PROCEEDINGS BOOK OF 2. INTERNATIONAL CONFECTIONERY SUNFLOWER SYMPOSIUM

20-22 NOVEMBER, 2025

Megasaray Westbeach Hotel, Antalya, Turkey

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Organized by

Trakya University
International Researchers Association
International Sunflower Association

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WELCOME NOTES

You are welcome to our 2nd our International Confectionery Sunflower Symposium which is organized by International Researchers Association and the in cooperation with Trakya University and International Sunflower Association. The symposium will be held in Megasaray Westbeach Hotel, Antalya, Turkey, on November 20-21, 2025 with the support of several national and international partners with normal as well as with online participation. The program will include oral talks by invited prominent scientists and oral and e poster presentations by participants in selected topics. The Symposium is intended that the subjects to be kept broad in order to provide opportunity to the science and research community to present their works as oral or poster presentations in a friendly environment of Antalya, Turkey to share their knowledge and experience and benefit from each other.

The 9th symposium will gather scientists from around the world, and present their recent achievements. The attendees will have ample opportunities for learning, reconnecting, engaging and networking with colleagues from academia and industry as well as meeting with various exhibitors.

As there have been many different scientific meetings around the world, we aimed to bring three different communities together, namely science, research and private investment groups considering practical information sharing that is of value for researchers and scientists from around the world, in a friendly environment of Antalya, Turkey to share their knowledge and experience and benefit from each other as well as prospects to overcome the limitation for sustainable crop production to feed the world.

There are 10 papers contributed by about 26 authors from 8 different countries from the world. 7 oral and 3 poster presentations existed in the symposium program both joining and presenting by 30 normal and 3 online as total by 33 participants.

With care for our nature and environment, we aim the green symposium, meaning that as little as possible papers will be used. Abstract book is published in electronic book and is distributed to the participants by e mail for online participants. All the e-posters are prepared in electronic form and then submit to via the symposium e mail and exhibited in electronical poster boards as well as in online e poster hall in our web page during the symposium.

The Symposium topics will cover on sunflower:

Plant Breeding and Genetics, Molecular Genetics and Biotechnology, Biology and Physiology, Genetic Resources, Plant Protection, Agronomy, Economy, Trade, Quality, etc

We would like to thank all of you for joining this symposium and we would like to give also special thanks to our sponsors and collaborators for giving us a big support to organize this event.

Prof Dr Yalcin KAYA
Head of the Organizing Committee

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CONFECTIONARY SUNFLOWER BREEDING IN UKRAINE

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ABSTRACT

In Ukraine, special breeding programs to create varieties-populations and heterotic hybrids suitable for the confectionery industry are performed at the Institute of Oilseed Crops (Zaporizhzhia) and Yuriev Plant Production Institute (Kharkiv) of the National Academy of Agrarian Sciences of Ukraine. A collection of 42 inbred lines has been created at the Institute of Oilseed Crops of NAAS; the lines enriched the seed bank of the National Center for Plant Genetic Resources of Ukraine (Kharkiv). The collection lines were selected by 8 achene characteristics, with size, shape and color being the main ones. Lines-parental components of hybrids, with a thousand-seed weight of up to 120 g and achenes up to 15 mm long, were created. Hybridological analysis revealed inheritance patterns of achene size in the first hybrid generation. It was proven that the trait "achene length" was most stable of all the linear sizes of achenes under any growing conditions. Thus, under changing weather scenarios, the selection of large-fruited biotypes should be driven by this trait. New methods have been applied in the breeding process, in particular phenotyping of achenes in heads. Software that allows for determination of achene sizes, division of heads into zones and estimation of a potential yield of seeds of the required fraction has been developed. A method has been introduced to determine the strength required for sunflower husk destruction using a specially designed device; the method makes it possible to group lines taking into account their ability to be dehusked. Large-fruited hybrid 'Smak' and varieties-populations 'Zaporizhzhia Kondyterskyi' and 'Kamlot' have been created. Using of varieties-populations from the collection of the National Center for Plant Genetic Resources of Ukraine (Kharkiv), the Yuryev Plant Production Institute of NAAS has created a huge number of inbred lines that differ in UPOV traits and show high combining ability for seed yield and thousand-seed weight. Selection was also driven by huskiness and biochemical characteristics of achenes. Commercial hybrids 'Hudvin', 'Kosmos' and 'Nasoloda' have been created and farming techniques of confectionery sunflower growing in the Eastern Forest-Steppe of Ukraine were honed on them.

Keywords: sunflower, breeding, confectionary type, inbred line, achene characteristics, phenotyping, varieties-populations, hybrids

SUNFLOWER VARIETIES-POPULATIONS AS STARTING MATERIAL TO CREATE LARGE-FRUITED HYBRIDS SUITABLE FOR DISSEMINATION IN UKRAINE

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ABSTRACT

The climate of Ukraine allows for high yields of confectionery sunflower with a thousand-seed weight of ≥150 g. As ready-to-eat sunflowers, the population uses edible varieties and hybrids with gray striped achenes and a husk content of £40%. However, many consumers prefer intermediate (oil-edible) hybrids with black achenes that are easily peeled due to a low content of thin husks (£28%). Kernels of such sunflowers are also used to manufacture various confectionaries. Large-fruited Ukrainian and foreign varieties-populations, which are used as donors of large achenes, high protein content, early ripeness, high seed productivity, and resistance to local pathogens of sunflower and broomrape, are valuable starting materials to breed heterotic intermediate hybrids. Varieties-populations of the collection of the National Center for Plant Genetic Resources of Ukraine were used at the Yuriev Plant Production Institute of NAAS (Kharkiv, Ukraine) to create lines – sterility fixers and lines – fertility restorers that will be parental components of heterotic hybrids. Breeding programs were implemented via multiple inbreeding of varieties-populations 'Kharkivskyi 7', 'Kharkivskyi 3', 'Zaporizhskyi Kondyterskyi', and intervarietal hybrid combinations and annual selections of the best biotypes with sets of valuable traits. As a result, lines – sterility fixers with black achenes were selected; they are characterized by high thousand-seed weight (up to 90 g), high seed productivity per plant (up to 60 g), and high kernel protein content (up to 30%). The lines' kernels remain intact during decortication; the husks are thin and their content is low (up to 27%); and the lines belong to different ripeness groups, with the "emergence – complete ripeness" periods of from 85 to 118 days. Using sterile counterparts of these lines as parental components, commercial confectionery hybrids were created; under various agroecological conditions (Steppe and Forest-Steppe of Ukraine), the hybrids had a thousand-seed weight of up to 135 g, yield of large seed fraction of up to 85%, and specific gravity of up to 400 g/L.

