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Evaluation of sesame (*Sesamum indicum L.*) lines to develop a high yielding black seeded sesame variety (ANKSE 3) in Sri Lanka

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Abstract

Sesame, an essential oilseed crop, holds the potential to significantly contribute to foreign exchange earnings in Sri Lanka. Black seeded sesame has high demand among the confectionery industry of the country. To meet this demand, development of high-yielding, black-seeded sesame is a key objective of the sesame breeding program at the Department of Agriculture in Sri Lanka, aiming to overcome the low yield potential of existing varieties. To achieve this, thirty-three sesame accessions collected from different regions of the country were evaluated for morphological and yield traits, and six promising lines were identified for station yield trials. Among them four promising lines were selected and tested in six research stations situated in the Dry and Intermediate

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zones of Sri Lanka in a Randomized Complete Block Design with three replicates and the yield data were recorded. Further, two promising lines that recorded high yields, were selected, and evaluated in farmer field conditions with the check variety, MI 1. The new candidate line recorded the highest yield of 1430 kg/ha and recorded a higher crude fat percentage (43.4%) and higher oleic/linoleic ratio (greater than 1). The new candidate line, ANKBS 5 is superior to the check variety, MI 1 and the other tested lines and fits well to the cropping pattern of the country. The line was named as "ANKSE 3" and released at the Varietal Releasing Committee in 2021, and it is suitable for general cultivation specially to fulfil the demand of black seeded sesame in Sri Lanka.

Keywords*:* Black seeded, Crude fat, Fatty acid, Linoleic, Oleic, Sesame

Introduction

Sesame (*Sesamum indicum* L.) is an annual flowering plant that belongs to the family Pedaliaceae and one of the earliest crops cultivated in the ancient times world (Zech-Matterne, 2015). It has been an important oil seed crop for centuries and is often referred to as the "Queen of Oilseeds" (Nayar, 1984). Sesame is cultivated extensively in various regions worldwide, mostly in tropical and subtropical areas particularly in Asia and Africa (Wen-Huey, 2007). The major producers of sesame in the world include Tanzania, China, India, Sudan, and Myanmar (Xu and Zhang, 2018). The plant is well-suited to warm climates and shows a remarkable tolerance to drought, making it an important crop in many arid and semi-arid regions across the globe.

Sesame is valued for its nutritional attributes, serving both confectionery and culinary purposes such as in cooking, pharmaceuticals, paint production, and lubricants (Thakur *et al*., 2018). Sesame seeds are rich in essential components, including oil (comprising 44–58% of the seed), protein (18–25%), carbohydrates (11–13.5%), and ash content (approximately 5%) (Kang, 2003). Sesame oil is characterized by its high unsaturated fatty acid content, proteins, vitamins, minerals, phytosterols and lignans (Charan and Panghal, 2012). Sesame oil contains a high amount of linoleic and linolenic acids, along with valuable natural compounds like lignans, vitamin E, and phytosterols (Hama, 2017). Analysis of oil composition has resulted in 30 to 53% of oleic acid and 33 to 52% of linoleic acid as major unsaturated fatty acids (Wei et al., 2015). The oil possesses high stability to oxidation due to the presence of antioxidants such as sesamol, sesamolin and sesamin) and tocopherols (Sabah, 2008). Moreover, Sesame seed hull which is the major by-product of sesame seed oil extraction can be used as cattle feed.

In Sri Lanka, sesame has been cultivated since ancient times, and it is mainly grown as a rainfed crop in the dry and intermediate zones. The cultivation extent of sesame in Sri Lanka was 16222 ha and the production was 10230 t in 2022 (Agstat, 2023). There is a high demand in the export market and, interestingly, the export volume was 7488 t in 2022 generating foreign exchange earnings of Rs million 785 (Agstat, 2022). Major sesame growing districts in Sri Lanka include Anuradhapura, Hambantota, Monaragala, Vavuniya and Jaffna. Sesame cultivations are mainly small-scale, and most farmers grow landraces of sesame or select varieties based on seed availability (Dissanayake, 2017). Most of these farmers own less than 5 ha of lands where sesame is cultivated. There is a variation of colour from white to black. Both pure black and pure white seeded sesame has high demand and is widely cultivated around the world. In Sri Lanka both black and white sesame varieties are cultivated. However, black seeded sesame is much preferred by the farmers in the Northern province of Sri Lanka. Black seeded sesame is mostly used in confectionary industries and for oil extraction. Processing industries prefer black colored sesame because it’s easy to differentiate the processed and unprocessed seeds after dehulling.

