Enhancing sesame seed yield through participatory identification and promotion of high-performing irrigated varieties for Northwestern Ethiopia

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ABSTRACT

In Ethiopia, irrigation-based sesame production is constrained by multiple factors, with the limited availability of improved varieties being a major bottleneck. This study aimed to evaluate the seed yield performance of improved sesame varieties through farmers' participation. Participatory variety selection followed by demonstration and pre-scaling up of selected varieties was conducted in Metema district during 2019 and 2022-2024 under irrigation, respectively. Seventeen varieties, including a local check, were evaluated to select the best-performing varieties. A mother-baby trial approach with an RCBD design with three replications was used. Agronomic data were collected from the mother trial, while farmers' varietal and trait preferences were gathered from the baby trial. The demonstration and pre-scaling-up were conducted on farmers' fields to assess further and identify varieties, and to create demand through promotion. Analysis of variance (ANOVA) was performed in R software and revealed significant differences ($p<0.05$) among the tested sesame varieties for all traits except branch number. The results revealed significant variation among the evaluated sesame varieties, with the highest seed yield recorded for Ado (2,084 kg ha^{-1}), followed by Adi (1,891.5 kg ha^{-1}). These two varieties also produced the highest number of capsules per plant, while thousand-seed weight ranged from 2.2 g in the local check to 3.7 g in Adi. Based on farmers' preference assessment, which considered traits such as number of capsules per plant, uniform maturity, plant height, seed color, and overall field performance, Adi was highly preferred due to its superior yield performance, attractive whitish seed color, and market desirability. Consequently, Adi was demonstrated and promoted under farmers' conditions, which generated considerable interest and demand for its seed. During the pre-scaling phase, Adi produced a mean seed yield of 1,330 kg ha^{-1} under farmers' management conditions. Considering its stable performance, preferred seed color, and strong farmer acceptance, Adi was recommended for wider promotion and commercial production under irrigated conditions, while Ado, despite its higher yield potential, requires further evaluation and scaling-up efforts to enhance its adoption.

Keywords: Sesame; Participatory Variety Selection; Promotion; Irrigation; Seed yield; Farmers
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INTRODUCTION

Sesame (*Sesamum indicum* L., 2n = 2x = 26) is an annual, warm-season crop mainly cultivated under rainfed conditions in semi-arid tropical and subtropical regions. It is one of the ancient oil seed crops cultivated in many parts of the world and is a high-oil-yielding (~ 56%) crop with polyunsaturated fatty acids as the major constituent (Pathak

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et al., 2014). Sesame is considered the queen of oilseeds due to its high oil content and rich flavor, and it is grown mainly for its seeds, which have one of the highest oil contents among major oilseed crops (Desawi Hdru Teklu *et al*., 2021; Sanni *et al*., 2024). The seeds are particularly prized for their rich composition of unsaturated fatty acids, primarily oleic acid (~38%) and linoleic acid (~46%), which together constitute more than 80% of the total fatty acid content (Anastasi *et al*., 2017; Dossa *et al*., 2018). Saturated fatty acids, such as palmitic acid (~12%) and stearic acid (~6%), comprise less than 20% of the total fatty acids (Wacal *et al*., 2019). Sesame seed is also a valuable source of protein (~24%), carbohydrate (~13.5%), lignans (sesamin and sesamolin), and others (Were *et al*., 2006; Dossa *et al*., 2018). These nutritional profiles render sesame seeds considered as a superfood, highly beneficial for human health and globally traded as an edible oilseed used for various purposes (Abbas *et al*., 2022; Irshad *et al*., 2023).

Worldwide, more than 75 countries actively produce sesame, with an estimated 6.7 million tons of seed production from 12.8 million hectares in 2022. Its production is mainly concentrated in Asia and Africa, where Africa is the largest producer (59 %), followed by Asia (36 %) and America (5 %) (FAOSTAT, 2024). Ethiopia is the center of origin and diversity for cultivated sesame and its allied species, and it is among the top producer countries with an average productivity of 716 kg ha^{-1}, placing fourth (FAOSTAT, 2024). In Ethiopia, sesame is a major oilseed crop, playing a crucial role in the country's export sector and economy, next to coffee in generating foreign exchange (Abadi Berhane, 2018).

In the year 2021, it was cultivated on 369,897 hectares with a total production volume of 260,257.6 tons, with an average of 0.7 t ha^{-1} (CSS, 2021). Under Ethiopian conditions, the major sesame production is concentrated mainly in Northwestern Ethiopia; the Amhara region alone covered 224,220.3 hectares with a total production of 153,809.7 tons at an average yield of 0.68 t/ha during the Meher season of 2021 (CSS, 2021). Ethiopian Northwestern regions, particularly the Amhara Regions Quara, Metema, Armachiho, Tegedie, Wolkayit, and Setit-Humera areas, are widely recognized for sesame production with exceptional qualities, including a whitish color and distinct taste and aroma (Zerihun Jalata, 2012). These attributes have earned Ethiopian sesame international recognition for its superior seed quality (Eryigit *et al*., 2017; Taghouti *et al*., 2017). Over 90% of production is destined for export markets (Kutoya Kusse *et al*., 2022). Hence, it is a highly valued crop contributing significantly to the nation's economic growth and stability.