Keywords: sunflower, variety-population, starting material, large-fruited, black achene, line, intermediate hybrids

ORGANIC CONFECTIONERY SUNFLOWER GENOTYPES CREATED AT NARDI FUNDULEA

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ABSTRACT

Oil seed content at confenctionery sunflower genotypes must be under 30-35% and is lower than oil-type sunflower. The main goal for breeding of confectionery sunflower is to reduce oil content under 30% In organic conditions, in year 2024, oil seed content of sunflower confectionery genotypes was between 18.48% at ECO 13 and 28.18% at Eco 1. In year 2024, in FUndulea location, in organic conditios, without seed treatment, attack degree of pathogen Plasmopara hastedii (sunflower downy mildew) were between 0% at confectionwery sunflower genotypes ECO 1, ECO 5, ECO 6, ECO 7, ECO 13 and 5% at ECO 4. Albugo tragopogonis (sunflower whitw rust) were observed only at ECO 5, ECO 6 between 5%-15%.

Keywords: organic, confectionery sunflower

PRESENT STATUS AND NEW TRENDS IN CONFECTIONERY SUNFLOWER BREEDING

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ABSTRACT

Confectionary sunflower accounts for less than 10% of the worldwide sunflower production, with around 2 million ha. The top-producing countries currently are Russia and China. This type of sunflower is mainly used in the snack food industry in the form of roasted sunflower seeds or dehulled as part of snacks and bakery goods, as well as for bird and pet feed. Breeding of confectionery sunflowers is characterized by the fact that different markets have different demands regarding seed size, hull color, and other traits, which makes this process more difficult and costly. Confectionery sunflower hybrids have significantly higher seed yield than the open-pollinated varieties, as well as resistance to biotic and abiotic stresses. When creating confectionery hybrids, it is also crucial to combine genes responsible for high yield potential and desirable technical and technological traits in the seed. To achieve high and stable yields from confectionery hybrids, it is also essential to develop a model of a sunflower plant that enables an increase in the number of plants per hectare under intensive cultivation practices and mechanized harvesting conditions. With the application of modern biotechnological methods, including molecular marker-assisted selection, genomics, gene editing, bioinformatics, and other emerging techniques, researchers are able to achieve more precise and efficient breeding. This enables more efficient introduction of important traits, such as oil and protein quality, CMS, fertility restoration genes, tolerance to biotic and abiotic stress, resistance to diseases, and control of broomrape and herbicides. Application of generative AI will enable further increase of the breeding efficiency, and creation of new hybrids with unique seed shape, tailor-made for different markets, by combining automated shape analysis, genomic analysis, and generative AI models to simulate seed geometry under known genetic and environmental conditions.

Keywords: AI, sunflower, breeding, seed shape

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A SCALABLE, AFFORDABLE PIPELINE FOR AI-DRIVEN PHOTOGRAMMETRIC QUALITY ESTIMATION OF CONFECTIONARY SUNFLOWER SEEDS

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ABSTRACT

This paper presents a plan for developing a scalable, affordable hardware and software pipeline for AI-driven photogrammetric reconstruction of confectionary sunflower seeds. The process of determining the morphological traits of a given batch of seeds is important in breeding, but is labor-intensive and tedious, due to the need to perform numerous manual measurements, in order to get a balanced sample. We propose an automated low-cost pipeline that produces measurements from reconstructed 3D geometry of individual seeds. The chief challenge of devising such a system is, first, ensuring that it can be scaled production use and acquired at affordable cost, and second ensuring adequate accuracy. Securing adequate accuracy is particularly challenging as the seed has poor surface detail, is too small for most detailed image-acquisition techniques, and is forced to rest on a platform or some other support structure which becomes difficult to disentangle from the geometry of the seed in the post-processing stage. This paper outlines an approach to resolve this issue by building an automated simulator of the acquisition process of both still images and video of the seeds, and using it to determine both the optimal configuration for the image acquisition rig, and the most effective software pipeline. This simulator will serve to help minimize development costs, eliminate unfruitful lines of inquiry from consideration, and help create a robust, effective technique for determination of seed morphological traits in confectionary sunflower. This technique should increase the quality of available data and the efficiency of selection process, but also to set the basis for effective use of AI in crop improvement, and in the breeding, cultivation, and seed production of confectionary sunflower in particular.

Keywords: photogrammetry, computer vision, AI, sunflower

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Vegetable Crops, Novi Sad. VP has been supported by the Ministry of Science, Technological Development and Innovation (Contract No.451-03-65/2025-03/200156) and the Faculty of Technical Sciences, University of Novi Sad through project ‘‘Scientific and Artistic Research Work of Researchers in Teaching and Associate Positions at the Faculty of Technical Sciences, University of Novi Sad’’ (No. 01-3394/1).

THE CURRENT STATE OF BREEDING OF CONFECTIONERY SUNFLOWER IN RUSSIA

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ABSTRACT

In recent years, sunflower is grown in Russia on an area of about 10 million hectares, with a gross seed yield of 17 million tons and a yield of 1.7 t/ha. The share of hybrids is 83 and varieties - 17%. In 2024, confectionery sunflower was grown on 447 thousand hectares, i.e. on 6% of the total sown area. At the same time, confectionery varieties accounted for 95% of the area, while hybrids accounted for only 5%. The Krasnodar Territory is the main region of sunflower confectionery cultivation with a share of 34%. Confectionery varieties of VNIIMK breeding occupy 32% of the total area of sunflower confectionery in Russia. VNIIMK has created confectionery dark-seed varieties with resistance to the G race of broomrape, resistance to imidazolinones, tribenuron-methyl, as well as high oleic oil in seeds. Work on the breeding of confectionery hybrids is also being carried out in various directions.