The Department of Agriculture (DoA) has released five sesame varieties until 2020 and out of them two are black colored sesame varieties named as MI 1 and MI 2. However, the average yield at farmers’ level and the yield potential of these varieties are comparatively low. The demand for black seeded sesame, especially for industrial and confectionery purposes, remains notably high. Therefore, the primary objective of this research was to develop a high-yielding black seeded sesame variety for general cultivation, primarily targeting the requirements of industrial applications.

Materials and method

Line evaluation and selection

An extensive field survey was carried out in sesame growing areas in Sri Lanka and seeds of thirty-three sesame accessions were collected. They were evaluated in field conditions (6.146368 N, 80.909687 E) at Grain Legumes and Oil crops Research and Development Centre (GLORDC), Angunakolapelessa in 2011 *Yala* and 2011/12 *Maha* seasons. Among them, six promising lines (ANKBS 1, ANKBS 2, ANKBS 3, ANKBS 4, ANKBS 5 and ANKBS 6) were selected and evaluated for their agronomic and yield performances during 2012 *Yala* and 2013/14 *Maha* seasons along with the check variety MI 1. The trials were conducted in a Randomized Complete Block Design (RCBD) with 3 replicates and maintained according to the guidelines of the [DoA].

Evaluation at different research stations

According to the agronomic and yield performances of the six lines evaluated, four lines were selected (ANKBS 2, ANKBS 4, ANKBS 5 and ANKBS 6) for further evaluation with the check variety MI1 at different research stations of the DoA representing different agro-ecological regions located in Dry and Intermediate Zones. So, the National Coordinated Varietal Trial (NCVT) were conducted at Field Crops Research and Development Institute (FCRDI), Mahailluppallama, GLORDC, Angunakolapelessa, Agriculture Research Station (ARS), Weerawila, Regional Agricultural Research and Development Centre (RARDC), Aralaganwila, Regional Agricultural Research and Development Centre Kilinochchi which are located in Dry Zone of Sri Lanka and situated in areas where sesame is cultivated. The experiments were conducted in a RCBD with three replicates.

Evaluation at farmer fields in different AEZ

One accession was selected according to the performances of the four lines in the above research stations (According to NCVT results), and it was evaluated with the check variety MI1 in the Variety Adaptability Testing (VAT) trials. The promising line, ANKBS 5 and MI1 were grown and evaluated in six farmer fields belonging to four AERs (Ambalantota, Weerawila, Bandagiriya and Hambantota in DL5, Saliyapura in DL1b, Aralaganwila in DL2b and Angunakolapelessa in DL1a) in a RCBD experiment with two replicates during 2017 *Yala* and 2018/19 *Maha* seasons.

Yield data were collected. All the agronomic and cultural practices were carried out as per the recommendations of the DoA throughout the entire study. Further, essential nutrients like nitrogen, phosphorus, and potassium (NPK) were applied at recommended levels as a basal fertilizer and at flowering stage.

Evaluation of sesame germplasm for resistance to major diseases

The sesame accessions in the station's yield trials were evaluated for major diseases, including stem and root rot as well as phyllody, under field conditions. Disease incidences for root rot and phyllody were recorded 70 days after sowing by counting the number of diseased plants and the total number of plants. Based on the infection percentage, the sesame accessions were classified as resistant, moderately resistant, moderately susceptible, susceptible, or highly susceptible, following the scale developed by Dinakaran and Naina Mohammed (2001).

Proximate analysis of promising lines

The selected promising line, ANKBS 5 was further tested for the composition by proximate analysis following the standard methods of the Association of Official Analytical Chemists (AOAC, 2000). Fatty acid profile was analysed using Gas Chromatography -mass spectrometry (GC-MS) at Industrial Technology Institute (ITI), Colombo. The promising line was compared with three recommended sesame varieties: Uma, Malee and MI1.

