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Sunflower (*Helianthus annuus* L.) genetic resources, production and researches in Turkey☆

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Abstract – Sunflower is one of the leading oilseed crops and it is widely grown in the Thrace region of Turkey. In 2017, in Turkey as a whole, oilseed and confectionary sunflowers were grown on 779.622 ha with a total production of 1 964 385 t of seed, and average yields of 2.64 t ha^{-1} for oilseed and 1.67 t ha^{-1} for confectionary types. Turkey is one of the important countries for crop diversity and has been described as a microcenter for some crops, which originated in different parts of the world. Landraces of sunflower (*Helianthus annuus* L.) show significant diversity in Turkey and have been collected in the framework of the "National Industrial Plant Genetic Resources Project" (NPGRP). Nine hundred and thirty two oilseed and confectionary sunflower accessions are in longterm conservation in the National Seed Gene Bank of Turkey. The mission of the National Sunflower Research Project is to develop improved germplasm and hybrid varieties by conventional and biotechnical breeding techniques in Turkey. New germplasm and breeding lines have been developed to improve oilseed and confectionary sunflower hybrids with desired characters including high yield and oil quality, resistance to diseases such as: *Plasmopara halstedii* (Farl.) Berl de Toni., *Puccinia helianthi* Schw., and *Orobanche cumana* Walr. Adverse conditions are also taken under consideration. These studies are integrated with agronomic and other related research.

Keywords: sunflower / *Helianthus annuus* L. / production / landraces / Turkey

Résumé – Tournesol (*Helianthus annuus* L.) en Turquie : ressources génétiques, production et recherche. En Turquie, le tournesol est l'une des principales cultures d'oléagineux et est principalement cultivé dans la région de Thrace. En 2017, les tournesols oléagineux et de bouche ont été cultivées sur 77 9622 hectares en Turquie pour une récolte de 1 964 385 t et des rendements moyens de 2640 t/ha pour le premier et 1 670 t/ha pour le second. La Turquie est l'un des principaux pays pour la diversité des cultures et est décrite comme un microcentre pour certaines cultures originaires de différentes régions du monde. Les variétés du tournesol (*Helianthus annuus L.*) présentent également une diversité importante en Turquie. Les variétés de pays de tournesol ont été rassemblées dans le cadre du « Projet national de ressources génétiques pour les cultures industrielles » (*National Industrial Plant Genetic Resources Project*, NPGRP). Neuf cent trente-deux entrées (932 entrées) de tournesol oléagineux et de bouche sont en conservation à long terme à la Banque nationale de ressources génétiques de Turquie. Le projet de recherche national sur le tournesol a pour mission de développer du matériel génétique amélioré au moyen de techniques de sélection conventionnelles et biotechnologiques pour la région de Thrace et d'autres zones de production en Turquie. De nouveaux germplasmes et lignées parentales ont été mis au point pour améliorer les variétés hybrides oléagineux et de bouches avec les caractères recherchés : rendement élevé et huile de bonne qualité, résistance aux maladies telles que *Plasmopara halstedii* (Farl.) Berl de Toni., *Puccinia helianthi* Schw. et *Orobanche cumana* Walr. Les comportements en conditions défavorables sont également pris en compte. Ces études sont également intégrées à des recherches en agronomie et d'autres sujets connexes.

Mots clés : tournesol / *Helianthus annuus* L. / production / variétés de pays / Turquie

☆ Contribution to the Topical Issue "The oil & protein crop supply chain in Eastern Europe / La filière oléoprotéagineuse en Europe de l'Est"

