OKU Fen Bilimleri Enstitüsü Dergisi
5(3): 1744-1752, 2022

OKU Journal of The Institute of Science and Technology, 5(3): 1744-1752, 2022

Osmaniye Korkut Ata Üniversitesi Fen Bilimleri Enstitüsü Dergisi

Osmaniye Korkut Ata University Journal of The Institute of Science and Technology

Susam (*Sesamum indicum* L.) Genotiplerinin Siirt Ekolojik Koşullarına Adaptasyonunun Belirlenmesi

Aynur BİLMEZ ÖZÇINAR[1*]

[1]Siirt Üniversitesi Ziraat Fakültesi Tarla Bitkileri Bölümü Endüstri Bitkileri Anabilim Dalı, Siirt

[1]https://orcid.org/0000-0002-3173-6147
*Sorumlu yazar: aynurbilmez@siirt.edu.tr

Araştırma Makalesi

Makale Tarihçesi:
Geliş tarihi: 22.04.2022
Kabul tarihi:12.09.2022
Online Yayınlanma: 12.12.2022

Anahtar Kelimeler:
Susam
Sesamum indicum L.,
Genotip
Adaptasyon
Ekoloji

ÖZ

Yağlı tohum bitkisi olan susam, ağırlıklı olarak dünyanın tropikal ve subtropikal bölgelerinde yetiştirilmektedir. Bitki tohumları %42-54 oranında kaliteli yağ, %22-25 protein ve %20-25 karbonhidrat içerir. Yüksek miktarda besin bileşeni içeren susam tohumları, spesifik antioksidan aktivitesi nedeniyle geleneksel bir sağlık gıdası olarak tüketilmektedir.Türkiye'nin Güneydoğu Anadolu Bölgesi'nde karasal iklimin hüküm sürdüğü Siirt'te çimlenme tarihi, vejetasyon dönemi, ilk çiçeklenme zamanı, son çiçeklenme zamanı, bitki boyu, ilk dal yüksekliği, dal sayısı, bitki başına düşen kapsül sayısı ve verim açısından yüksek performans gösteren toplam 23 farklı susam genotipinden en iyi genotipi seçmek amacıyla bir araştırma yapılmıştır. Çalışma sonucunda, çalışmada gözlenen parametreler için genotipler arasında önemli farklılıklar tespit edilmiştir. Bitki boyu, ilk dal boyu, dal sayısı, bitkideki kapsül sayısı, kapsüldeki tohum sayısı sırasıyla, 80,8-115,9 cm arasında; 5,9-18,3 cm; 3,1-8,5 adet; 65,6-154,2 adet; 62,8-135,2 adet olmuştur. Tohum verim değerleri SUS10 ve SUS1 genotiplerinde sırasıyla en düşük (38,2 kg/da) ve en yüksek (97,4 kg/da) olmuştur.Sonuç olarak, SUS1 genotipi Siirt koşullarına iyi uyum sağlamıştır. Sonuç olarak, bazı susam çeşitlerinin Siirt ekolojik koşullarında verimli şekilde yetiştirilebileceği belirlenmiştir.

Determination of Adaptability of Sesame (*Sesamum Indicum* L.) Genotypes in Siirt Ecological Conditions

Research Article

Article History:
Received: 22.04.2022
Accepted: 12.09.2022
Published online: 12.12.2022

Keywords:
Sesame
*Sesamum indicum*L.
Genotype
Adaptation
Ecology

ABSTRACT

Oilseed crop sesame is mainly grown in tropical and subtropical parts of the world. Plants seeds contain 42-54% quality oil, 22-25% protein and 20-25% carbohydrates. Sesame seeds with high amounts of nutritional components are consumed as a traditional health food for its specific antioxidative activity. A research was carried out at in South Eastern Anatolia Region of Turkey in Siirt where continental climate prevails, with the aim to select the best genotypes from a total of 23 different sesame genotypes showing high performance in terms of germination date, vegetation period, the first flowering time, the last flowering time, plant height, first branch height, number of branches, number of capsules per plant and yield.