Data analysis

The yield data were subjected to analysis of variance (ANOVA) using SAS (SAS, 2013). Multilocational data were analysed by variance component methods (Abeysiriwardana *et al*., 1991) and the treatment means were compared using Least significant Difference (LSD) at $p = 0.05$.

Results and discussion

Performance of sesame lines in station yield trials

The yield performances of six selected accessions, namely ANKBS 1, ANKBS 2, ANKBS 3, ANKBS 4, ANKBS 5, and ANKBS 6, were compared to that of the check variety, MI1, during station yield trials conducted at GLORDC, Angunakolaplessa. The results, presented in Table 1, show the performance of these accessions across different seasons. ANKBS 2 recorded the highest yield in 2012 *Yala* season which was statistically similar to ANKBS 3, ANKBS 4, ANKBS 5 ANKBS 6 and MI1, while ANKBS 5 recorded the highest in 2013/14 *Maha* season which was statistically similar to ANKBS 2, ANKBS 4, ANKBS 5 and ANKBS 6. Considering the yield and other yield related traits, ANKBS 2, ANKBS 4, ANKBS 5 and ANKBS 6 were selected for NCVT trials. These results show the adaptability of the promising lines within the context of the specific environmental and climatic conditions of the two seasons.

Table 1. Average yield (kg/ha) of selected lines at GLORDC, Angunakolapelessa

Variety/line	**Average yield (kg/ha)**	
	Yala 2012	*Maha* 2013/14
ANKBS 1	529.4 c	773.0 c
ANKBS 2	1283.0 a	1117.5 ab
ANKBS 3	960.9 ab	827.3 bc
ANKBS 4	907.4 ab	1106.5 ab
ANKBS 5	872.4 ab	1173.1 a
ANKBS 6	889.5 ab	1057.8 abc
MI 1-Check	1020.9 ab	750.8 c
CV%	25.80%	16.9%
LSD	429.8	185.28

Mean in each column followed by the same letters are not significantly different (p = 0.05)

Performance of promising sesame lines in multi locational trials

Multi-locational data in sesame is crucial for understanding the performance and diversity of the crop. The lines tested at six research stations in consecutive three seasons (2015 *Yala*, 2015/16 Maha and 2016 *Yala*) showed a yield performance range from 0.77-1.03 t/ha (Table 2). In comparison, the check variety exhibited yields between 0.64 and 0.81 t/ha.

To estimate the adaptability of these sesame lines, the yield data were analysed through the variance component method. During *Yala* 2015 season, one promising line, ANKBS 5, performed well in terms of adaptability, recording the highest rank, followed by ANKBS 6 (Table 2). Further, in 2015/16 *Maha* season, three lines; ANKBS 4, ANKBS 5 and ANKBS 6 equally recorded the highest adaptability ranks, while ANKBS 5 had the highest adaptability rank again in *Yala* 2016 signifying their vigorous performance across multiple research stations (Table 2).

Most adaptable variety in the test could be selected by the variety/line having the higher number of positive deviations, low mean deviation and non-significant variance in deviations across locations among the varieties/lines in the test (Abeysiriwardana *et al*., 1991). In accordance with this analysis, the ANKBS 5 variety consistently demonstrated the highest average yield across all three seasons, with an adaptation rank of 1. Conversely, the MI1 variety consistently recorded the lowest average yield, with the least favorable adaptability rank.

Considering all the data in NCVT, it revealed that ANKBS 5 was superior to the check variety, MI 1 in all three seasons and superior to other tested lines in both 2015 *Yala* and 2016 *Yala* seasons. Hence, ANKBS 5 line was selected for VAT trials in different locations under farmer management. Adaptability trials at farmer fields are crucial for identifying the best performing varieties.