Under Ethiopian conditions, sesame is traditionally a rain-fed commercial crop with significant potential for expansion into non-traditional areas and under irrigation. Even though it is cultivated under rain-fed conditions, it can also adapt well to irrigation, achieving seed yields as high as 2,700 kg ha^{-1} (Anastasi *et al*., 2017). Reports by Sisay Ambachew and Assefa Sintayehu (2020) also indicated yields of 1840 kg ha^{-1} under optimal irrigation conditions, while Fiseha Baraki *et al*. (2020) indicated yields as high as 2044 kg ha^{-1}. In general, crop yield is higher under irrigation; this is due to optimization of water availability during sensitive growth stages, thus sustaining photosynthesis, improving nutrient uptake, and increasing seed number and seed weight (Steduto *et al*., 2012). Observing the yield potential and its national importance, the governments of Ethiopia provide direction along with the expansion of irrigation farming in the country. In addition to those opportunities, sesame is particularly well-suited as an alternative crop for irrigated agriculture due to its low water requirements (Pabuayon *et al*., 2019) and drought-tolerant characteristics, making it an excellent choice for cultivation in semi-arid regions and water-scarce agricultural systems (Eryigit *et al*., 2017). Despite these indicators, irrigation-based sesame farming remains underdeveloped and untapped, particularly in the rainfed-sesame production belt of Northwestern Ethiopia. This is mainly associated with a lack of adaptable varieties, limited awareness among producers, inefficient irrigation infrastructure and schemes, and insufficient research on irrigation-based agricultural technologies. To tackle these challenges, efforts are made to identify and select high-yielding sesame varieties adapted to irrigation environments. The research also aims to demonstrate and promote those selected varieties, enhancing agricultural productivity and supporting successful sesame cultivation in irrigated settings.

MATERIALS AND METHODS

Description of the study area

The experiment was conducted at Metema Irrigation Research Station of the Gondar Agricultural Research Center in the Northwestern lowland of Ethiopia. The study site was chosen based on irrigation potential for sesame production and the crop's market demand in the study area. Metema is geographically located between 12º 17′ 31″ to 13º 5′ 40″ N latitude and 36º 0′ 15″ to 36º 46′ 30″ E longitude (Figure 1). The experimental site is located at an altitude of 760 m above sea level. The irrigated season, which typically spans from December to early May, is generally dry, except for occasional random raindrops. The minimum and maximum annual long-term average daily temperature ranges from 16 °C to 24 °C and 30 °C to 40 °C, respectively (Sisay Ambachew and Assefa Sintayehu, 2020; Atikilt Abera *et al*., 2023). The lowlands of Northwestern Ethiopia have a monomodal rainfall pattern, mainly the rainy season covering June to September, with a range of 700 to 1160 mm. The soil characteristics of the site were dark brown with clay-loam texture, low salinity, neutral pH, low total nitrogen, and low available phosphorus (Sisay Ambachew and Assefa Sintayehu, 2020).

Experimental materials, design, and trial management

The evaluation and promotion study was conducted over successive irrigation seasons from 2019 and 2022 to 2024. The 2019 season was used for initial evaluation and participatory selection of sesame varieties, while the farmer-preferred variety was subsequently demonstrated and pre-scaled during 2022 - 2024 to validate its on-farm performance, demand creation, and facilitate wider dissemination.

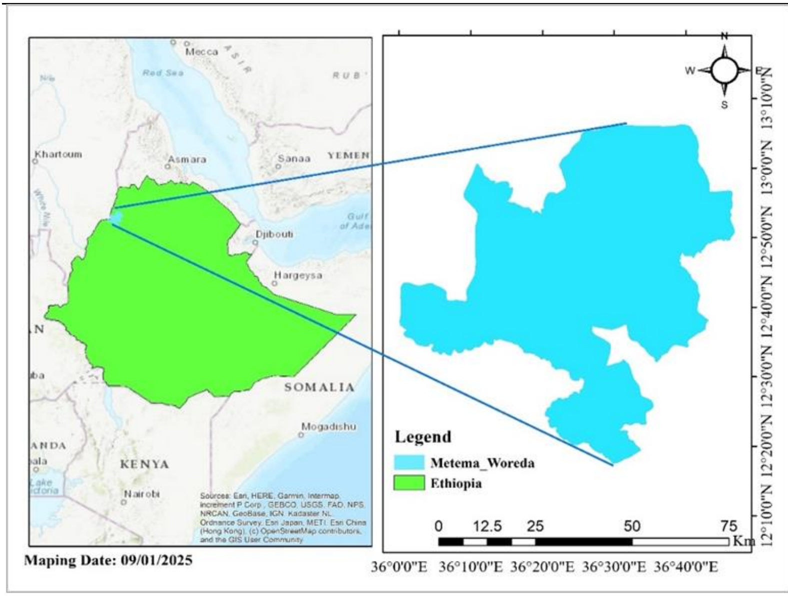

Figure 1. Map of the study area (Metema district)

During the 2020 and 2021 irrigation seasons, the selected variety was multiplied to produce sufficient quality seed for subsequent demonstration and pre-scaling activities. Seventeen released sesame varieties, including the local checks, were evaluated under irrigated conditions with a mother-baby trial approach. The details of the tested varieties are listed in Table 1. According to the Amhara Agricultural Research Institute (ARARI), participatory variety selection (PVS) (ARARI, 2018, unpublished) guideline, a mother trial is demarcated as the trial that is managed by a researcher and can be conducted at a research station, farmer training center (FTC), and/or farmers' field with designed and replicated ways. While a baby trial refers to a trial conducted jointly by farmers, extension workers, and researchers, and conducted at farmers' fields. The mother trial was done using a Randomized Complete Block Design (RCBD) with three replications, while the baby trials were non-replicated versions of the mother trial. The baby trials were established to facilitate farmers' easy and independent selection of preferred varieties, thus avoiding confusion during the evaluation process. Two baby trials were set up with defined distances from the mother trials, with similar plants and row spacing to the mother trial. The mother trials were served for statistical analysis, while the baby trials were used for evaluation and collection of farmers' preferences on the tested varieties.