As a result of the study, significant variations were determined between genotypes for the observed parameters in the study. Plant height, first branch height, branches number, capsules number per plant, seed number per capsule were between 80,8-115,9 cm; 5,9-18,3 cm; 3,1-8,5 pieces; 65,6-154,2 pieces; 62,8-135,2 pieces, respectively. The seed yield values were lowest (38,2 kgda^{-1}) and highest (97,4 kg/da) at SUS10 and SUS1 genotypes, respectively. As a conclusion, SUS1 genotype fit well to Siirt conditions. As a result, it was determined that some sesame varieties can be cropped under Siirt ecological conditions with good yield levels.

To Cite: Özçınar AB. Determination of Adaptability of Sesame (*Sesamum Indicum* L.) Genotypes in Siirt Ecological Conditions. Osmaniye Korkut Ata Üniversitesi Fen Bilimleri Enstitüsü Dergisi 2022; 5(3): 1744-1752.

1.Introduction

Sesame (*Sesamum indicum* L.) is an old oil seed crop that has been produced in Asia and Africa for over 7.500 years, even in arid environments (Langham et al., 2010). This dicotyledonous oil seed crop is mainly grown in tropical and subtropical parts of the world for its oils and proteins. Sesame crop is grown for dry seeds for food; leaves and young branches for feed and diversified parts of the plant for the treatment of several diseases (Pusadkar et al., 2015). Main form for utilization of sesame seeds is roasting seeds, which provides nutrients to diets (Makinde & Akinoso, 2014). Vegetable oils are essential part of human diet for their health beneficial roles. Instead, fatty acid profile of most edible oil seed crops are imbalanced (Bhunia et al., 2016). Sesame seeds contains 42-54% quality oil, 22-25% protein, 20-25% carbohydrates and 4-6% ash. This composition varies with genetic and environmental factors (Akinoso et al., 2010).

Sesame seeds, which contain a significant number of essential components, have long been used as a traditional health food due to their antioxidative properties (Yokota et al., 2007). Sesame seeds have a high oil content and are of high quality. Saturated fatty acids, unsaturated fatty acids, proteins, and antioxidants in its seeds are very appealing, resulting in increased seed consumption (Zhang et al., 2019). Sesame fat is important in the food business because of its flavor and stability, as well as its high-quality cooking value. Sesamin and sesaminol lignans found in sesame oil's nonglycerol fraction contributed to the oil's oxidative stability and antioxidative activity (Wu, 2007). Because of the high amounts of oil, proteins, vitamins, carbs, fiber, and antioxidants in sesame seed, it has a wide range of applications in the food, cosmetics, and pharmaceutical industries (Amoo et al. 2017).

This crop is widely grown in arid and semi-arid regions of the world for its high quality edible oil (Eskandari et al., 2009). Sesame, the main source of "queen oil," can set seed and yield astonishingly well in hot weather, and it has a deep taproot system for absorbing moisture and nutrients from lower soil layers, allowing it to thrive with as little as 200–400 mm of rain during the growing season (Bedigian, 2010). Because of their sessile nature, plants are substantially hampered in their development and output by a variety of environmental conditions such as drought, waterlogging, or high salinity (You et al., 2018). Sesame is an essential oilseed crop, but its growth and productivity are severely hampered by abiotic stressors (You et al., 2018). One of the limiting variables impacting its global development and production is its sensitivity to drought at the seedling stage (Mehmood et al., 2022). Sesame has a wide range of root morphological and anatomical characteristics, and a high root biomass boosts the plant's aboveground biomass and seed output (Su et al., 2019). Sesame yields are reduced by waterlogging stress. The shortage of oxygen accessible to submerged tissues is a significant cause of waterlogging stress (Wang et al., 2012). The crop is commonly grown on marginal terrain and is subjected to a range of challenges. However, there have been few attempts to generate sesame cultivars that are more resistant to abiotic stressors and provide higher yields. The crop is drought tolerant because to its vast root system, but it may suffer significant yield losses when exposed to other environmental challenges such as waterlogging, salinity, heavy metals, and chilling stress. Despite a substantial collection of germplasm, few research initiatives using conventional and biotechnology approaches have resulted in negligible progress in sesame crop sustainability (Islam et al., 2016).

