as a potential source for improvement of the technical and technological properties of cultivated. They found that the achene length of wild perennial species changed from 3.2 to 6.0 mm, while the achene width was between 1.2 and 2.5 mm. Presotto et al. (2019) indicated that the number of branches and tertiary head diameter could be direct selection criteria for wild sunflower genotypes under stress conditions. Flowering and self-pollination are among the most important characters in sunflower hybrid breeding (Onemli, 2005a; 2005b). The results found in this study are in agreement with previous studies.

4. Conclusion

This study presented data on some phenological and agronomic characteristics of annual wild sunflower species in field conditions containing very valuable preliminary information for plant breeders. The information we have obtained for flowering date adjustments in hybridization studies and important yield components includes very valuable findings for future breeding studies. We had significant problems obtaining seeds from some species. This was due to the difficulty of adapting these species to the local field conditions. Because the gene center of these species is in special climatic regions such as the desert. Studies should be continued, and precautions should be taken for these species which are difficult to adapt to field conditions.

Table 10. Mean comparisons for some characters observed in other species.

Helianthus species/subspecies	**Plant spreading diameter (cm) 2012/2013**	**Plant height (cm) 2012/2013**	**Head diameter (cm) 2012/2013**	**Main stem diameter (cm) 2012/2013**	**NDFP+ to first flowering 2012/2013**	**NDFP to 50% flowering 2012/2013**
H. agrestis	-/104	-/106	-/1.20	-/1.14	-/223	-/244
H. anomalus	-/82	-/78	-/1.40	-/1.35	-/117	-/153
H. debilis subsp. tardiflorus	-/256	-	-	-	-/125	-/160
H. deserticola	-	-	-	-	-/108	-
H. exilis	-/101	-/102	-/1.50	-/1.72	-/132	-/162
H. niveus	28/18	77/50	0.70/0.50	0.70/0.63	108/129	142/174
H. petiolaris subsp. *fallax*	-/187	-/208	-/3.90	-/4.06	-/127	-/169
H. petiolaris subsp. *petiolaris*	-/107	-/124	-/2.80	-/1.63	-/111	-/161
H. porteri	125/111	78/51	-/1.20	1.80/1.14	-/214	-/227
Helianthus species/subspecies	**NDFP to the end of flowering (No) 2012/2013**	**Flowering period days (No) 2012/2013**	**Seed number per head (No) 2013**	**1000 seeds weight (g) 2013**	**Seed yield per plant (g) 2013**	**Seed length/ width (mm) 2013**
H. agrestis	192/280	84/57	50	3.40	-	4.93/1.50
H. anomalus	-/207	-/90	16	0.90	-	5.33/1.13
H. debilis subsp. tardiflorus	-/273	-/35	-	-	-	-
H. deserticola	-	-	-	-	-	-
H. exilis	-/198	-/30	49	1.70	6.20	2.50/1.16
H. niveus	-/232	-/42	28	1.00	-	3.76/1.30
H. petiolaris subsp. *fallax*	-/224	-/42	212	5.30	-	4.60/2.43
H. petiolaris subsp. *petiolaris*	-/217	-/50	182	2.10	--	4.16/5.10
H. porteri	-/251	-/13	23	3.50	2.74	3.40/1.80

NDFP+: Number of days from planting

References

Atlagić, J., Terzić, S., Škorić, D., Marinković, R., Vasiljević, L. and Panković-Saftić, D. (2006). The wild sunflowers collection In Novi Sad. *Helia*, 29(44): 55-64.

De Haro, A. and Fernandez-Martinez, J. (1991). Evaluation of wild sunflower (*Helianthus*) species for high content and stability of linoleic acid in the seed oil. *The Journal of Agricultural Science*, 116(3): 359-367.

Fernández-Aparicio, M., Del Moral, L., Muños, S., Velasco, L. and Pérez-Vich, B. (2022). Genetic and physiological characterization of sunflower resistance provided by the wild-derived OrDeb2 gene against highly virulent races of Orobanche cumana Wallr. *Theoretical and Applied Genetics*, 135(2): 501-525.

Gavrilova, V. A. and Anisimova, I. N. (2017). Genealogy of the sunflower lines created on the basis of Russian varieties. *Helia*, 40(67): 133-146.

Hajjar, R. and Hodgkin, T. (2007). The use of wild relatives in crop improvement: a survey of developments over the last 20 years. *Euphytica*, 156(1): 1-13.

Heiser, C. B. (1951). The sunflower among the North American Indians. *Proceedings of the American Philosophical Society*. 95(4): 432-448.