Table 2. Adaptability parameters derived on variance component method inNCVT during 2015 *Yala*, 2015/16 *Maha* and 2016 *Yala* seasons

2015 *Yala*					
Line	Average yield over 3 locations t/ha	Adaptability Parameters			
		No. of + deviations out of 3	Mean deviation over locations	Interaction Variance	Adaptability Rank
ANKBS 2	0.695	2	-0.075 b	0.012	4
ANKBS 4	0.772	1	0.001 b	0.026	3
ANKBS 5	0.956	3	0.186 a	0	1
ANKBS 6	0.788	3	0.017 b	0.012	2
MI 1	0.64	0	-0.129 b	0.000	5
2015/16 *Maha*					
Line	Average yield over 4 locations t/ha	Adaptability Parameters			
		No. of + deviations out of 4	Mean deviation over locations	Interaction Variance	Adaptability Rank
ANKBS 2	0.776	3	-0.015 a	0.006	4
ANKBS 4	0.803	2	0.011 a	0.007	1
ANKBS 5	0.777	3	0.083 a	0.009	1
ANKBS 6	0.807	2	0.015 a	0.022	1
MI 1	0.695	1	-0.096 a	0.034	5
2016 *Yala*					
		Adaptability Parameters			
Variety	Average yield over 3 locations t/ha	No. of + deviations out of 3	Mean deviation over locations*	Interaction Variance	Adaptability Rank

ANKBS 2	0.922	3	0.019 b	0.004		2
ANKBS 4	0.878	3	-0.024 b	0.001	3	
ANKBS 5	1.03	3	0.173 a	0.006	1	
ANKBS 6	0.826	2	-0.076 b	0.016	3	
MI 1	0.81	0	-0.092 b	0.006	3	

**Mean followed by the same letters are not significantly different (p = 0.05)*

Performance of promising lines at farmer fields

The lines were tested in two seasons (2017 *Yala* and 2018/19 *Maha*) at 6 farmers' fields (in VAT trials) in different AEZ of Sri Lanka and the results revealed that the yield ranged from 0.91 t/ha to 1.4 t/ha for ANKBS 5 and 0.7 to 1.2 t/ha for MI 1 (Table 3). According to the results, average yield of ANKBS 5 at farmer fields was superior to check variety, MI 1 in both seasons. The adaptability ranks were obtained for each season separately considering the distance from the maximum response and the average yield in the seasons (Abeysiriwardana *et al*., 1991). Accordingly, the promising line, ANKBS 5 showed the best adaptability in both seasons, suggesting more stable performance compared to MI 1.

Table 3. Mean and variance of the distance from the maximum response and the adaptability ranks of ANKBS 5 and MI 1 in VAT under farmer field conditions during 2017 *Yala* and 2018/19 *Maha* seasons

2017 *Yala*				
Variety/Line	Distance from Maximum response		Average Yield (t/ha) *	Adaptability Rank
	Mean*	Variance		
ANKBS 5	0.586 a	0.501	0.913 a	1
MI 1	0.799 a	1.381	0.736 b	2
2018/19*Maha*				
Variety/Line	Distance from Maximum response		Average Yield (t/ha) *	Adaptability Rank
	Mean*	Variance		
ANKBS 5	0.32852 b	0.19299	1.43 a	1
MI 1	0.51833 a	0.04595	1.203 b	2

**Mean followed by the same letters are not significantly different (p = 0.05)*

Pest and disease recordings

The sesame lines were evaluated for the major diseases occurring for sesame in Sri Lanka. The promising line, ANKBS 5 and MI 1showed moderate resistance to stem and root rot disease (Table 4) and ANKBS 5 was potentially more resilient against phyllody, which would be important to ensure better crop health and productivity.

Table 4. Response of sesame lines to major diseases during 2017

Variety/Line	Stem and root rot disease	Phyllody
ANKBS 5	MR	R
MI 1	MR	MR

R: Resistant, MR: Moderately Resistant

Nutritional analysis

Ash content of promising line, ANKBS 5 recorded 10.8% while Uma, Malee and MI 1 recorded 9.4%, 7.8% and 8.1% respectively (Table 5). Proximate analysis revealed that promising line, ANKBS 5 had crude fat percentage of 43% while a widely cultivating variety Uma recorded 37.6%. These results were similar to those reported in other studies (Gharby, 2017; Hassan, 2012). The crude fat content in sesame varieties plays a pivotal role in determining their nutritional value, storage stability, oil extraction potential, flavour attributes, and their utilization in various culinary applications. Managing and understanding the fat content is crucial for both the quality of sesame seeds and the extraction of sesame oil, contributing to their overall significance in the food and agricultural industries.