Each variety was planted in a plot size of 2.5 m x 3.2 m (8 m^2) and was separated from adjacent plots within the replicates by 1 m and 1.5 m between replicates. Seeds were sown manually in double rows on ridges that are 80 cm apart, with row spacing of 40 cm and plant spacing of 10 cm under furrow-irrigating systems. The test varieties were randomly assigned to the plots in every replication. A seed rate of 4 kg ha^{-1} was consistently hand-drilled across all plots and finally adjusted to require population by thinning. Fertilizer was applied at a rate of 46 kg ha^{-1} of nitrogen (N) and 23 kg ha^{-1} of phosphorus (P_2O_5) in the form of urea and DAP. Nitrogen was applied in two splits: half was applied at planting, and the remaining half at the flowering initiation stage. The irrigation schedule was adopted from Awoke Tadesse and Muhaba Sultan (2022), which was every 3 days from planting to emergence, 6 - 8 days during flowering and seed formation stages, and 12 days as the plants approached physiological maturity. All other agronomic practices, including weeding, were applied, and timely plant protection measures and assessment were also carried out.

Table 1. Details of the tested sesame varieties

Varieties	**Year of release**	**Seed color**	**Oil (%)**	**Maturity date**	**Yield (kg ha^{-1})**		**Releasing Center/Maintainer**
					Rain-fed	**Irrigation**	
Humera-1	2011	white	54-56	90-110	800 -1000		Humera ARC
Setit-1	2011	white	52-54	80-90	700 -1000	2000-2400	Humera ARC
Abasena	1990	white	44-48	110-120	900	1200-1400	Werer ARC
Tate	2000	grey	47 -49	110-120	700	1500-1800	Werer ARC
Ado	2017	white	51-55	110-114	1274	900-1300	Werer ARC
Adi	1993	white	40-58	85-91		1600-2000	Werer ARC
Gondar-1	2016	white	50.0	101	500 - 900		Gondar ARC
Mechal	2013	white	50.4	105-120	700 - 800		Srinka ARC
Setit-3	2017	white	54.4	87	900 -1300		Humera ARC
Obsa	2010	white	51.5	120-137	800-1000		Bako ARC
Chalasa	2013	white	51.0	95-120	1050-1200		Bako ARC
Setit-2	2016	white	53.7	80-87	930		Humera ARC
BaHa-zeyit	2016	grey	56.0	113-134	1300		H. University
BaHa-necho	2016	white	52.0	114-129	1200		H. University
Benshangul-1	2016	white	54.0	90-115	800-1000		Humera ARC /Asossa ARC
Dangur Local	2015	grey white	56.7	124	750		Pawe ARC

ARC = Agricultural Research Center

Following the PVS trial, in 2020 and 2021, for two consecutive seasons, a seed increase of farmer-selected varieties was performed. The demonstration and pre-scaling up of the selected varieties were conducted from 2022 to 2024, under irrigation conditions in the Metema District. During the one-year demonstration and two-year pre-scaling up, representative farmers participated under the close supervision of researchers and extension experts.

Agronomic data collection

All plant and plot-based data were taken from the central six rows (6 m^2), and plant-based data were particularly taken from ten randomly selected plants. Data were collected for days to 75% maturity, plant height (cm), primary branches per plant, length of capsule-bearing zone (cm), capsules per plant, seeds per capsule, 1000-seed weight (grams), and seed yield (g plot^{-1} and kg ha^{-1}).

Farmers' participatory varietal selection and procedures

Variety evaluation and selection were organized at the baby trial plots at both sites during the physiological maturity stage of the test crop (Figure 2). Participants of agricultural experts from the districts, development agents, and representative and host farmers from each site participated in the evaluation and selection program. Farmers' research extension group (FREG), which comprised 25 male and 2 female farmers, was established for field evaluation and variety selection. Evaluation and selection were conducted independently at each site. Selections of farmers were performed in collaboration with the district's agricultural office and based on their willingness to participate as well as their knowledge of sesame crop production. Before farmers were going to evaluate and select the varieties, they were given clear awareness about how to select and order the varieties as per the procedure proposed by ARARI (2018, unpublished guideline). Farmers were provided with the evaluation criteria for the varieties based on their preferences and discussed each listed trait and prioritized capsule per plant, plant height, primary branches per plant, lodging tolerance, uniformity in maturity, and earliness. A direct matrix is employed to evaluate varieties based on those traits. Farmers used a 1 to 5 scale of ranking, in which 1 refers to poor, 2 = fair, 3 = moderate, 4 = good, and 5 = excellent (de Boef *et al*., 2013). Finally, varieties were ranked using the product of the rank of the total acceptance of the farmers and the weight of the traits given by farmers.