Hernández, F., Poverene, M. and Presotto, A. (2018). Heat stress effects on reproductive traits in cultivated and wild sunflower (*Helianthus annuus* L.): evidence for local adaptation within the wild germplasm. *Euphytica*, 214(8): 1-15.

Hernández, F., Presotto, A., Poverene, M. and Mandel, J. R. (2019). Genetic diversity and population structure of wild sunflower (*Helianthus annuus* L.) in Argentina: reconstructing its invasion history. *Journal of Heredity*, 110(6): 746-759.

Jocković, J., Rajčević, N., Terzić, S., Zorić, L., Jocković, M., Miladinović, D. and Luković, J. (2020). Pericarp features of wild perennial Helianthus L. species as a potential source for improvement of technical and technological properties of cultivated sunflower. *Industrial Crops and Products*, 144: 112030.

Mesihovic, A., Iannacone, R., Firon, N. and Fragkostefanakis, S. (2016). Heat stress regimes for the investigation of pollen thermotolerance in crop plants. *Plant Reproduction*, 29(1): 93-105.

Nooryazdan, H., Serieys, H., Baciliéri, R., David, J. and Bervillé, A. (2010). Structure of wild annual sunflower (*Helianthus annuus* L.) accessions based on agro-morphological traits. *Genetic Resources and Crop Evolution*, 57(1): 27-39.

Onemli, F. (2005a). Efficiency of various bagging materials for self fertilization and hybridization on yield components in sunflower. *Journal of Tekirdag Agricultural Faculty*, 2(1): 1-6.

Onemli, F. (2005b). The self fertility rates of some hybrid sunflower cultivars. *Journal of Tekirdag Agricultural Faculty*, 2(1): 7-12.

Onemli, F. (2012a). Impact of climate changes and correlations on oil fatty acids in sunflower. *Pakistan Journal of Agricultural Sciences*, 49(4): 455-458.

Onemli, F. (2012b). Changes in oil fatty acid composition during seed development of sunflower. *Asian journal of plant sciences*, 11(5): 241-245.

Onemli, F. and Gucer, T. (2010a). Response to drought of some wild species of Helianthus at seedling growth stage. *Helia*, 33(53): 45-54.

Onemli, F. and Gucer, T. (2010b). Self-fertilization and restoration to cytoplasmic male sterility of some wild species of helianthus. *Helia*, 33(53): 31-36.

Onemli, F. and Gucer, T. (2010c). The characterization of some wild species of Helianthus for some morphological traits. *Helia*, 33(53): 17-24.

Perez, E. E., Crapiste, G. H. and Carelli, A. A. (2007). Some physical and morphological properties of wild sunflower seeds. *Biosystems engineering*, 96(1): 41-45.

Presotto, A., Hernández, F. and Mercer, K. L. (2019). Phenotypic selection under two contrasting environments in wild sunflower and its crop–wild hybrid. *Evolutionary Applications*, 12(8): 1703-1717.

Qi, L. L., Ma, G. J., Li, X. H. and Seiler, G. J. (2019). Diversification of the downy mildew resistance gene pool by introgression of a new gene, Pl35, from wild *Helianthus argophyllus* into oilseed and confection sunflowers (*Helianthus annuus* L.). *Theoretical and Applied Genetics*, 132(9): 2553-2565.

Rauf, S. (2019). Breeding Strategies for Sunflower (*Helianthus annuus* L.) Genetic Improvement. In Advances in Plant Breeding Strategies: *Industrial and Food Crops* (pp. 637-673). Springer, Cham.

Rieseberg, L. H. (2006). Hybrid speciation in wild sunflowers 1. *Annals of the Missouri Botanical Garden*, 93(1): 34-48.

Seiler, G. J. (2007). Wild annual *Helianthus anomalus* and *H. deserticola* for improving oil content and quality in sunflower. *Industrial Crops and Products*, 25(1): 95-100.

Seiler, G. J., Qi, L. L. and Marek, L. F. (2017). Utilization of sunflower crop wild relatives for cultivated sunflower improvement. *Crop Science*, 57(3): 1083-1101.

Talukder, Z. I., Long, Y., Seiler, G. J., Underwood, W. and Qi, L. (2019). Introgression and monitoring of wild Helianthus praecox alien segments associated with Sclerotinia basal stalk rot resistance in sunflower using genotyping-by-sequencing. *PloS one*, 14(3): 1-18.

Vear, F. (2016). Changes in sunflower breeding over the last fifty years. *OCL Oilseeds and Fats Crops and Lipids*, 23(2): 1-8.

Whitney, K. D., Randell, R. A. and Rieseberg, L. H. (2010). Adaptive introgression of abiotic tolerance traits in the sunflower *Helianthus annuus*. *New phytologist*, 187(1): 230-239.