Keywords: Confectionery sunflower, seeds, breeding, large seed, yield

SUNFLOWER SEED PRODUCING AND PROCESSING IN ROMANIA

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ABSTRACT

Sunflower crop has un important place in the word agriculture, due to many advantages: the capacity to release high seed yield and good oil content. Sunflower kernels are used in industry for obtaining good oil for human food as well as, the secondary matter used in animal food. After being obtained first sunflower hybrids with high oil content, area cultivated with sunflower crop has increased over the world, including our country, Romania. There have been obtained sunflower hybrids with low oil content and high protein content, these being used as confectionary sunflower. Romania has the largest area cultivated with sunflower in EU. Each year it is cultivated around 1 million hectares. Also, Romania is releasing the highest sunflower seed production in EU. In 2021 year, on 1.010 million hectares it has been obtained 3.16 million tones. Unfortunately, 60% of obtained seed is going to Export and only 40% is processed inside of the country. Sunflower (Helianthus annuus) oil is the major product of seed processing, that contributes 95% to the total value of the crop. The oil is mainly used as a salad oil and cooking but industrial applications include use as frying oil and manufacture of mayonnaise, margarine, shortening and other products. There are many oil factories which are producing oil with very high quality: good color, good smell, high nutritive value (90% unsaturated fatty acids), high stability, high capacity for long period of conservation. In the last years there have been developed the factories for producing sunflower crude oil, obtained by cold pressing method. Many of these are kind of family factories, but they are producing very healthy and high oil quality. In Romania there are cultivated some sunflower hybrids belonging to confectionery type, but not enough as the consumption is. People know the benefits of sunflower seeds referring to therapeutic and nutritive value (many vitamins and minerals), these being a valuable source of good protein. In Romania there are many small factories for dehulling, also for packing sunflower seeds. Much sunflower seed, confectionery type is imported from Bulgaria, Turkey or Spain.

Keywords: sunflower; oil producing; seed producing; seed processing

SHELF-LIFE STABILITY OF CONFECTIONERY SUNFLOWER SEED KERNEL (CSSK) BY GREEN SUSTAINABLE HIGH-PRESSURE PROCESSING (HPP) TECHNOLOGY

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ABSTRACT

Confectionery sunflower seed kernel (CSSK) are a cost-effective option for producing high-protein snack foods. It can be concluded that the natural environment and/or room temperature is not suitable for storing sunflower seeds. Regardless of the packaging, sunflower seeds can remain viable for 12 months in a dry refrigerator, refrigerator or freezer. CSSK products were prepared as traditional conditions and were stored up to 2 months in ambient conditions (25–30 °C; RH 40–60 %) packaged in low density polyethylene (LDPE) and laminated pouches as control groups (n=6). For the high-pressure treatment group, the CSSK product was immersed in pure water in a sealed LDPE container under high pressure of 200-350 MPa for 2-4 min.Then the HHP processed CSSK were dried at 45-50°C for 4-5 hours (n=6). HHP processed products have an integrity rate of ≥85.88%. It is stated that integrity rate = (dry weight of intact sunflower seeds after drying / dry weight of sunflower seeds before treatment) * 100%. A sunflower seed is considered whole if its external integrity is at least 4/5. This technology assessment can be performed manually and can be given the industry standard. Confectionery sunflower seed kernel (CSSK) treated current newly processing can be stored at room temperature for 12 month after being sealed in conventional packaging without producing any perceptible odor; and the sensory quality of CSSK was preserved with this applied green and sustainable HHP technology.

Keywords: Confectionery Sunflower Seed Kernel, CSSK, shelf life, high pressure processing, HHP, storage

CURRENT STIUATION OF CONFECTIONERY SUNFLOWER IN TURKEY

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ABSTRACT

Confectionery sunflower is an important sector in Turkey both for domestic use as primary snack and also export possibility to around Turkish neighbor countries which are one the most consuming countries. Normally, confectionery sunflower areas have been 70-80.000 ha and seed production 160-170,000 tons in the last ten years. However, with entering high yielding Chinese hybrids entering Turkish confectionery market, the first time in 2024 cultivated areas passed over 100,000, and with a significant increase of 30% in cultivation areas and 50% in seed production was observed in 2024. Türkiye 50-60% of confectionery sunflower cultivation, this production is concentrated in Central Anatolian provinces such as Ankara, Kayseri, and Konya. Yields vary greatly, ranging from 100 kg to 300 kg per decare, depending on irrigation possibilities. Local populations like OP İnegöl Alası which is the lack of homogeneity leads to both yield loss and quality problems during processing but its market share has been lowering year by year. Turkey imports $70-80 million worth of seeds annually from China to meet domestic demand and satisfy the consumer's preference for large, black-and-white striped seeds. These large-grained products from China have led to a decrease in demand for local white varieties. From the perspective of both producers and industrialists, the development of high-yielding and homogeneous domestic hybrid varieties with the physical characteristics (color, size) desired by the market stands out as an urgent need.

Keywords: Confectionery sunflower, Seed yield, Hybrids, Seed quality

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is a strategic agricultural product grown in Türkiye for both oil and snack purposes. Especially confectionery sunflower seeds, among other snacks like pumpkin seeds, peanuts, chickpeas, and hazelnuts, hold a significant place in the dietary habits of the Turkish people (Demir; 2021). Turkey is one of the leading producers of confectionery sunflower seeds worldwide, with the largest cultivation areas and the highest production volume in Europe. Confectionery sunflower seed production is mainly carried out in the Central and Eastern Anatolia, Southern Marmara, and Aegean regions, under both dry and irrigated farming conditions (Figure 1) (Sincik, Goksoy; 2014; Aldemir et al., 2016; Beser et al., 2020). In oil type production, hybrid seeds are fully using and are utilizing from modern mechanization techniques in almost process from planting to harvesting but with entering high yielding Chinese similar modern techniques also started in confectionery sunflower production as well (Yilmaz et al., 2020).