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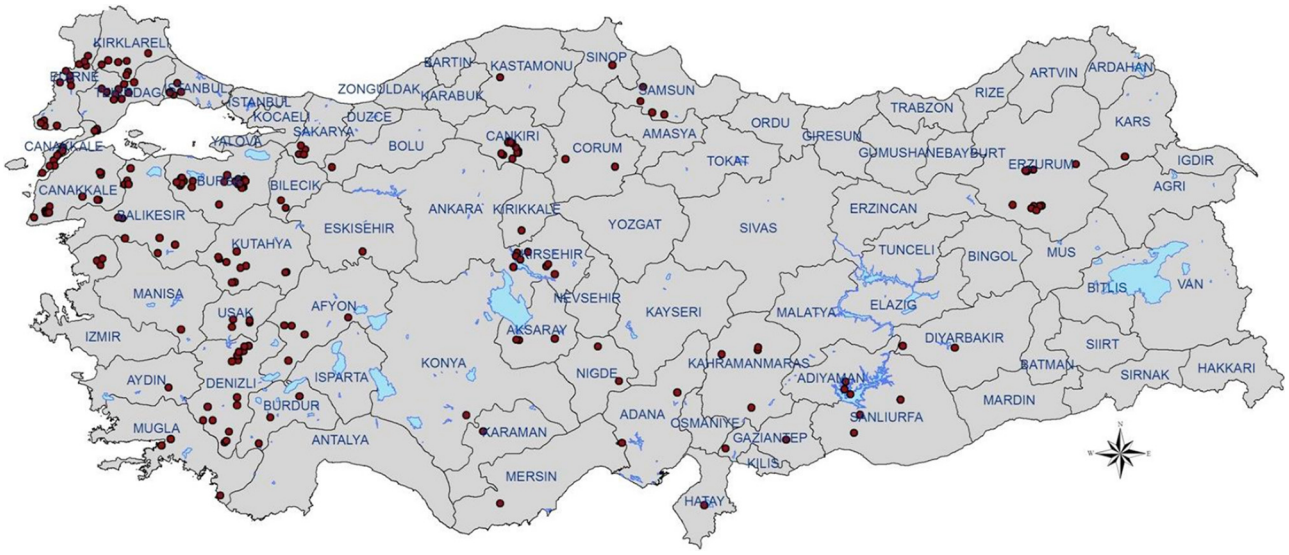

Fig. 1. Collection sites of sunflower land races in Turkey.

1 Introduction

Turkey is an important country concerning plant genetic resources and center of origin or micro gene center for several crop species (Harlan, 1951) that did not originate in the country, but shows diversity for many characteristics (Tan, 2009; Tan, 2010a, b; Karagoz *et al.*, 2010). Two centers of origin (Mediterranean and Near Eastern) overlap in Anatolia. About 3700 of the 11 707 plant taxa found there are endemic to Turkey (Guner *et al.*, 2012). The National Industrial Crops Genetic Resources Research Project aims to survey, collect, conserve long term, characterize, regenerate and utilize the industrial crop genetic resources of Turkey. This collection is a source of germplasm to be used in breeding programs.

Helianthus annuus L. originated in North America, where wild sunflowers provide important genetic diversity for crop improvement (Heiser *et al.*, 1969; Heiser, 1978; Putt, 1978; Zeven and de Wet, 1982; Miller, 1987; Gobbelen *et al.*, 1989; Schneiter, 1997). Landraces are also important sources of genetic variability, because they have adapted to local environments as a result of natural selections over centuries. Thus, the evaluation of existing confectionary and oilseed sunflower land races is essential for increased utilization. Characterization studies indicated that confectionary land races are highly variable for morphological characters (Tan, 1993; Tan, 2002; Tan, 2010a, b; Tan and Tan, 2010; 2011; 2012; Tan *et al.*, 2013a, b; Tan *et al.*, 2016a, c; Tan *et al.*, 2017b; Altunok Memiş, 2018; Altunok Memiş *et al.*, 2018).

2 Sunflower genetic resources in Turkey

Crop genetic bases became narrowed since landraces were replaced by modern cultivars (Tanksley and McCouch, 1997). Therefore, in the framework of National Plant Genetic Resources Program (NPGRP), since the 1960s, Turkish landraces of many species have been surveyed, identified then collected before they disappeared and conserved at the National Seed Gene Bank at the Aegean Agricultural Research Institute (AARI) in Izmir, Turkey (Tan, 2000; Tan, 2010b). The sunflower genetic resources collections are included in this seed bank as part of the "Industrial Crops Genetic Resources Project" (Tan and Tan, 1998a, b; Tan, 2000; Tan, 2009;Tan and Tan, 2010, Tan, 2010a, b; Tan and Tan, 2011; 2012; Tan *et al.*, 2013a, b; Tan *et al.*, 2016a, c; Tan *et al.*, 2017c).

These landraces or primitive cultivars are very important sources of genetic diversity, with their adaptability to local environments as a result of natural or farmer selection over centuries. To date, over 932 oilseed and confectionary sunflower accessions collected from sunflower fields, farmer storage and markets are long term *ex situ* conserved at the National Seed Gene Bank of Turkey (Anonymous, 2017a; Altunok Memiş *et al.*, 2018). Figure 1 shows the collection areas of sunflower land races in Turkey (Anonymous, 2017a; Tan *et al.*, 2017c; Altunok Memiş, 2018).