Table 5. Proximate analysis of sesame varieties/lines

Variety/Line	Moisture %	Ash %	CrudeFat %	Crude Protein %	Carbohydrate%
ANKBS 5	5.5	10.8	43.4	21.5	18.8
Uma	5.4	9.4	37.6	22.3	25.4
Malee	3.7	7.8	40.9	23.3	54.2
MI 1	5.1	8.1	42.6	21.9	22.3

The fatty acid composition is an important indicator of the nutritional assessment of sesame oil. ANKBS 5 had a high oleic percentage of 44.42% and a low linoleic percentage of 40.62% (Table 5). Lower linoleic acid content and a higher oleic acid content in the fat profile benefit with a higher oxidative stability of oil seeds (Bakal, 2022; Betrand, 2018; Hama, 2017). Oleic to linoleic ratio of ANKBS 5 line was greater than 1 and all other varieties recorded ratio less than 1 revealing that ANKBS 5 could have comparatively higher oil stability. In a study conducted to develop a high yielding sesame variety, the promising line, Til-8 recorded 20.7% of linoleic acid and 61% of linolenic acid (Aftab *et al.,* 2020). Cevheri (2019) recorded 39.43%-44.76% of oleic and 39.10%-44.76% of linoleic acid while Harfi (2009) recorded 37.15%-39.99% and 40.59%-44.11% of oleic and linoleic acid respectively in sesame seeds. Oleic to linoleic ratio of that variety was 0.33 which was much less compared to ANKBS 5.

Table 6. Average fatty acid percentages of sesame varieties/lines

Variety/line	Palmitic (% in oil)	Stearic (% in oil)	Oleic (% in oil)	Linoleic (% in oil)
ANKBS5	8.68±0.10	5.03±0.07	44.42±0.06	40.62±0.13
Uma	8.97±0.10	4.29±0.03	36.92±0.04	48.46±0.10
Malee	8.21±0.11	4.38±0.03	35.15±0.04	51.21±0.10
MI 1	9.80±0.09	4.25±0.02	40.52±0.02	44.31±0.07

Considering the yield, yield related characteristics, proximate and fatty acid profile, ANKBS5 was recognized as a superior black seeded sesame variety for general cultivation especially concerning the demand from confectionery industry. The line has been nominated to the Variety Releasing Committee 2021 and released as ANKSE3 for general cultivation in Sri Lanka.

Conclusion

A promising black seeded sesame line was selected through an evaluation of local sesame accessions at different agro-ecological regions of the Dry and Intermediate Zones of Sri Lanka. The highest yield recorded by the promising line over the research was 1.43 t/ha and the average yield is about 1000 kg/ha. It has oleic/linoleic ratio of 1.09 showing higher oxidative stability of oil. Further the new line was resistant to phyllody and moderately resistant to stem and root rot disease. The candidate line has been released at the Variety Releasing Committee in 2020 naming it as ANKSE3 considering its higher performances and the demand towards a black seeded sesame especially in the confectionary industry in the country.

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Declaration of conflict of interest

Authors have no conflict of interest to declare.

References

Abeysiriwardena, S.D.Z., Buss, G.R., Paul, F. & Reese, J.R. (1991). Analysis of multi-environmental yield trials for testing adaptability of crop genotypes. *Tropical Agriculturist*, *147*, 85-97.

Aftab, M., Ghias, M., Anwar, M., Mustafa, H. S. B., Din, A. M., Ali, S., Shah, S. A. H. & Hanif, M. K. (2020). Til-18 (50022): A high yielding variety of sesame (*Sesamum indicum* L.). *Life Science Journal, 17*(3)

Agstat (2023). *Pocketbook of agricultural statistics.* Volume xvii, Socio Economic and Planning Centre, Department of Agriculture, Peradeniya, Sri Lanka.

Agstat (2022). *Pocketbook of agricultural statistics*. Volume xvi, Socio Economic and Planning Centre, Department of Agriculture, Peradeniya, Sri Lanka.