Turkish consumers generally prefer large-sized, white-colored sunflower seeds with gray stripes, while black-hulled varieties are more popular in Balkan countries (Kaya et al., 2025). Despite having a high processing capacity and a modern industry, local production is insufficient to meet domestic demand, leading to significant imports. The fundamental differences between oilseed and confectionery sunflower production, the introduction of new hybrid varieties to the market and their impact on local varieties, and issues such as harvesting

and storage policy recommendations and research and development (R&D) needs necessary for the sustainable growth of the sector was evaluated in the study.

On the other hand, in confectionery sunflower production, even though some hybrids are started to plant especially Chinese types in recent two years mostly open pollinated seeds are planting. Besides, especially harvesting mostly are performed by hands then it drying process of the seeds are laying at the grounds to reduce cracking seed rates (Evci et al., 2011). Therefore, this hand harvesting process increase the production costs as well as that it is one of the main reasons of not increasing of confectionery sunflower areas in Turkey. However, combine harvesting is started while planting hybrid seeds in confectionery sunflower production with arranging of combine harvester threshing drum and speed.

THE CURRENT SITUATION OF CONFECTIONERY SUNFLOWER IN TURKEY

In Türkiye, the production of sunflower seeds for snacking differs significantly from that of oilseed sunflowers. Oilseed sunflower production generally utilizes hybrid seeds and benefits from a high level of mechanization throughout the entire process, from planting to harvesting. In snack sunflower production, however, the cultivation of hybrid varieties, particularly those originating from China, has become widespread in recent years, significantly reducing the use of open-pollinated (OP) varieties. Harvesting processes constitute a significant cost item in snack sunflower production. A large portion of the harvest is still done manually, primarily to reduce seed cracking and obtain whole seeds. Manual harvesting increases labor costs and is one of the main obstacles to expanding snack sunflower cultivation areas. However, in recent years, with the planting of hybrid seeds, combined harvesting methods have also begun to be implemented by adjusting combine harvester settings (threshing drum and speed). Despite possessing a modern and high-capacity processing industry, Turkey does not have sufficient domestic production of snack sunflowers. This situation makes the country significantly dependent on imports. In particular, approximately 100 million USD worth of snack sunflower seeds are imported annually from China. These imported seeds are generally large, with white stripes and black kernels, which has gradually reduced the demand for white varieties in the local market.

In previous years, local populations such as İnegöl Alası were widely cultivated in Türkiye. However, these varieties led to problems such as low yields and loss of homogeneity in processing due to their non-homogeneous seed structure. In recent years, hybrid varieties of Chinese origin have come to the forefront in the Turkish snack sunflower market. These hybrids are preferred because of their high yield potential as well as their longer and larger seeds. The Thrace Agricultural Research Institute has been conducting snack sunflower breeding studies for the last 20 years. As a result of these studies, both open-pollinated (OP) and some hybrid varieties have been registered, but these varieties have not been able to remain in the market for a long time (Yilmaz et al., 2020). Some confectionery sunflower hybrids have also been registered by private companies (Table 1); however, recently registered varieties generally focus on long-seeded, gray-colored, and white-striped Chinese types (Kaya et al., 2025).

In Türkiye, snack sunflower cultivation areas do not follow a stable trend due to market instability, price fluctuations, and year-to-year varying yield rates. While cultivation areas have hovered around 100,000 hectares in the last 10 years, production has varied between 160-180 thousand metric tons. However, a significant increase of 30% in cultivation areas and 50% in seed production was observed in 2024. The inclusion of high-yielding Chinese type hybrids in local production has had a major impact on this increase (Table 2).

In 2024, the provinces with the most intensive snack sunflower cultivation were Konya, Kayseri, Aksaray, Sivas, Erzurum, Denizli, Kahramanmaraş, and Karaman (Table 3). Many promising hybrid varieties are currently undergoing registration trials, with some receiving

production approval and expected to be registered in the coming years. Additionally, several Chinese commercial hybrids, developed by Chinese or local seed companies, are also participating in registration trials.

Hybrid confectionery sunflower breeding studies has been started for 20 years in Trakya Agricultural Research Institute, Edirne Turkey and open pollinated ones as well as some hybrids were registered this public institute (Table 1). Furthermore, some confectionery hybrids were also registered by private companies but recent ones mostly focused on Chinese types as longer seeds grey color with white stripes. Since, the recent trend in the confectionery market in Turkey is Chinese type hybrids which have high yielding as well as longer and larger seeds (Beser et al., 2020).

Table 1. The registered confectionery sunflower cultivars in Turkey in last twenty years

Cultivar name	Type	Owner Institution	Registration date
Çiğdem 1	Open Pollinated	Trakya Agric. Res. Inst. Edirne	15.04.2008
Confeta CL	Hybrid IMI resistant	May-Agro Seed Co.	15.04.2010
Palancı 1	Hybrid	Trakya Agric. Res. Inst. Edirne	06.04.2011
İnegöl Alası	Open Pollinated	Uludağ University, Bursa	10.04.2013
09 TR Ç 004	Hybrid	Trakya Agric. Res. Inst. Edirne	09.04.2014
Çetinbey	Hybrid	Trakya Agric. Res. Inst. Edirne	31.03.2015
Avesa 2012	Hybrid	Trakya Agric. Res. Inst. Edirne	31.03.2015
Metinbey	Hybrid	Trakya Agric. Res. Inst. Edirne	13.04.2016
13 TRÇ 020	Hybrid	Trakya Agric. Res. Inst. Edirne	13.04.2016
Ahmetbey	Hybrid	Trakya Agric. Res. Inst. Edirne	13.04.2016
X 4237	Hybrid	Agrovizyon Seed Ltd. Co.	13.04.2016
X 4337	Hybrid	Agrovizyon Seed Ltd. Co.	13.04.2016
Ikon	Hybrid	Agrovizyon Seed Ltd. Co.	11.04.2017
Somun Beyazı	Hybrid	Trakya Agric. Res. Inst. Edirne	11.04.2017
Avesa Beyazı	Hybrid	Trakya Agric. Res. Inst. Edirne	11.04.2017
Muratbey	Hybrid	Trakya Agric. Res. Inst. Edirne	11.04.2017
Pasinler 6	Open Pollinated	Atatürk University, Erzurum	11.04.2017
Pasinler 2	Open Pollinated	Atatürk University, Erzurum	11.04.2017
Ege Güneşi	Open Pollinated	Ege Agric. Res. Inst. Izmir	08.04.2019
Belo	Open Pollinated	Günedoğan Ltd. Co.	30.04.2020
S400	Hybrid	Aybaklar Seed Co.	16.04.2021
S300	Hybrid	Aybaklar Seed Co.	16.04.2021
TG400	Hybrid	Trakya Genetik R&D Co	14.04.2023
STRIPY I	Hybrid	Agrovizyon Seed Ltd. Co.	14.04.2024
Guanr 10	Hybrid	Guanr Agriculture Ltd Co.	14.04.2024