There are indeterminate and determinate growth characteristics in sesame cultivars. Sesame's indeterminate growth habit and seed shattering at maturity resulted in a plant architecture that was poorly adapted to modern farming techniques (Cagirgan, 2006). Sesame flowering lasts a long period due to its indeterminate growth behavior, and this heterogeneous capsule maturation creates harvesting issues and yield losses. Sesame cultivars with superior crop structure and a more consistent habit could aid yield improvement efforts. Early senescence and vulnerability to biotic and abiotic stressors have a detrimental impact on sesame yield potential (Rao et al. 2002).

In 2020, the world’s total harvested area of sesame was 13.96 million hectare (ha), with an annual production of 6.80 million tons. Sudan was the largest producer, with a sesame production of (1.53 million tons), followed by Myanmar (0.74 million tons), Tanzania (0.71 million tons) and India (0.66 million tons) (FAO, 2022).

It is insufficient in terms of production of oilseed plants in Turkey. Compared to sesame producing countries, sesame yield is insufficientand the local oil sufficiency produced is still not sufficient. This study was carried out at in South Eastern Anatolia Region of Turkey in Siirt to select the best of 23 different sesame genotypes showing high performance.

2. Material and Method

The study was carried out in the field crops experiment area of the Faculty of Agriculture of Siirt University in 2016. Total 23 different sesame genotypes, were used in the study. The seeds were local populations, which were obtained from local farmers from different regions of Turkey (Aegean, Mediterranean and Southeast Anatolian regions). The seeds were light brown, brown and dark brown in color. The genotypes used in the study were established according to the randomized complete blocks experimental design. Genotypes were obtained from the material collected within the scope of the project supported by Dicle University Scientific Research Projects Coordinatorship (DUBAP). Row length was 6 m, interrow spacing was 70 cm, and intrarow spacing was 15 cm. Study was conducted by randomized complete block design with three replications. Under the second crop conditions, following the wheat harvest, sowings was carried out manually by hand. Complete emergences were achieved approximately one week after plantings. After the plant emergence stage, intrarow plant populations were reduced to homogenous distances. Twice hoeing was conducted.

Since no diseases, pests and weeds were observed as a result of hoeing, pesticide spraying was not applied.

The soil samples were collected from the depth of 0–30 cm and 30-60 cm at the research area before experimentation and analysis in the laboratory following the standard protocols. The soil was high in clay, slightly alkaline, non-saline, medium-level calcareous. Some physical and chemical properties of the soil are given in Table 1.

Table 1. Some physical and chemical properties of the experimental field soil

Soil Properties	**Soil Layer (cm)**	
	0-30	**30-60**
Texture	Clay	Clay
Clay(%)	57.12	55.12
Silt(%)	22.0	16.0
Sand(%)	20.88	28.88
Fieldcapacity(FC)	33.52	36.04
Wiltingpoint(Pw)	24.44	26.08
Bulkdensity(gcm^{-3})	1.42	1.39
pH(1:2.5s/w)	7.50	7.66
Electricalconductivity(dSm^{-1})	1.55	1.77

Considering the soil analysis, diammonium phosphate and urea fertilizer were applied to each plot homogeneously, with calculation of 8 $kgda^{-1}$ of phosphorus and 4 $kgda^{-1}$ of nitrogen over the pure substance by Arslan and Gür (2018).

The climate data throughout the study period and long term are presented in Table 2.