Figure 2. Agronomic performance of sesame varieties in the mother trial (left panel) and baby trial (middle panel), and farmers' evaluation and preference ranking of sesame varieties (right panel) under irrigation

Demonstration of farmer-selected varieties

The first preferred varieties, namely Adi and Ado, along with variety Abasena from the PVS trial, were demonstrated at six farmers' fields on a plot size of 10 x 10 m in the 2022 irrigation season. A non-replicated plot was used to demonstrate the varieties by applying similar agronomic practices as described in the PVS trial. It was managed in coordination with researchers, host farmers, and district agricultural extension experts. Agricultural extension workers (3 M), hosts and follower farmers (15 M, 11 F), and researchers (4 M) participated during the demonstration and selection procedures. Farmers were selected by considering the gender disaggregation, experience in cultivating sesame, and willingness to participate in the varietal demonstration process. Before the start of evaluation and selection in the field, the participants were oriented about the objective of the demonstration and their role in the course of varietal evaluation. Farmers established their own criteria for evaluating demonstrated varieties, and traits of preference were recorded using the methods as indicated in the above PVS section (Lelo *et al*., 1995; de Boef *et al*., 2013).

Pre-scaling up of farmer-preferred varieties

Pre-scaling up was conducted for two years (2023 and 2024). Farmers during the PVS and demonstration phase expressed higher interest in hosting and participated in the pre-scaling-up activity. Accordingly, both large-scale and small-scale producer host farmers were selected using a cluster approach at two sites, covering a total of 5 hectares of land, and supplied with pre-basic seed of the selected Adi variety each year. Field management activities were done by the host farmers, and they were informed and agreed to deliver seeds from their harvest to the other farmers either in the form of cash or seed exchange for the subsequent irrigation and cropping season. Training was given to participant farmers, district experts, and development agents on the improved sesame production packages under irrigation. A multi-disciplinary team of researchers and agricultural experts made regular field visits to observe the progress, fix problems, and give advice on proper field and crop management practices, starting from land preparation to harvesting.

Field day organization

Field days were conducted during the physiological maturity stage of the crop in both 2023 and 2024 to evaluate the performance of the pre-scaled Adi sesame variety and promote its wider dissemination under irrigation. The events involved a range of stakeholders, including farmers, Kebele development agents (DAs), district and zonal agricultural experts, and administrators (Table 2).

Table 2. Number of participants in the field day for the pre-scaling-up of the Adi variety under irrigation

Participant category	Male	Female	Total
Farmers	151	12	163
Kebele experts/DAs	6	4	10
District agri. experts & administrators	4	1	5
Zonal agri. experts & administrators	4	3	7
Total	165	20	185

Participants were selected based on their interest in irrigated sesame production. During the field days, host farmers shared their experiences and observations regarding the management practices and performance of the variety under field conditions. Feedback from participants was systematically collected and documented, followed by discussions on strategies to enhance sesame production and productivity under irrigation and improve seed availability of preferred varieties within the target districts. The pre-scaling-up activity was implemented using a cluster-based approach involving seven host farmers in 2023 and eleven host farmers in 2024. Given the limited experience of farmers with irrigated sesame production in the study area, comprehensive training on recommended agronomic practices was provided each year before implementation. Seed yield data (kg ha^{-1}) were collected from all host farmers and averaged to assess the performance of the variety across seasons.

Data analysis

Data were analyzed using R software. Prior to analysis, the assumptions of normality and homogeneity of variances were assessed using the Shapiro–Wilk and Levene's tests, respectively. Analysis of variance (ANOVA) was performed, and treatment means were compared using the least significant difference (LSD) test at the 5% significance level. Farmers' varietal preferences were evaluated using a direct matrix ranking approach.

RESULTS AND DISCUSSION

Agronomic performance of varieties

Significant difference ($p < 0.05$) was observed among the varieties evaluated in the mother trial for the measured traits under irrigation for phenological, seed yield, and yield-related traits except for the number of branches per plant (Tables 3 and 4). This study's results agree with the findings of Alhassan *et al*. (2025) and Fiseha Baraki *et al.* (2020), who evaluated sesame varieties under irrigation and found significant differences.

In the results, wide variation was detected among the varieties for days to maturity (111 - 127), plant height (123.3 - 175.6 cm), capsule bearing zone (53.8 - 86.7 cm), capsule length (2 - 3.4 cm), number of capsules per plant (48 - 83.1), seeds per capsule (42.1 - 67.3), and 1000-seed weight (2.2 – 3.7 gram) (Table 3 and 4). Seed yield is one of the most important and complex quantitative traits in crops. The analysis of variance for seed yield revealed a range from 1095.3 to 2084 kg ha^{-1}, with an overall mean of 1504.1 kg ha^{-1}. The highest seed yield was recorded from Ado variety (2084 kg ha^{-1}), followed by Adi (1891.5 kg ha^{-1}) and Chalasa (1728.9 kg ha^{-1}), while the lowest yield was observed in Setit-1 variety (1095.3 kg ha^{-1}) (Table 4). Previous studies have shown that sesame seed yield is governed by multiple loci and influenced by the interaction of genotypic, phenotypic, and environmental factors (Agrawal *et al*., 2017; Zhang *et al*., 2019). In the current study, key traits contributing to sesame seed yield included length of capsule-bearing zone, capsule length, capsule per plant, seeds per capsule, and thousand-seed weight. The observed yield differences may be attributed to genetic variation among the varieties, with environmental factors also potentially contributing to these variations. The results are consistent with the findings of Awoke Tadesse and Muhaba Sultan (2022) and Mohammed Hassen and Daniel Endale (2023), who observed significant differences among sesame varieties.