Confectionery sunflower areas are not stable because of not having the steady market as well as having changeable prices and yields year by year. There is around 90.000 ha areas and 160-180.000 MT production in last 10 years. There is an increase both production and also seed yield in 2021 because high yielding Chinese type confectionery hybrids existed in local production in Turkey (Table 2). Denizli, Kayseri, K. Maraş, Aksaray, Bursa, Konya and Afyon are the most planted provinces (Table 3).

Table 2. Confectionery sunflower planted area, production and seed yield in Turkey

Year	Planted area (da)	Production (Ton)	Seed Yield (kg/da)
2007	689 778	84 407	122
2008	700 000	91 613	131
2009	690 000	96 825	140
2010	900 000	150 000	167
2011	997 000	165 000	165
2012	1 000 000	170 000	170
2013	895 239	143 000	160
2014	1 049 925	157 900	150
2015	1 163 224	180 700	155
2016	1 033 281	170 716	165
2017	982 241	164 385	167
2018	855 307	149 229	174
2019	766 484	150 000	196
2020	779 832	167 004	214
2021	898 415	200 000	223
2022	804 355	200 000	249
2023	879 373	238 000	277
2024	**1 184 779**	**340 000**	**287**

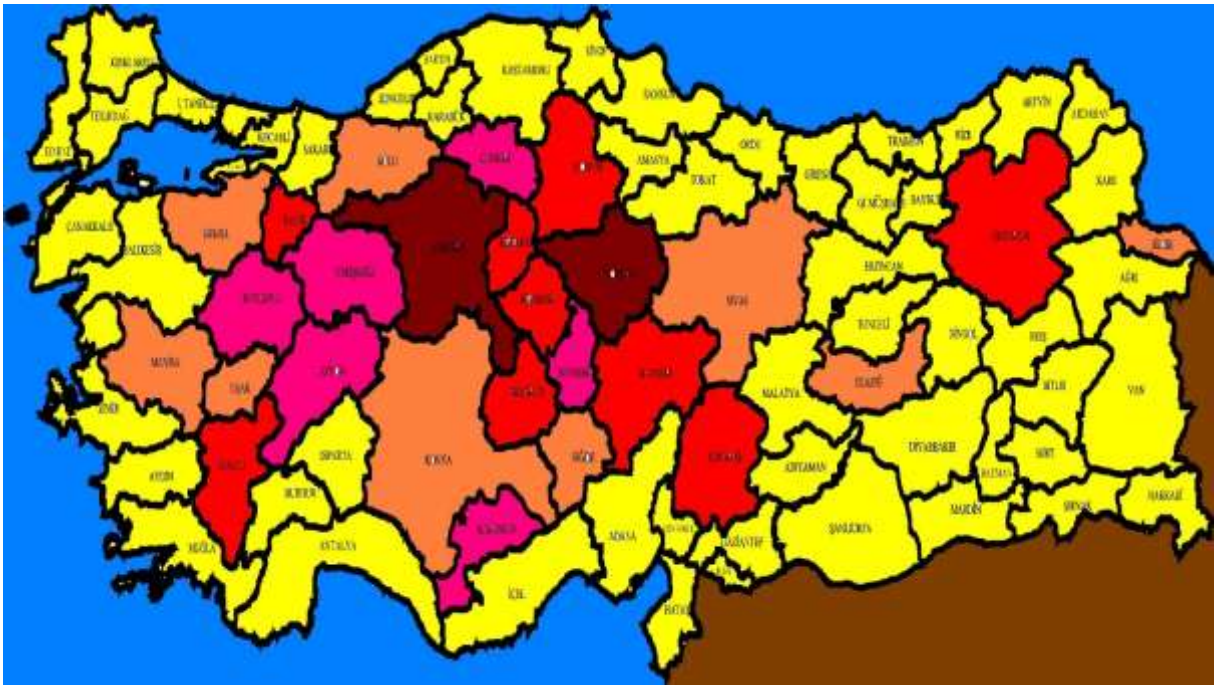

Figure 1. Confectionery sunflower areas in Turkey

Table 3. Confectionery sunflower by provinces in the recent years in Turkey

2021				2024			
Provinces	Planted Area	Production	Yield	Provinces	Planted Area	Yield	Production
Aksaray	94690	29756	314	Konya	247210	3090	76297
Kayseri	117243	29040	248	Kayseri	171254	357	60000
Denizli	137020	27452	200	Aksaray	161750	346	56035
Konya	81338	23878	295	Sivas	110972	198	21964
K.Maraş	66570	17993	270	Erzurum	72456	307	22215
Bursa	47890	15433	322	Denizli	67890	246	16725
Yozgat	66997	6302	94	K.Maraş	40695	291	11841
Afyon	31249	5321	184	Karaman	38591	187	7202
Eskişehir	17605	4467	254	Erzincan	30953	254	7870
Erzincan	17858	3874	244	Muş	29441	273	8023
Ankara	26018	3707	142	Bursa	27843	341	9503
Erzurum	19978	3395	188	Malatya	21804	324	7065
Muş	22514	3332	148	Eskişehir	20610	248	5120
Bilecik	19125	3250	170	A.karahisar	19203	235	4521
Kırıkkale	21521	3163	148	Yozgat	16162	119	1929
Sivas	23100	2976	129	Ağrı	14118	277	3916
Çorum	12915	2905	225	Ankara	13076	177	2320
Manisa	8920	2607	292	Kırşehir	12714	122	1548
Malatya	8350	2415	289	Sakarya	11043	192	2117
Sakarya	11140	2034	183	Bilecik	8280	186	1541
Kırşehir	14146	1878	133	Kırıkkale	8005	156	1246
Karaman	15468	1748	113	Manisa	7035	291	2048
Ağrı	2833	633	223	Uşak	6667	260	1733
Uşak	4350	537	123	Çorum	6214	238	1476
Kastamonu	1487	425	286	Çankırı	4200	121	510