AOAC (2000). Official methods of analysis. 17th Edition, Association of Official Analytical Chemists (AOAC), Washington, DC

Bakal, H. (2022). Comparison of oil content and fatty acids composition of Sesame (*Sesamumindicum* L.) varieties grown as main and double crop in Mediterranean environment in Turkey. *Turkish Journal of Field Crops*, *27*(1), 119-126

Betrand, M. (2018). Fatty acid composition and Tocopherol contents of some sesame seed oils. *Iranian Journal of Chemistry and Chemical Engineering,37*(5)

Charan, S. & Panghal, A. (2018). Importance of traceability in food supply chain for brand protection and food safety systems implementation. *Annals of Biology*, *34*,111–8.

Cevheri, C.I., Yilmaz, A., Beyyavas, V., Haliloglu, H. & Boydak, E. (2019). Fresenius Environmental Bulletin, *28*

Dinakaran, D. & Naina Mohammed, S. E. (2001). *Sesame and Safflower Newsletter.16*, 68-71.

Dissanayake, I., Ranawala, S. & Perera, S. (2017). Agronomic status of Sesame/Thala (*Sesamum indicum* L.) cultivations in dry regions of Sri Lanka. *International Journal of Agronomy and Agricultural Research (IJAAR)*, *11*(1),42-50

Gharby, S., Harhar, H., Bouzoubaa, Z., Asadi, A., Yadini, A.E. & Charrouf C. (2017). Chemical characterization and oxidative stability of seeds and oil of sesame grown in Morocco. *Journal of the Saudi Society of Agricultural Sciences*, *16*,105-111.

Hama, J.R. (2017). Comparison of Fatty Acid Profile Changes between Unroasted and Roasted Brown Sesame (Sesamum indicum L.) Seeds Oil. *International Journal of Food Properties*, *20*, 957–967

Harfi, M.E., Nabloussi, A., Rizki, H., Ennahli, S. & Hanine, H. (2009). Proximate Composition and Fatty Acid Composition, Phytochemical Content of Sesame (Sesamum indicum L.) Seeds Landrace from Morocco. *Advances in Crop Science and Technology, 7*(3)

Hassan, M. A. M. (2012). Studies on Egyptian sesame seeds (*Sesamum indicum* L.) and its products 1-physicochemical analysis and phenolic acids of roasted Egyptian sesame seeds (*Sesamum indicum* L.). *World Journal of Dairy and Food Sciences*, *7*,195-201.

Kang, M.H., Choi, J.S. & Ha, T.Y. (2003). Chemical Properties of Sesame Seed Cultivated in Korea and China. *Food Science Biotechnology*, *12*, 621–624.

Nayar, N.M. (1984). Sesame In: evaluation of crop plants, Longman, London.

Statistical Analysis Software. Users' Guide Statistics Version 9.4. (2013). SAS Institute Inc., Cary.

Sabah El Khier, M.K., Khogali Elnur, A.I. & Abu El Gasim, A.Y. (2008). Chemical composition and oil characteristics of sesame seed cultivars grown in Sudan. *Research Journal of Agricultural Biological Sciences,4*, 761-766.

Thakur, V., Paroha, S. & Mishra, R.P. (2018). Free fatty acid profile of seven sesame (*Sesamum Indicum* L.) Verities. *International Journal of Current Microbiology and Applied Sciences*, *7*, 3439–53.

Wei, X., Liu, K., Zhang, Y., Feng, Q., Wang, L., Zhao, Y., Li, D., Zhao, Q., Zhu, X., Zhu, X., Li, W., Fan, D., Gao, Y., Lu, Y., Zhang, X., Tang, X., Zhou, C., Zhu, C., Liu, L., Zhong, R., Tian, Q., Wen, Z., Weng, Q., Han, B., Huang, X. & Zhang, X. (2015). Genetic discovery for oil production and quality in Sesame. *Nature Communications, 6*.

Wen-Huey, W. (2007). The contents of lignans in commercial sesame oils of Taiwan and their changes during heating. *Food Chemistry*, *104*, 341–344.

Xu, G. 7 Zhang, W. (2018). Analysis of the changing trend of world sesame production and trade structure. *World Agriculture*, *10*, 131–137.

Zech-Matterne, V., Tengberg, M. & Van Andringa, W. (2015). *Sesamum indicum* L. (Sesame) in 2nd Century BC Pompeii, Southwest Italy, and a Review of Early Sesame Finds in Asia and Europe. *Vegetation history and Archaeobotany*, *24*, 673–68

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