The oilseed and confectionary sunflower genetic resources received from the National Seed Gene Bank of Turkey were observed for 43 morphological, phenological and technological characters identified by UPOV (Anonymous, 2000) and IBPGRI (IBPGR, 1985).

The data were evaluated by Principal Component Analysis (PCA), and Cluster Analysis and the eco-geographical distribution and agro-morphological variation of both oilseed and confectionary sunflower landraces at National Gene Bank have been published (Sneath and Sokal, 1973; Clifford and Stephenson, 1975; Tan, 1983). The distribution areas of sunflower samples showed significant variation within and between accessions. Distinct groupings were determined in principal components and the results of analyses exhibited broad morphological variation for land races (Tan and Tan, 2010, 2012; Tan *et al.*, 2013a, b; Altunok Memiş, 2018).

This genetic diversity and its characterization are very important for hybrid sunflower variety breeding because parental lines with diverse origin have higher potential heterosis, then hybrids made from closely related parents (Kaya, 2010; Kaya, 2014a; Kaya, 2016). Thus, both

Table 1. Oilseed and confectionary sunflower production values in Turkey (Anonymous, 2017b).

Year	Production area (da)			Production (Metric tons)			Yield (kg/da)	
	Oilseed	Confectionary	Total	Oilseed	Confectionary	Total	Oilseed	Confectionary
2004	4 800 000	700 000	5 500 000	8 00 000	1 00 000	900 000	167	143
2005	4 900 000	760 000	5 660 000	8 65 000	1 10 000	975 000	177	145
2006	5 100 000	754 000	5 854 000	1 010 000	10 8 000	111 8000	198	143
2007	4 857 000	689 778	5 546 778	7 70 000	84 407	854 407	159	122
2008	5 100 000	700 000	5 800 000	900 387	91 613	992 000	177	131
2009	5 150 000	690 000	5 840 000	960 300	96 825	1 057 125	186	140
2010	5 514 000	900 000	6 414 000	1 170 000	150 000	1 320 000	212	167
2011	5 560 000	997 000	6 557 000	1 170 000	165 000	1 335 000	210	165
2012	5 046 160	1 000 000	6 046 160	1 200 000	170 000	1 370 000	238	170
2013	5 202 600	895 239	6 097 839	1 380 000	143 000	1 523 000	265	160
2014	5 524 651	1049 925	6 574 576	1 480 000	157 900	1 637 900	268	150
2015	5 689 950	1163 224	6 853 174	1 500 000	180 700	1 680 700	264	155
2016	6 167 800	1033 281	7 201 081	1 500 000	170 716	1 670 716	243	165
2017	6 813 976	982 241	77 96 217	1 800 000	164 385	1 964 385	264	167

Table 2. Oilseed sunflower production values in major provinces of Turkey in 2016 (Anonymous, 2017b).

Provinces	Production area (da)	Production (Metric tons)	Yield (kg/da)
Tekirdag	1 420 265	283 838	200
Edirne	988 286	222 064	225
Kırklareli	782 569	170 278	218
Adana	539 542	166 524	309
Konya	526 832	205 274	390
Corum	243 244	56 048	230
Istanbul	171 484	37 544	219
Canakkale	170 421	39 097	229
Balikesir	157 148	30 555	194
Samsun	151 901	35 546	234
Tokat	137 141	39 306	287
Amasya	122 547	33 122	270
Bursa	99 564	23 172	233

Table 3. Confectionary sunflower production values in major provinces of Turkey in 2016 (Anonymous, 2017b).

Provinces	Production area (da)	Production (Metric tons)	Yield (kg/da)
Ankara	258 217	27 799	108
Denizli	159 370	32 155	202
Kayseri	97 086	20 341	210
Kırıkkale	82 035	6 004	73
Yozgat	78 802	7 906	100
Kahramanmaraş	63 100	19 515	309
Kırsehir	48 650	4 681	96
Aksaray	47 660	10 323	217
Bursa	37 680	10 592	281
Afyon	28 560	3 564	125
Konya	25 128	7 038	280
Eskisehir	19 058	4306	226
Erzurum	16 504	3 938	239
Karaman	15 418	1 402	109
Bilecik	14 910	2 330	156
Corum	11 528	3 021	262

confectionary and oilseed sunflower land races have been evaluated and utilized in breeding programs at AARI and TARI (Thrace Agricultural Research Institute).