Confectionery sunflower breeding is different characters from oil type and mostly focus on quality especially seed size but bigger seed sizes have higher husk contents also have some self-pollination problems (Velasco et al., 2014; Hladni et al., 2017; Sandrinelli et al., 2022; Vedmedeva et al., 2023; Latif et al., 2025). The efforts to develop of new high yielding confectionery hybrids continue both by public institutes and also private companies in Turkey (Pekcan et al., 2015; Kaya and Beşer. 2018). There are some promising Chinese commercial hybrids also in the registration trials in recent years by Chinese or local seed companies in Turkey. Turkey is one of the big markets for confectionery sunflower both for production and also consumption in the world (Hladni and Miladinović, 2019; Feng et al., 2022). Furthermore, Turkey exports much confectionery sunflower neighbor countries, Europe and North Africa because Turkey having because of modern and dynamic confectionery industry having higher capacity and potential., Chinese types have higher yielding potential so they were preferred by farmers also it increase rates in the production year by year. Local open pollinated types having white color with grey stripes market share is reducing year by year because of having the lower yielding, less mechanization use as well as less homogeneity.

There are several problems in Türkiye that negatively affect the productivity and quality of confectionery sunflower seed production:

Sale of Uncertified Seeds

The sale of uncertified hybrid seeds imported from China and known in the market under names such as 361, 363, or T-6 leads to significant problems. This situation causes deterioration in genetic purity, low germination rates, and consequently, yield losses. Institutions such as the Agricultural Molecular Diagnostics Laboratory of Trakya University play a role in identifying these problems by conducting genetic analyses of such seeds.

Germination and Emergence Problems

Sunflower seeds for snacking have a highly hygroscopic structure. This causes them to easily absorb moisture under unsuitable storage conditions, reducing their germination power. Another problem encountered during planting is soils that appear well-prepared but are very smooth and contain air pockets. Seeds planted in such soils cannot continue their growth process due to insufficient contact with the soil. To overcome this problem, the soil should be compacted with tools such as rollers after planting.

Figure 2. Germination tests for confectionery sunflower

Recommendations for High Seed Yield: Early planting is of great importance for obtaining high seed yield. It is recommended to prepare the seedbed and plant as soon as the soil is ready for planting after March. In this way, the plants can complete the seed filling period under more favorable conditions, avoiding the high temperature stress of July and August. For example, planting in the first week of April ensures that sunflowers flower in the first week of June, allowing them to complete seed filling by the end of June or the beginning of July.

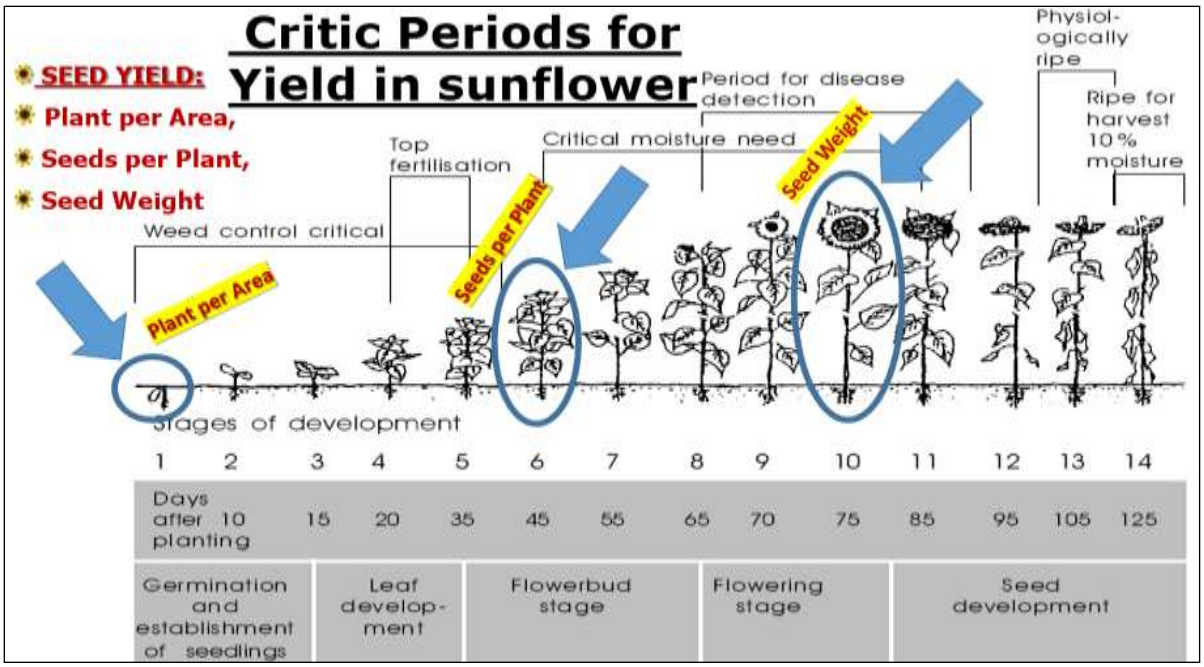

Figure 3. Critical periods for confectionery sunflower production

Broomrape Problem

Broomrape (Orobanche spp.) is one of the most serious and widespread problems in snack sunflower production in Türkiye. Unfortunately, there are no broomrape-resistant snack sunflower varieties on the Turkish market. However, the development of IMI (imidazolinone)-resistant snack hybrids offers significant potential in solving this problem.