The study area is under a continental climate which is characterized by cold and rainy/snowy winters, and hot and dry summers. Long term average temperature of the region in summer is 26 ºC and 2.7 ºC in winter (MGM, 2022). The maximum and minimum relative humidiies are 50,9% and 32.7% in May and July. Long term annual precipitation is 669.2 mm, and monthly precipitation ranges from 103,6 mm to 1.3 mm (Table 2).

Table 2. Climatic data for 2016 and 2017 years and long-term average (1962-2015)

Years	**Months**	**Min Temp, (°C)**	**Temp, (°C)**	**Max Temp, (°C)**	**Humidity (%)**	**WindSpeed ($m s^{-1}$)**	**Daily Sunshine (h)**	**Total precipitation (mm)**
Average of 1962-2015 (Long years)	May	25.2	19.4	9.0	49.3	1.0	9.1	36.9
	June	27.2	26.0	17.8	34.9	1.1	11.6	11.5
	July	35.1	30.5	23.4	30.3	1.1	12.3	0.6
	August	34.5	30.3	27.0	29.5	1.0	11.4	2.7
	September	30.0	25.1	14.7	37.4	1.0	10.1	7.0
	October	24.5	17.9	12.7	42.0	1.0	7.2	50.9
2016	May	26.62	19.29	14.52	50.9	1.0	8.7	39.6
	June	26.09	28.16	20.0	35.5	1.1	11.5	10.6
	July	34.13	31.45	24.35	32.7	1.0	12.4	0.1
	August	33.92	31.19	24.23	32.9	1.0	11.3	0.4
	September	31.23	25.43	21.5	39.9	1.1	10.0	9.2
	October	24.3	16.8	11.5	42.3	1.1	7.0	55.1

Before harvesting, 0,5 m was removed from the beginning and end of the rows in each plot and the middle two rows were harvested. Harvesting was conducted manually by cutting the stems of the plants close to the ground with pruning shears.

The obtained data were analyzed according to the randomised complete blocks design by Jump Statistics Program.

3. Results and Discussion

In the sesame genotypes evaluated under the conditions of Siirt province, there were statistically significant variations in branch number and seed yield characteristics. With the analysis, it was determined that there was a 5% significant difference in terms of branch number and seed yield among the characteristics examined in the genotypes (Table 3).

Table 3. Analysis table of the data optained in the study

Genotype	Plant Height (cm)	First branch height (cm)	Branches number (pieces/plant)	Capsules number per plant (pieces/plant)	Seed number per capsule (pieces/plant)	Seed yield (kgda^{-1})
SUS 1	89.6	8.6	3.1 r	131.1	74.8	97.4 a
SUS 10	91.6	5.9	8.5 a	119.4	62.8	38.2 ı
SUS 11	102.4	8.1	6.6 f	80.7	63.7	44.3 fghı
SUS 12	114.0	9.2	5.3 m	120.0	68.8	72.4 b
SUS 13	99.8	7.4	6.2 h	114.7	70.8	61.9 c
SUS 14	96.3	8.5	5.6 k	78.6	126.4	42.8 ghı
SUS 15	95.8	7.4	7.6 d	147.5	65.2	43.2 ghı
SUS 17	110.6	10.5	3.7 q	72.4	67.2	45.5 fgh
SUS 19	115.9	17.1	4.7 n	106.4	72.4	64.7 c
SUS 2	99.0	9.4	5.7 j	101.3	72.0	50.9 ef
SUS 20	104.0	18.3	6.0 ı	85.3	77.2	44.8 fghı
SUS 21	105.0	10.5	7.9 b	154.2	72.0	43.2 ghı
SUS 22	107.0	11.4	6.3 g	106.6	67.6	50.8 ef
SUS 23	93.2	15.0	4.6 o	80.4	82.0	55.1 de
SUS 24	111.1	12.8	5.7 j	97.8	72.8	74.6 b
SUS 25	97.6	15.7	5.5 l	65.6	74.0	43.8 ghı
SUS 26	115.9	11.2	6.6 f	103.2	135.2	40.8 ghı
SUS 27	103.5	12.6	7.1 e	92.2	126.4	78.9 b
SUS 3	106.3	16.0	7.8 c	108.7	78.0	39.9 hı
SUS 4	113.0	7.5	7.8 c	143.5	64.8	61.3 cd
SUS 6	87.8	7.9	6.0 ı	96.0	64.9	46.7 fg
SUS 7	80,8	8.7	3.7 q	67.9	72.4	44.1 ghı
SUS 8	90,4	7.2	4.5 p	84.2	97.8	42.9 ghı
Mean	**101.33**	**10.73**	**5.93**	**102.51**	**79.53**	**53.40**
LSD genotype	**12**	**11.5**	*** 9**	**7**	**7.5**	*** 12.5**