In the present study, the maturity date indicated a significant variation, with the shortest date of maturity (111 days) being recorded from BeHa-necho, while the longest maturity date (127 days) was recorded from Tate variety. The observed variation in maturity duration can be attributed to genetic and environmental differences in how the varieties respond to environmental factors. Similar findings were reported by Tewoderos Legesse and Bekelech Sharew (2024), who reported that maturity date variation ranging from 82 to 120 days was detected in sesame varieties. The plant height trait displayed a wide range of values, from 123.3 to 175.6 cm, with varieties exceeding the mean of 149 cm being potential varieties for maximum capsule-loading. The tallest plant height (175.6 cm) was found at variety Benshangul-1, while the lowest value (123.3 cm) was recorded at Setit-2. Abasena variety also resulted in better plant height than the mean value (149 cm). The results showed that taller plant height did not necessarily result in higher seed yield. This may be attributed to the fact that plant height alone is not a direct determinant of yield, as seed yield in sesame is influenced by the combined effects of yield-contributing traits. In consistent with this finding, Amare Kebede (2017), Tadese Mesera1 and Misgana Mitiku (2017), and Fiseha Baraki *et al*. (2020) noted significant plant height differences among sesame genotypes and varieties. The highest capsule-bearing zone (86.7 cm) was recorded on Setit-2 variety, while the lowest (53.8 cm) was recorded on Dangur variety. The results align with Fiseha Baraki and Muez Berhe (2019) and Tewoderos Legesse and Bekelech Sharew (2024), who reported significant differences in the length of the capsule-bearing zone among sesame genotypes. In the present study, varieties with a longer capsule-bearing zone produced a moderate number of capsules per plant, which contributed to achieving optimum seed yield. This suggests that an extended capsule-bearing zone may enhance yield potential by providing greater capacity for capsule development and seed production. This result is supported by Sintayehu Gedifewa *et al*. (2024) and Raju *et al*. (2025), who reported that the capsule-bearing zone contributes positively to seed yield.

Capsule number per plant showed a significant difference among varieties. Ado, Adi, and Dangur varieties produced a large number of capsules per plant, while Dangur and Setit-1 produced the least (Table 3). Similarly, on the sesame crop, Tewoderos Legesse and Bekelech Sharew (2024) obtained varietal effects on the number of capsules per plant and seeds per capsule. The ANOVA also revealed that there was significant variation among varieties in hundred-seed weight, similar to other traits. Adi variety exhibited the highest 1000-seed weight (3.7 g), followed by Tate (3.6 g) and Ado (3.5 g). The lowest 1000-seed weight was found in the local variety (2.2 g) (Table 4). The highest 1000-seed weight of sesame varieties might be attributed to their relatively larger seed size and greater assimilate accumulation in the developing seeds. This indicates that seed weight is an important yield component that contributes to overall productivity and should be considered in sesame variety selection and breeding programs. Previous studies have also identified thousand-seed weight as a key yield-related trait with a positive association with seed yield in sesame (Wang e*t al*., 2024). This result is also supported by Enaney Tigabu *et al.* (2020), who found significant variation in 1000-seed weight and seed yield among sesame varieties.

Table 3. Mean performance of sesame varieties evaluated under irrigation at Metema District, Northwestern Ethiopia, during the 2019 irrigation season

Varieties	**Traits**				
	MD	**PH (cm)**	**NB**	**LP (cm)**	**PL (cm)**
Humera-1	120	136.4	2.9	79.1	2.2
Setit-1	121	127.2	3.5	85.9	2.2
Setit-2	116	123.3	2.4	86.7	2.9
HuARC-4	119	130.9	2.9	82.7	2.6
Abasena	123	167.7	3.6	82.6	2.7
Adi	121	161.5	3.6	73.2	2.5
Tate	127	147.2	4.6	71.9	2.1
Ado	121	139.9	3.7	68.6	2.1
Obsa	119	146.4	3.6	66.2	2.2
Chalasa	122	152.3	3.1	67.9	2.2
Dangur	124	151.7	2.5	53.8	2.1
Gondar-1	115	161.1	3.5	71.8	2.4
Mechale	115	151.6	2.9	70.9	2.2
Benshangul-1	116	175.6	3.7	65.6	2.4
BeHa-necho	111	152.6	3.3	62.4	2.0
BeHa-zeyit	114	154.1	3.5	71.0	2.2
Local	120	148.7	3.3	63.3	3.4
Mean	119	149.0	3.3	71.9	2.3
CV (%)	3.2	6.3	21.9	15.2	8.7
LSD $_{(0.05)}$	6.4	15.5	1.2	18.1	0.4
Significance	*	**	NS	*	**

*MD = Days to 90% maturity, PH = Plant height (cm), NB = Number of primary branches per plant, LP = Length of capsule bearing zone (cm), PL = Capsule length.

Farmers' varietal preferences

Participatory varietal selection (PVS) plays a crucial role in identifying farmers preferred improved varieties, offering a sustainable solution to the challenges that force farmers to cultivate low-yielding, stress-prone landraces (Courtois *et al.,* 2001). The selection criteria used by farmers to evaluate the sesame varieties, and the results of the preference analysis, are presented in Table 5. Farmers defined their own varietal selection criteria and were eager to compare and rank these criteria based on their importance using a pairwise ranking method.

Accordingly, the number of capsules per plant, uniform maturity, number of branches, lodging tolerance, plant height, and earliness were the traits considered and were ranked 1st, 2nd, 3rd, 4th, 5th, and 6th, respectively (Table 5).

As indicated above, the number of capsules per plant received the highest weight, as it was most frequently favored by farmers as a selection criterion and therefore placed first. This indicates that capsules per plant is the most important factor in sesame cultivation, as it has a direct influence on productivity.