Figure 4. Broomrape problem in confectionery sunflower production areas in Turkey

Harvesting Challenges with Combine Harvesters

Sunflower seeds for snacking are generally harvested by hand, as is the case in China, to prevent seed cracking and obtain whole seeds. This increases labor costs and necessitates spreading the seeds out in the fields for drying after harvesting. However, recently developed new Chinese hybrids have become suitable for combined harvesting by optimizing combine harvester settings (counter-rotation/thresher speed and front table adjustments), allowing for a

reduction in harvesting costs. Storage Problems: Despite their thick hull structure, sunflower seeds for snacking easily absorb moisture from the environment during storage, rapidly losing their freshness and uality. Therefore, proper drying of the seeds after harvesting and ensuring suitable storage conditions are of great importance.

Figure 5. Harvesting confectionery sunflower areas in Turkey

CONCLUSIONS

Turkey has great potential in the global sunflower seed market, both in terms of production and consumption. Thanks to its modern and dynamic sunflower seed industry, the country exports significant amounts of sunflower seeds to neighboring countries, Europe, and North Africa. Recently, the import of Chinese varieties and their integration into local production has met the demand for longer, larger, and tastier seeds. These Chinese hybrids are also preferred by farmers due to their high yield potential, and their share in production is increasing every year. Local open-pollinated (OP) varieties with white and gray stripes, which previously dominated the market, are losing market share due to low yields and lack of homogeneity. Unfortunately, new local sunflower seed hybrids developed by state institutions are not sufficiently preferred by the sunflower seed industry because they do not have larger and longer seeds. This situation shows that local breeding efforts need to develop varieties that are more suitable to market demands.

The Turkish confectionery sunflower market has great potential thanks to its geographical location and highly developed confectionery industry. The country exports various snacks to neighboring countries, the Middle East, Europe, and North Africa every year. Adopting high-yielding varieties and new product management techniques is the fundamental solution to ensure the development of the sector and producers. In conclusion, new R&D policies and government support are needed to achieve a better situation in snack sunflower production. There is an urgent need for high-yielding and homogeneous hybrid varieties for producers, industrialists, and consumers alike. Nevertheless, promising programs exist in snack sunflower breeding.

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DEVELOPPING HYBRIDS AND LINES FOR HIGH QUALITY AND DESIRED TRAITS IN CONFECTIONERY SUNFLOWER IN TURKEY

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ABSTRACT

Turkey is one of the biggest confectionery sunflower producer countries in the world and has the largest planted areas and production in Europe. Turkish confectionery sunflower production areas are mostly located in Middle Anatolia, as well as in South Marmara and Denizli and Kahramanmaraş provinces. Turkish people used to prefer confectionery sunflower with bigger sizes, white color with grey stripes, or the white color type consumed in the shell. But this has changed in the last decades. Now, Chinese-type brown, black, big kernel size confectionery sunflower is leading the market. With the changing demand regarding quality, confectionery sunflower breeding programs in Turkey have also changed their selection criteria. Breeding programs aim to develop varieties with large black-brown seeds, short plant height, high-yielding as well as being resistant to IMI herbicides, broomrape and downy mildew. Turkey import big quantity seed and crop of confectionary sunflower, so that there is need to improve local varieties for accepted new quality types. This study examines these ongoing efforts.

1. INTRODUCTION

Sunflower (*Helianthus annuus* L.) is primarily cultivated as an oil crop. However, it is also economically cultivated over large areas for confectionery use, as well as for birdseed and as an ornamental plant. In Turkey, it is generally grown as an oil crop. Besides, confectionery sunflower is planted in an area corresponding to about 15% of the oilseed sunflower acreage. Confectionery sunflower is the most consumed snack in Turkey. Other important snacks can be listed as pumpkin seed, peanut, pistachio, chickpea, and hazelnut (Beşer et al., 2020). Turkey is one of the biggest confectionery sunflower producer countries in the world and has the largest planted areas and production in Europe. Turkish confectionery sunflower production areas are mostly located in Central Anatolia, as well as in South Marmara and Denizli and Kahramanmaraş provinces (Kaya et al., 2013; Kaya and Beşer 2018, Beşer et al., 2020).

Confectionery sunflower has significant economic value in Turkey, not only for the domestic market but also for export. Turkey has highly developed and large-capacity confectionery sunflower processing facilities, therefore it also exports processed snacks to the world. Although Turkey has approximately 100,000 hectares of confectionery sunflower cultivation area, it imports about 100,000 USD worth of confectionery sunflower from China every year. The reason for this is the highly dynamic confectionery sunflower market and the high volume of exports. Turkish people used to prefer confectionery sunflower with bigger sizes, white color with grey stripes, or the white color type consumed in the shell. But this has changed in the last decades. Now, Chinese-type brown, black, big kernel size confectionery sunflower is leading the market. The Chinese '361' confectionery sunflower variety is leading the market. Some varieties like 363, 601, T5, and T6, etc., are also marketed under different names by different companies in Turkey. Even in the market, farmers and the industry have

started using Chinese quality standards, such as the number of seeds in 50 grams becoming an important quality criterion. In the past, breeding of striped white and white types was important, and registered varieties were generally of this type. However, in the last decade, the demand for Chinese-type brown-black, large kernel size has increased, and as a result, breeding programs have started focusing on these types.

Confectionery sunflower breeding programs in Turkey, considering changing domestic and foreign demands, have shifted towards developing Chinese-type quality, large black-type sunflowers. Additionally, developing broomrape (*Orobanche* spp.) resistance and imidazolinone-tolerant varieties has become important. On the other hand, Downy mildew and Rhizopus have become problems in some areas. Current objectives for confectionery sunflower breeding programs are: Chinese-type black-brown (like 361) confectionery F_1 sunflower variety, branched restorer lines, short CMS and B lines, Orobanche resistant cultivars and lines, Downy Mildew (*Plasmopara halstedii*) resistant cultivars and lines, Root and stalk disease resistant cultivars and lines, early cultivars and lines, high-yielding F_1 varieties, varieties suitable for machine harvesting. The white type sunflower market is decreasing, but there is still a need for local consumption and also for export to some countries.