*; P < 0.05

Plant height of sesame genotypes were between 80,8-115,9 cm (Table 3). In the study of Teklu et al., (2014), in which total 32 accessions were tested for crop performance in Ethiopia, plant heights were ranged between 71-147 cm which were higher than our study probably due to environmental and genotypic differences.

First branch height of sesame genotypes were between 5,9-18,3 cm (Table 3). The height to the first capsule is also an important trait for mechanical harvest in sesame production (Van Zanten 2001; Langham et al. 2002). Similar to this study, in their study, Arslan et al., (2018) was determined the first branch height of varieties between 3,7-13,0 cm in the first year and 2,9-9,9 cm in the second year in their experiments.

Branches number of sesame genotypes were lowest (3,1 pieces) at genotype "SUS 1" and (8,5 pieces) at genotype "SUS 10" (Table 3). Ozkan et al., (2012) determined the branch number per plant between 4.2 to 9.4 pieces in their study, similar to this study.

Capsules number per plant of sesame genotypes were between 65,6-154,2 pieces (Table 3). In the study of Teklu et al., (2014), in which total 32 accessions were tested for crop performance in Ethiopia, capsule numbers were between 11-76 pieces, which were lower than our study, probably due to environmental and genotypic differences. Naim et al., (2010) 59,5-185 pieces in their study, similar to this study.

Seed number per capsule of sesame genotypes were between 62,8-135,2 pieces (Table 3).

Seed yield of sesame genotypes were lowest (38,2 kgda^{-1}) at genotype "SUS 10" and highest (97,4 kgda^{-1}) at genotype "SUS 1" (Table 3). Varieties with high yield potential can subsequently be combined with improvements of other traits (Ozcinar and Sogut, 2017). In the study of Teklu et al., (2014), in which total 32 accessions were tested for crop performance in Ethiopia, seed yields were between 23-129 kgda^{-1}, Şimşek et al., (2003) 160,5-115,3 kg da^{-1}, Gerçek et al., (2004) 173,2 kg da^{-1}, Eskandari et al., (2009) 58,82-146,42 kg da^{-1},Naim et al., (2010) 89-97,5 kg da^{-1}, Nadeem et al., (2015) 74,23 kg da^{-1}, Anğın and Çatalkaya (2019) 112-192 kg da^{-1}which are similar to our study. Branch number was negatively effected the seed yield where highest yield was obtained under lowest branch number and vice versa.

Among the genotypes, the Sus10 genotype shows the most branching feature, while the Sus1 genotype shows the least branching feature. However, in terms of yield, Sus1 genotype had the highest yield and sus10 genotype had the lowest yield. Thus, it is seen that the yield decreases as the branching increases.

4. Conclusions

Significant variations were determined between genotypes for the observed parameters in the study. Generally, most of the genotypes were significantly different from each other for the seed yield. The seed yield values were lowest (38,2 kg/da) and highest (97,4 kg/da) at SUS10 and SUS1 genotypes, respectively. The differences between the genotypes might be due to the inherent genetic potential differences of the genotypes and appeared phenotype in tested environments. As a conclusion, SUS1 genotype fit well to Siirt conditions.