Table 4. Mean performance of sesame varieties evaluated under irrigation at Metema District, Northwestern Ethiopia, during the 2019 irrigation season

	Traits			
Varieties	**NP**	**SP**	**TSW (g)**	**GY (kg ha^{-1})**
Humera-1	67.9	42.7	3.3	1307.9
Setit-1	70.4	42.1	3.2	1095.3
Setit-2	53.5	54.4	3.1	1462.2
HuARC-4	70.4	49.2	3.4	1552.3
Abasena	70.3	60.3	2.4	1570.3
Adi	82.1	45.3	3.7	1891.5
Tate	56.7	52.2	3.6	1649.2
Ado	83.1	58.5	3.5	2084.0
Obsa	61.9	55.5	2.4	1292.2
Chalasa	60.4	59.6	2.4	1728.9
Dangur	48.0	52.9	2.4	1411.9
Gondar-1	64.5	59.3	2.5	1551.3
Mechale	58.0	57.0	2.5	1175.3
Benshangul-1	64.2	55.5	2.5	1559.0
BeHa-necho	55.7	58.5	2.6	1511.7
BeHa-zeyit	56.6	52.8	2.7	1518.1
Local	58.0	67.3	2.2	1208.6
Mean	62.9	53.7	2.8	1504.1
CV (%)	8.3	13.1	5.3	16.3
LSD $_{(0.05)}$	8.7	11.8	0.25	408.0
Sig.	**	*	**	*

*NP = Number of capsules per plant SP = Number of seeds per capsule TSW = Thousand seed weight (gm) GY = Seed yield (kg ha^{-1})

Table 5. Direct matrix-based pairwise ranking of farmers' selection criteria and trait priorities for sesame participatory variety selection under irrigation at Metema District, 2019

Traits	**No. of capsules**	**Plant height**	**No. of branch**	**Lodging tolerant**	**Uniform maturity**	**Earliness**	**Total**	**Rank**
No. of capsules (1)							5	1st
Plant height (2)	1						1	5th
No. of branches (3)	1	3					3	3rd
Lodging tolerant (4)	1	4	3				2	4th
Uniform maturity (5)	1	5	5	5			4	2nd
Earliness (6)	1	2	3	4	5		0	6th

*Numbers in parentheses represent the codes of selection traits used in the pairwise comparison matrix

Many quantitative studies and participatory varietal selection studies converge that capsules per plant are a central trait for sesame yield and farmer preference (Desawi Hdru Teklu *et al.*, 2021; El-Kader *et al.*, 2022). Moreover, farmers' perception of earliness referred to a short growing period, consistent with how a breeder would normally interpret this trait. The rank of each selection criterion was considered as the weight of that criterion.

All the FREG members had a strong discussion during the evaluation of the test varieties of sesame at physiological maturity. Varietal preferences were determined following PVS principles, where end users drive variety choice and trait prioritization, with farmers using their own selection criteria as outlined in Table 5. Farmers' preference rating based on the aforementioned evaluation and selection criteria showed that Adi and Ado were the top-ranked varieties (high-yielding varieties), with the local variety being the third preference, under irrigation conditions in the Metema district (Table 6).

Table 6. Rank of sesame varieties based on farmers' preference weights under irrigation at Metema District, 2019

Varieties	**Traits**							
	NCPP	**PH**	**UM**	**Earliness**	**NBPP**	**LT**	**Total**	**Rank**
Humera-1	6	2	5	3	12	3	31	16th
Setit-1	6	2	5	2	4	3	22	17th
Setit-2	12	2	5	4	12	6	41	15th
HuARC-4	12	6	20	3	12	6	59	14th
Abasena	12	10	20	3	12	15	72	10th
Adi	24	10	25	4	16	15	94	1st
Tate	18	6	25	3	16	15	83	6th
Ado	24	10	25	4	12	15	90	2nd
Obsa	12	6	20	4	8	15	65	12th
Chalasa	12	6	20	3	8	15	64	13th
Dangur	18	8	20	3	12	15	76	8th
Gondar-1	24	10	15	4	12	15	80	7th
Mechale	12	6	25	5	4	15	67	11th
Benshangul-1	18	10	25	4	12	15	84	5th
BeHa-necho	24	10	25	4	12	12	87	4th
BeHa-zeyit	12	8	25	4	12	15	76	8th
Local	24	10	25	4	12	15	90	2nd

*NCPP=Number of Capsule per Plant, PH=Plant Height, UM= Uniform maturity, NBPP=Number of Branch per Plant and LT= Lodging Tolerance

This pattern, where improved varieties outcompete local checks and farmers favored improved varieties primarily for higher yield, branching, capsule number, early maturity, and overall adaptability, while retaining some appreciation for local checks. The emphasis on structured, farmer-led variety evaluation aligns with broader evidence that farmer participation in varietal selection enhances the identification and promotion of farmer-preferred, high-yielding cultivars and improves the likelihood of adoption (Lawali *et al*., 2024). Demelash Bassa *et al*. (2024) also emphasized the importance of farmer participation in variety selection. The results indicated that farmers' preferred varieties were also the highest-yielding, showing strong agreement between agronomic performance and farmers' selection. A similar trend has also been reported in previous studies of the sesame crop by Yasin Goa and Genene Gezahagn (2017).