Confectionery sunflower breeding efforts started at the Trakya Agricultural Research Institute about 30 years ago and were followed by the Aegean Agricultural Research Institute and later two more public institutes. As mentioned before, local populations were used at the beginning, and they had significant selfing problems for improving CMS and restorer lines. Later, some private companies brought varieties from Israel and the USA and registered them, but their quality was not widely accepted in the market. After the registration of Chinese-type varieties, more private companies entered variety registration, some of them from the snack industry. Now, 4 governmental institutes and a few numbers of private companies have confectionary sunflower breeding activities. One of them is our company established at Trakya Technopark in Trakya University.

Before 2020, registered confectionery sunflower varieties were developed from local material. After 2020, Chinese-type varieties started to be registered; examples include S300, S400, TG400, G1, Guanr1, Guanr 10, and Strpy. Among these, the TG400 variety is a high-quality black Chinese-type variety developed by us. However, because its restorer line is unbranched, there are difficulties in seed production. Most Chinese varieties have unbranched restorer lines, but they can produce large quantities of seed by manual cross-pollination. The necessity to develop confectionery sunflower varieties suitable for changing domestic and foreign demands and compete with Chinese varieties has emerged.

2. MATERIALS AND METHODS

In this study, material brought from abroad, local material, and segregating material obtained their cross constituted the material of this work. In the study, high-yield and quality hybrids brought from China were crossed with local material, and backcrosses were performed when necessary. The pedigree selection method was used in selection. Crosses were made to develop A, B and restorer lines (Fig 1), in addition to the large black seed, selection was made for the traits given below. Selection for seed shape and color were made at field and laboratory During selection, laboratory selection for downy mildew and broomrape was performed in winter nurseries, and field observations were also made (Fig 2). Selection for seed shape and color were done at field and laboratory (Figure 3).

Selection goals in confectionery sunflower breeding program:

a-High yield
b- medium and short height
c- *Orobanche* resistance
d- Imidazolinone tolerance
e- Earliness
f- Branched restorer lines
g- Root and stalk disease resistance
h- Downy mildew and other disease resistance.

Figure 1. Crossing and selection studies in confectionery sunflower

Figure 2. Selection for downymildew and broomrape

Figure 3. Selection for kernel type in confectionary sunflower

3. RESULTS AND DISCUSSION

Confectionery sunflower breeding studies continue at the Agricultural Research Institutesof Ministry of Agriculture and Forestry. In the studies conducted at Trakya Genetics, R&D, Consultancy, Production, Import, Export and Marketing Company Ltd., operating within Trakya Technopark at Trakya University, one Chinese-type large black-seeded variety has been registered, and yield trials of new candidate varieties are ongoing. The list of material obtained as of the end of 2024 is given below.

3.1.Studies to improve Imidazolinone-tolerant confectionary sunflower restorer material

As a result of restorer line improved studies one restorer line registered, and materials given below have been improved (Table 1).

Table 1. List of restorer material improved

Generation	**Number of line/population**
Homozygot R lines	44
IMI TG-400 BC_5F_1 R	89
IMI TG-400 BC_3F_2 R	44
IMI TG-400 K_2F_3 R	35
IMI TG-400 BC_1F_4	13
IMI TG-401 BC_3F_1 R	53
IMI TG-401 BC_2F_2 R	23
IMI TG-401 BC_3F_1 R	37
TG-402 BC_2F_3	8
IMI TG-401 BC_2F_2	6
IMI TG-401 BC_1F_4	4
IMI F_6	27
IMI F_8	7
IMI F_3	44
IMI F_9	7
F_6	34
F_9	43

3.2. Studies to improve Imidazolinone-tolerant confectionary sunflower A and B material

As a result of A and B line improved studies one restorer line registered, and materials given below have been improved (Table 2).

Table 2. List of A and B line improved

Generation	**Number of line/population**
F_3 B Air	10
TG 400 X İMİ TG400 F6 B	4
TG 400 X İMİ TG400 F10 B	12
TG 401 X İMİ TG401 F_1 B	10
IMI TG400 BC_5F_1 B	20
IMI TG400 BC_4F_2 B	195
IMI TG400 BC_3F_2 B	155
IMI TG400 BC_2F_4 B	94
IMI TG400 BC_1F_5 B	30
IMI TG401 BC_2F_1 B	13
IMI TG402 BC_2F_1 B	17
IMI TG402BC_2 F_3 B	18
IMI TG402 BC_1F_4 B	16
F_4 B	85
F_8 B	10
F_{10} B	11
F_{11} B	22

3.3. Test hybrid studies

Five IMI CMS lines obtained from the Trakya Agricultural Research Institute and the inbreed IMI restorer lines developed by our company were planted, and test hybrids were made with among them. Furthermore, the TG 400 CMS and TG 401 CMS lines, which were previously developed with backcrossing studies to confer IMI herbicide resistance, were also planted for making test hybrids, and test hybrids were made with IMI confectionery R lines.

3.4. Quality Analyses

Selections have been made for quality characters in the field and after harvest at the laboratory in segregation and inbreed material

3.5. Phytotoxicity Tests

IMI group herbicides were applied for selection IMI tolerant plants during breeding studies. In the breeding studies, phytotoxicity was checked by applying IMI group herbicides at 125 gr/da and double that amount to inbreed lines and hybrids.

3.6. Preliminary Yield Trial

A total of 20 varieties, consisting of test hybrids made in 2023 and 3 IMI confectionery control hybrids, were used to establish two regional yield trials in Edirne and Tekirdağ in 2024. In these trials, both phenotypic characteristics and post-harvest yield and quality characteristics are being examined. IMI herbicides were applied to plants at the 6-8 leaf stage for IMI phytotoxicity tests.

CONCLUSION

In the last decade, quality criteria for confectionery sunflower in Turkey have changed for both domestic consumption and export. Especially Chinese-type confectionery sunflower with large, black-brown seed color has dominated the market. For this type of sunflower, approximately 100 million USD is spent on imports, both as seed and as product. There is a need to improve domestic varieties to compete important ones.

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