Conflict of Interest Statement

The article author declares that there is no conflict of interest.

Contribution Rate Statement Summary of Researchers

The author declares that she has contributed 100% to the article.

References

Akinoso R., Aboaba SA., Olayanju TMA. Effects of moisture content and heat treatment on peroxide value and oxidative stability of un-refined sesame oil. African Journal of Food, Agriculture, Nutrition and Development 2010; 10(10): 4124-4138.

Amoo S., Okorogbona A., Du Plooy C., Venter S. *Sesamum indicum*. Medicinal spices and vegetables from Africa. Elsevier, Amsterdam 2017; 549–579.

Anğın N., Çatalkaya V. Çukurova koşullarında 2. ürün susamın farklı gelişim dönemlerinde yapılan sulamaların verim ve yağ kalitesine etkileri. Mustafa Kemal Üniversitesi Tarım Bilimleri Dergisi 2019; 24; 112-119.

Arslan H., Gür MA. Effects of phosphorus and nitrogen aplication on sesame (*Sesamum indicum* L.) yield in semi-arid climatic conditions. İnternational Journal of Scientific and Technolojical Research 2018; 4(4): 483-489.

Arslan H., Ekin Z., Hatipoglu H. Performances of sesame genotypes (*Sesamum indicum* L.) with different seed shell colors in semi-arid climate conditions. Fresenius Environmental Bulletin 2018; 7: 8139-8146.

Bedigian D. Sesame: The Genus *Sesamum*, CRC Press, Boca Raton, FL2010.USA.

Bhunia RK., Kaur R., Maiti MK. Metabolic engineering of fatty acid biosynthetic pathway in sesame (*Sesamum indicum* L.): assembling tools to develop nutritionally desirable sesame seed oil. Phytochemistry Reviews 2016; 15(5): 799-811.

Cagirgan MI. Selection and morphological characterization of induced determinate mutants in sesame. Field Crop Res 2006; 96: 19–24.

Eskandari H., Zehtab-Salmasi S., Golezani KG., Gharineh MH. Effects of water limitation on grain and oil yields of sesame cultivars. Food Agric. Environ 2009; 7: 339-342.

FAO. https://www.fao.org/faostat/en/#data/QCL. (Access date: 2022) 2022.

Gerçek S., Boydak E., Şimşek M. Effect of irrigation methods and row spacing on yield and yield components of sesame (*Sesame İndicum* L.). Pakistan Journal of Biological Sciences 2004; 7 (12): 2149-2154.

Islam F., Gill RA., Ali B., Farooq MA., Xu L., Najeeb U., Zhou W. Sesame. In breeding oilseed crops for sustainable production Academic Press 2016; 135-147.

Langham D., Riney J., Smith G., Wiemers T., Pepper D., Speed T. Sesame producers guide. Sesaco Corp 2010; 33-41.

Langham DR.,Wiemers T. Progress in mechanizing sesame in the US through breeding. In Trends in New Crops and New Uses; Janick, A., Whipkey, A., Eds.; ASHS Press: Alexandria, Egypt 2002; 157–173.

Makinde FM., Akinoso R. Comparison between the nutritional quality of flour obtained from raw, roasted and fermented sesame (*Sesamum indicum* L.) seed grown in Nigeria. Acta Scientiarum Polonorum Technologia Alimentaria 2014; 13(3): 309-319.

Mehmood M., Khan MJ., Khan MJ., Akhtar N., Mughal F., Shah STA., Sadiq I. Systematic analysis of HD-ZIP transcription factors in sesame genome and gene expression profiling of SiHD-ZIP class I entailing drought stress responses at early seedling stage. Molecular Biology Reports 2022; 1-13.