3 Sunflower production in Turkey

An increasing world population makes necessary increased availability of human foods. Vegetable oils are an important source of energy. Production of sunflowers with high yield, oil percentage and oil quality will help to reduce the oilseed production gap in Turkey, which is one of the leading countries for sunflower production. Data presented in Table 1 shows that oilseed and confectionary sunflowers were grown on 77 9622 ha producing with 1 964 385 t of seed and an average yield of 2.64 t/ha oilseed and 1.67 t/ha for confectionary types in 2017 (Anonymous, 2017b).

Hybrid varieties constitute approximately 95% of production, but farmers generally prefer to use low yielding landraces when they grow confectionary sunflowers. Major provinces producing oilseed and confectionary sunflower in 2016 are given in Tables 2 and 3.

The Thrace region produces 49.3% of Turkish oilseed sunflowers in Tekirdag, Edirne, Kırklareli, and Canakkale provinces. This is followed by the Mediterranean, Central Anatolia, Southeastern Anatolia, Black Sea, South Marmara and Aegean regions. These provinces produce a total of 39.7% of production (Anonymous, 2017b). Linoleic (conventional) types represent 97% of sunflower production, high oleic types 3%. The main confectionary seed production areas are in Central Anatolia and the Aegean Region (Anonymous, 2017b).

Sunflower contributes 1 800 000 tons to the total production of 2 700 000 tons of all oilseed crops in Turkey. This production is not sufficient to cover local oil consumption,

Table 4. Sunflower oil export and import values of Turkey (Anonymous, 2017c).

Years	Import		Export	
	Metric tons	US $	Metric tons	US $
2007	163 115	138 039 000	31 906	36 002 000
2008	411 660	647 095 000	98 714	164 582 000
2009	323 596	468 305 000	101 432	110 618 000
2010	223 998	271 020 000	75 886	100 509 000
2011	469 858	629 068 000	204 872	338 658 000
2012	742 877	987 295 000	271 257	416 884 000
2013	625 849	908 122 000	346 256	496 198 000
2014	812 401	1 177 993 000	665 241	790 130 000
2015	798 170	1 101 230 000	618 525	680 701 000
2016	738 417	1 015 306 000	600 777	637 448 000

Table 5. Sunflower seed export and import values of Turkey (Anonymous, 2017c).

Years	Import		Export	
	Metric Ton	US $	Metric Ton	US $
2007	596 147	260 166 000	10 052	26 598 000
2008	455 995	365 145 000	7826	30 277 000
2009	468 277	240 620 000	16 195	35 054 000
2010	645 607	348 113 000	21 643	58 912 000
2011	905 686	589 577 000	32 402	81 161 000
2012	754 162	443 958 000	56 268	114 321 000
2013	710 843	474 001 000	34 700	103 301 000
2014	556 909	406 154 000	33 521	111 730 000
2015	340 192	237 984 000	35 202	78 875 000
2016	382 263	263 925 000	48 259	120 887 000

Table 6. Sunflower seed processing capacity and sunflower oil consumption in Turkey (Anonymous, 2017c).

	1000 Metric tons /Years							
	2009	2010	2011	2012	2013	2014	2015	2016
Seed processing capacity	1590	1730	1695	1640	1900	1560	1630	1750
Sunflower oil consumption	650	726	846	825	870	827	876	971

partly because, although 9 71 000 tons of oilseed sunflower are used directly, 600 777 tons are exported (Tab. 4). To cover the oilseed deficit, Turkey paid 3.5×10^9 US $ in 2016 to import oilseed and its derivatives, including 738 417 tons of sunflower oil at a cost of 1.015×10^9 $ (Tab. 4). While 382 263 tons of oilseed sunflower were imported with a value of 264×10^6 $; 48 259 tons were exported (Tab. 5). It would be useful to increase, perhaps even double sunflower production in Turkey.

Turkey oil seed processing capacity is 1 750 000 tons but only 55% of the capacity of the 110 oil plants is utilized. Seed processing capacity and sunflower oil consumption in Turkey are given in Table 6. Turkish refinery capacity is 4 million tons per year, but the utilization rate of the existing 110 facilities was 70% in 2016 (Anonymous, 2017c). The production of additional oil seeds would create added value. There are some additional potential sunflower production areas such as Aegean Region and South East Anatolia with suitable ecological conditions for both main and second crop sunflower production in Turkey.