Demonstration of farmer-selected varieties

Agronomic performance of demonstrated varieties

The demonstration results for the sesame varieties Adi, Ado, and the check variety Abasena are presented in Figure 3, which summarizes their mean seed yield under irrigation. The productivity of the improved variety Ado, evaluated with its recommended irrigation technology package, was superior to that of the check variety Abasena (Figure 3). Variety Ado recorded the highest seed yield (1,586 kg ha^{-1}), followed by Adi, while the check variety Abasena produced the lowest mean yield (887 kg ha^{-1}), which was about 44% lower than the highest-yielding variety. These results demonstrate the distinct performance and adaptability of sesame varieties under similar irrigated environmental conditions. Consistent with these findings, previous studies have also reported significant yield variation among sesame varieties grown under irrigation (Jahan *et al*., 2008; Fiseha Baraki *et al*., 2020; Awoke Tadesse and Muhaba Sultan, 2022), suggesting that both genetic factors and environmental conditions strongly influence sesame yield potential and underscoring the importance of appropriate variety selection for optimized productivity under irrigation. The observed yield gap between PVS and demonstration plots may be attributed to differences in management intensity and field conditions. In PVS trials, plots are managed under close supervision with timely irrigation and optimal agronomic practices at research stations, whereas demonstration plots (on-farm) often experience less precise management. Therefore, yield differences may arise due to variability in input use, irrigation scheduling, and overall agronomic management under farmer field conditions. Similar findings have been widely reported in previous studies (Snapp *et al*., 2002).

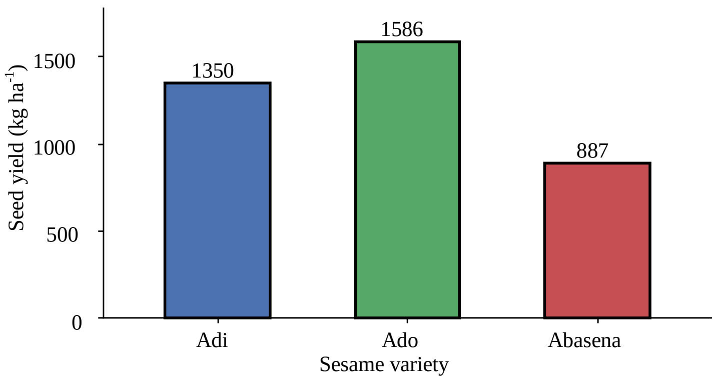

Figure 3. Mean seed yield of sesame varieties demonstrated under irrigation

Farmers' varietal preference in demonstrated sesame varieties

Participation of farmers and other agricultural stakeholders in agricultural research has gained increasing attention in recent years. Accordingly, in the present study, farmers and stakeholders were actively involved in identifying and prioritizing key agronomic and yield-related traits for the selection of sesame varieties under irrigated production conditions. The selected criteria included number of capsules per plant, number of branches per plant, plant height, disease tolerance, capsule length, stalk thickness, and maturity date (earliness). A pairwise ranking method was employed to evaluate the relative importance of these traits. The results revealed that the number of capsules per plant was the most preferred selection criterion, reflecting its direct contribution to seed yield. This was followed by the number of branches per plant, plant height, disease tolerance, capsule length, stalk thickness, and maturity date, which ranked 2nd, 3rd, 4th, 5th, 6th, and 7th, respectively (Table 6).

The predominance of yield-contributing traits among the top-ranked criteria indicates that farmers primarily emphasize attributes associated with productivity and economic returns when evaluating sesame varieties. Traits such as capsule number and branching capacity are widely recognized as major determinants of seed yield, while plant height and disease tolerance contribute to crop vigor, adaptability, and production stability. Although earliness was considered important, its relatively lower ranking suggests that farmers in the study area placed greater emphasis on yield potential and field performance than on early-maturing sesame variety under irrigation conditions. The varietal evaluation process involved 33 participants comprising 26 farmers, 3 agricultural extension officers, and 4 agricultural researchers. The participation of multiple stakeholder groups strengthened the evaluation process by integrating farmers' indigenous knowledge and production objectives with technical expertise from extension personnel and researchers. Such a participatory approach enhances the relevance and acceptability of improved varieties by aligning varietal selection with farmers' preferences and local production conditions. It also increases the potential for adoption of selected varieties by farming communities. Similar findings have been reported in sesame varietal demonstration and selection (Demelash Bassa *et al*., 2024; Lawali *et al*., 2024).

Table 6. Pairwise ranking matrix of traits for sesame varieties demonstration under irrigation

Traits	PL	BPP	PH	PPP	DT	MD	ST	Total	Weight	Rank
Capsule length (PL) (1)		2	3	4	5	1	1	2	3	5th
Branch/plant (BPP) (2)			2	4	2	2	2	5	6	2nd
Plant height (PH) (3)				4	3	3	3	4	5	3rd
Capsule/plant (PPP) (4)					4	4	4	6	7	1st
Disease-tolerant (DT) (5)						5	5	3	4	4th
Maturity date (MD) (6)							7	0	1	7th
Stalk thickness (ST) (7)								1	2	6th

The results of the farmers' preference analysis based on the evaluation criteria applied in the demonstration plots are presented in Table 7, where the evaluation was conducted using the criteria detailed in Table 6. The preference ranking indicated that

Adi was the most preferred variety, reflecting its high suitability and desirability based on the traits most valued by the farmers. Ado variety followed as the second preference. These rankings reveal the specific merits of these varieties that align with the needs and expectations of local farmers, highlighting the importance of matching crop selection to local agricultural practices and preferences. Even though the agronomic performance and farmers' preferences did not exactly coincide, farmers' voices were given priority since it was a farmer-based participatory trial. Farmers are the ultimate end-users of agricultural technologies, and their preferences play a critical role in determining the adoption and sustainability of improved varieties. Consequently, Adi was identified as the most preferred variety and was selected for subsequent pre-scaling-up activities.