MGM.https://www.mgm.gov.tr/2022.

Nadeem A., Kashani S., Ahmed N., Buriro M., Saeed Z., Mohammad F., Ahmed S. Growth and yield of sesame (*Sesamum indicum* L.) under the influence of planting geometry and irrigation regimes. American Journal of Pant Sciences 2015; 6: 980-986.

Naim A., Ahmed M., İbrahim K. Effect of Irrigation and cultivar on seed yield,yield’s components and harvest ındex of sesame (*Sesamum indicum* L.) Research Journal of Agriculture and Biological Sciences 2010; 6(4): 492-497.

Ozkan A., Curat D., Kulak M. Morphological properties and chemical compositions of some sesame (*Sesamum indicum* L.) populations cultivated in Kilis, Turkey. African Journal of Agricultural Research 2012; 7(19): 3029-3033.

Ozcinar AB.,Sogut T. Analysis of sesame (*Sesamum indicum* L.) accessions collected from different parts of Turkey based on qualitative and quantitative traits. Ekin Journal of Crop Breeding and Genetics 2017; 3(1): 45-51.

Pusadkar PP., Kokiladevi E., Bonde SV., Mohite NR. Sesame (*Sesamum indicum* L.) importance and its high quality seed oil: a review. Trends Biosci 2015; 8(15): 3900-3906.

Rao KR., Kishor PBK., Vaidyanath K. Biotechnology of sesame-an oil seed crop. Plant Cell Biotechnol Mol Biol 2002; 3: 101-110.

Su R., Zhou R., Mmadi MA., Li D., Qin L., Liu A., Dossa K. Root diversity in sesame (*Sesamum indicum* L.): insights into the morphological, anatomical and gene expression profiles. Planta 2019; 250(5): 1461-1474.

Şimşek M., Boydak E., Kırnak H., Gerçek S., Kasap Y. Susam bitkisinde farklı sulama ve sıra aralıklarında yağmurlama sulamanın su-verim ilişkisine etkisi. Tarım Bilimleri Dergisi. Tarım Bilimleri Dergisi 2003; 9(2): 136-142.

Teklu DH., Kebede SA., Gebremichael DE. Assessment of genetic variability, genetic advance, correlation and path analysis for morphological traits in sesame genotypes. Asian Journal of Agricultural Research 2014; 8(4): 181-194.

Uçan K., Kıllı F., Gençoğlan C., Merdun H. Effect of irrigation frequency and amount on water use efficiency and yield of sesame (Sesamum indicum L.) under field conditions. Field Crops Research 2007; 101(3): 249-258.

Van Zanten L. Sesame improvement by induced mutations. Results of the coordinated research projects and recommendation for future studies. Final reports of an FAO/IAEA Coordinated research project organized by joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, Vienna 2001; 1-12.

Wang L., Zhang Y., Qi X., Li D., Wei W., Zhang X. Global gene expression responses to waterlogging in roots of sesame (*Sesamum indicum* L.). Acta Physiologiae Plantarum 2012; 34(6): 2241-2249.

Wu WH. The contents of lignans in commercial sesame oils of Taiwan and their changes during heating. Food Chem 2007; 104: 34-44.

Yokota T., Matsuzaki Y., Koyama M., Hitomi T., Kawanaka M., Enoki-Konishi M. Sesamin, a lignan of sesame, down-regulates cyclin D1 protein expression in human tumor cells. Cancer Science 2007; 98: 1447-1453.

You J., Wang Y., Zhang Y., Dossa K., Li D., Zhou R., Zhang X. Genome-wide identification and expression analyses of genes involved in raffinose accumulation in sesame. Scientific Reports 2018; 8(1): 1-11.

Zhang Q., Li Q., Huang M., Wu J., Li H., Sun J., Sun B. Analysis of odoractive compounds in 2 sesame-flavor Chinese Baijius. Food Science (Chinese) 2019; 40(14): 214-222.