Turkey imports the oilseed sunflower seeds mainly from Bulgaria, Ukraine, Romania, Russia and Moldova. On the other hand, almost half of the raw sunflower oil import is from Ukraine, while the other part is from Russia, Argentina, Romania and Bulgaria. The most exported countries of refined sunflower oil are Iraq, Syria, Lebanon and Thailand (Anonymous, 2017c).

4 Sunflower research in Turkey

The mission of the "National Sunflower Research Projects" at TARI and AARI, and the other Agricultural Research Institutes in Turkey is to breed well adapted and high

yielding varieties, and to develop knowledge and technology for the Turkish sunflower industry. Research is conducted to develop sunflower varieties with improved yield, oil quality, resistance to diseases such as downy mildew [(*Plasmopara halstedii* Farl de Toni)], rust (*Puccinia helianthi* Schw.), *Sclerotinia*, *Rhizopus*, *Botrytis Macrophomina* and broomrape (*Orobanche* sp.), other desired characters and adverse conditions (Tan, 1993; Kaya *et al.*, 2004; Kaya and Evci, 2007; Kaya *et al.*, 2009; Kaya, 2010; Tan, 2010a, b, c; Kaya *et al.*, 2013, 2014; Kaya, 2016).

In Turkey, the main constraints for sunflower are attacks by broomrape and downy mildew (DM) but resistance is available to both parasites. Sunflower rust races have been identified under field conditions (Kaya *et al.*, 2004; Kaya and Evci, 2007; Kaya *et al.*, 2009; Tan, 2010a, b, c; Tan, 2010a; b; Kaya *et al.*, 2012, 2013, 2014; Tan, 2014; Tan *et al.*, 2016a, b; Tan *et al.*, 2017a, b).

To date, oilseed and confectionary sunflower open pollinated variety, parental lines (CMS, maintainer, and restorer lines) and hybrid varieties have been developed and evaluated in yield trials under main and catch crop production seasons. Variety performance tests and yield trials indicated that sunflower can give with satisfactory yield performance (2.50–5.5 t/ha) in both seasons in Thrace, Aegean, and Mediterranean Regions of Turkey (Kaya, 2010; Tan, 2010a, b; Kaya, 2014b; Tan, 2014; Tan *et al.*, 2016b; Kaya, 2016; Tan *et al.*, 2017a, b). The Aegean Region that has suitable ecological conditions for both cropping systems should be considered for sunflower production, in order to decrease the vegetable oil gap in Turkey.

High oleic and herbicide resistant (IMI and SU groups) sunflower varieties are being developed. There are research programs to develop oilseed and confectionary sunflowers for both main and catch crop production seasons. Sunflower germplasm has been developed from sources such as cultivars and breeding populations and tested for general and specific combining ability. Inbred lines, candidate and commercial varieties are evaluated in preliminary and yield trials on a regional basis for both main and catch production seasons in the Aegean Region and other parts in Turkey. In addition, agronomic studies are made on effects of sowing date, plant population, fertilization, irrigation and honeybee pollination on seed yield, oil content, oil quality, silage quality and other plant characteristics.

There is a lack of certified confectionary seed production with desired quality for this type of crop. Consequently, land races are generally used for confectionary sunflower production in Turkey. However, they are not suitable for combine-harvesting because they are not uniform in terms of plant height and physiological maturity (Tan, 2010b; Tan and Tan, 2010). New high yielding oilseed and confectionary sunflower hybrids have been improved and registered for the direct benefit of the agricultural sector and increased sunflower production in the country (Kaya, 2010; Tan, 2010a, b; Aldemir *et al.*, 2016; Altunok *et al.*, 2016; Tan *et al.*, 2016b, Tan *et al.*, 2017a, b).

New high yielding oilseed and confectionary sunflower hybrids have been improved and registered for the direct benefit of the agricultural sector and increased sunflower production in the country.

5 Conclusion

Sunflower is one of the main oilseed crops that contribute to the economy of Turkey for both human and animal nutrition, creating employment and internal and external trade. Production needs to be increased by breeding high yielding varieties tolerant and or resistant to biological and physiological constraints. Sunflower landraces having diversity will also contribute improving high yielding oilseed and confectionary sunflower hybrids.

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