Table 7. Farmers' varietal preference ranking on demonstration plots under irrigation in Metema district, 2022

Trait	**Varieties**		
	Adi	**Ado**	**Abasena**
Capsule number	96	110	64
Branch number	116	102	108
Plant height	120	66	120
Disease tolerant	104	118	76
Capsule length	114	68	76
Stalk thickness	102	66	106
Maturity date	76	114	58
Total value	1867	1639	1553
Rank	1	2	3

Participatory variety selection is increasingly recognized as an effective approach for enhancing the relevance and adoption of agricultural technologies by integrating farmers' knowledge, experiences, and production priorities into the research process. Similarly, Snapp *et al*. (2002) and Tripathi and Singh (2012) emphasized that active farmer participation in varietal evaluation facilitates the identification of superior varieties that are not only agronomically competitive but also responsive to farmers' needs and preferences. Comparable findings have been reported in several participatory sesame variety selection studies in Ethiopia, where varieties preferred by farmers often exhibited a combination of desirable agronomic performance, adaptability, and market-oriented traits, thereby improving their likelihood of adoption and wider dissemination.

Pre-scaling up of farmers' selected variety

Following the participatory variety selection and demonstration activities, the farmers' preferred sesame variety, Adi, was pre-scaled under farmers' field conditions to verify its performance under real farming conditions, facilitate wider dissemination, and improve farmers' access to quality seed. It was conducted using a cluster approach. In current farming, cluster-based pre-scaling-up approaches are increasingly recognized as more effective than scattered approaches, as they facilitate collective learning, enhance technology dissemination, and promote more efficient adoption among farmers (Dureti *et al*., 2023). The variety produced seed yields ranging from 1,250 to 1,410 kg ha^{-1} across sites, with an average yield of 1,330 kg ha^{-1} under irrigation during the pre-scaling-up. This result indicated the variety's adaptability to the irrigation environment in the test areas. Although seed yield during pre-scaling-up was lower than that obtained in the PVS and demonstration trial phases, the variety demonstrated stable performance under broader farmer-managed conditions. The yield difference is likely associated with greater field heterogeneity, variations in management practices, and the larger scale of implementation during pre-scaling-up, compared with the more controlled conditions of PVS and demonstration trials. Despite the observed yield variation, Adi maintained good adaptation and strong farmer acceptance under irrigated conditions, indicating its potential for wider dissemination and enhanced sesame productivity in the district.

A primary objective of farmer-based participatory varietal selection, demonstration, and promotion is to identify and promote varieties that are both favored by farmers and exhibit the best biological performance. To support this, a field day was organized at the physiological maturity stage of the crop to raise awareness among farmers and other stakeholders about the Adi variety during the pre-scaling-up activity. The event was attended by various stakeholders as indicated in the methodology section (Table 1). The field day provided a platform for farmers and stakeholders to exchange experiences and provide feedback on the performance of the Adi variety and the recommended irrigated sesame production package. Participants highly appreciated Adi for its high branch number, tall plant stature, thick stem, high capsule number, uniform maturity, attractive whitish seed color, and overall adaptability under irrigation. The host farmers were also recognized for properly implementing the recommended production practices. Overall, farmers responded positively to the pre-scaling activity, expressed strong interest in continuing the production of Adi, and committed to expanding its cultivation within their communities. Their active participation throughout the process enhanced their confidence in the variety and the recommended production package, demonstrating that participatory pre-scaling can effectively promote technology dissemination, farmer-to-farmer knowledge sharing, and the adoption of improved sesame varieties under irrigation (Dejene Mengistu *et al.*, 2025). Strengthening the supply of quality seed and providing continued technical support through extension services will further enhance adoption and contribute to increased sesame productivity and market competitiveness in the irrigated lowlands of northwestern Ethiopia.

CONCLUSION

The involvement of farmers in the process of evaluating and selecting crop varieties plays a crucial role in the adoption of improved varieties for production. The analysis of variance from the participatory varietal selection revealed significant differences among sesame varieties across most traits, including seed yield. Varieties Ado and Adi produced the highest seed yields, with yield advantages of 72.4 and 56.5%, respectively, over the local cultivar. Farmers considered the traits of each variety and ranked them based on their importance. Farmers preferred Adi and Ado as the first and second most preferred varieties because of its high yield, good capsule number, and overall adaptability. Despite Adi being the first variety farmers preferred, Ado gave the highest seed output (1586 kg ha^{-1}) during the demonstration experimentation. Considering both agronomic performance and farmers' preferences assessed through participatory variety selection, demonstration, and pre-scaling-up activities, Adi was identified as a suitable variety for irrigated production in Metema district. Although Ado showed higher yield potential, varietal superiority cannot be determined solely by yield, as both varieties possess distinct advantages. During the pre-scaling-up phase, Adi maintained stable performance under farmer-managed conditions, achieving a mean seed yield of 1,330 kg ha^{-1} and generating substantial demand among producers for seed and seed production under irrigation. Based on this, recommendations of both varieties to enhance varietal diversity and provide farmers with options tailored to their production objectives and local conditions. Nevertheless, given its superior yield potential, Ado deserves further scaling-up efforts, whereas Adi can be promoted for immediate wider dissemination in Metema and similar irrigated agro-ecologies of Northwestern Amhara. Strengthening seed multiplication, distribution, and exchange systems will be essential to ensure the sustainable adoption and effective dissemination of these varieties.

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