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Appraisal of the Sesame Production Opportunities and Constraints, and Farmer-Preferred Varieties and Traits, in Eastern and Southwestern Ethiopia

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Abstract: Sesame (*Sesamum indicum* L.) is an important oilseed crop with well-developed value chains. It is Ethiopia's most valuable export commodity after coffee (*Coffea arabica* L.), contributing to socioeconomic development. The productivity of the crop is low and stagnant in Ethiopia and other major sesame growing regions in sub-Saharan Africa (<0.6 t/ha) due to a multitude of production constraints. The objective of this study was to document sesame production opportunities and constraints, as well as farmer- and market-preferred varieties and traits, in eastern and southwestern Ethiopia as a guide for large-scale production and breeding. A participatory rural appraisal (PRA) study was conducted in two selected sesame growing regions and four districts in Ethiopia. Data were collected from 160 and 46 sesame farmers through semistructured questionnaires and focus group discussions. Sesame is grown by all respondent farmers in the study areas for food and as a source of cash. Most respondent farmers (56%) reported cultivating sesame using seeds of unknown varieties often sourced from the informal seed sector. About 83% of the respondents reported lack of access to improved seeds as the most important production constraint, followed by low yield gains from cultivating the existing varieties (reported by 73.8% of respondents), diseases (69.4%), and low market price (68.8%). Other production constraints included insect pests (59.4%), lack of market information (55%), and high cost of seed (50%). The above constraints were attributed to the absence of a dedicated breeding programme, lack of a formal seed sector, poor extension services, and underdeveloped pre- and postharvest infrastructures. The most important market-preferred traits of sesame included true-to-type seed (reported by 36.3% of respondents), white seed colour (28.8%), and high seed oil content (23.8%). The vital farmer-preferred attributes included reasonable market price (reported by 11.3% of respondents), resistance to crop diseases (10.9%), drought tolerance (10.3%), resistance to crop insect pests (9.2%), higher seed yield (8.9%), higher thousand-seed weight (7.2%), higher oil content (6.3%), white seed colour (6.1%), early maturity (6.1%), and good oil qualities such as aroma and taste (5.7%). Therefore, there is a need for a dedicated sesame genetic improvement programme by integrating the above key production constraints and market- and farmer-preferred traits to develop and deploy new generation varieties to enhance the production, productivity, and adoption of sesame cultivars in Ethiopia.

Keywords: Ethiopia; market-preferred traits; participatory rural appraisal; production constraints; *Sesamum indicum*

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1. Introduction

Sesame (*Sesamum indicum* L.) is an important oilseed crop valued in the food, feed, and cosmetics industries. The seed oil content of sesame is the highest (60%) when compared to other oilseed crops such as soybean (~20%), rapeseed (~40%), sunflower (~45%), and groundnut (45-56%) [1–5]. The seed oil is a rich source of protein (~24%), carbohydrate (~13.5%), vitamins (e.g., A and E), lignans (sesamin and sesamolin), and lipids [4,6–8]. Sesame seed has essential nutritional benefits to human health, including antioxidant, antiaging, antihypertensive, anticancer, and cholesterol-lowering properties. Further, the sesame oil seedcake contains about 32% crude protein (CP) and 8-10% oil serving as an essential feed for livestock and poultry [9]. The sesame biomass is used for animal feed, soap production, compost manure, and the production of potash, a cooking ingredient widely used in West African countries [10]. These and other benefits make sesame a highly valued industrial crop globally [11].

Sesame is Ethiopia's second most crucial export crop after coffee (*Coffea arabica*). In 2020, the area allocated for sesame production was 375,119.95 ha, 45.7% of the estimated area under oil crop production [12]. It is an eminent crop and a significant contributor to the gross domestic product in Ethiopia [13]. Globally, a total of 2,211,339 tons of sesame grain was traded with a monetary value of 3.4 trillion USD in 2019 [14]. In 2019, sub-Saharan African countries exported about 1,465,493 tons of unprocessed sesame with a cash value of 1.9 trillion USD [14]. In 2019, Ethiopia's sesame export share was 8.96% of global exports, valuing 307 million USD [14]. In terms of global total sesame production, Ethiopia ranked ninth in 2019 with an annual production of 262,654 tons, after Sudan (1,210,000 tons), Myanmar (744,498 tons), India (689,310 tons), Tanzania (680,000 tons), Nigeria (480,000 tons), China (469,104 tons) and China Mainland (467,000 tons) [14].

In Ethiopia, sesame is mainly produced for household food and as a source of cash. It is predominantly grown by smallholders (95.5%) and medium-to-large commercial farmers (0.5%) under rainfed conditions. Sesame production is primarily localized in the lowland areas of the country, where drought and heat stresses are common episodes. According to the Ethiopian Central Statistical Agency (CSA), during the 2019/2020 production seasons, the total area and volume of sesame production under medium-to-large commercial farming conditions was the highest in Tigray (56.42%), followed by Amhara (32.03%), Benishangul-Gumuz (7.25%), and Oromia (3.17%), whereas the total area and volume of production under smallholder farming systems was the highest in Amhara (51.82%), followed by Tigray (30.88%), Oromia (9.41%), and Benishangul-Gumuz (7.34%) [15].

The productivity of sesame is low and stagnant in Ethiopia and other major sesame growing regions in sub-Saharan Africa (<0.6 t/ha) because of many production constraints. The low yield of sesame is attributable to a lack of high-yielding and well-adapted varieties, susceptibility to capsule shattering, the prevalence of biotic and abiotic stresses, and a lack of modern production technologies such as optimal agronomic managing practices, row planters, harvesters, and storage facilities [6,10,16–19]. Furthermore, Ethiopian farmers use landrace varieties of the crop that are inherently low yielders and prone to capsule shattering, leading to reduced productivity and low income. However, landraces are highly valued for having farmer-preferred attributes such as unique taste, aroma, and adaptation to grow under low-input farming systems and marginal agricultural lands. Consequently, these production constraints have yet to be systematically studied, prioritized, and documented in Ethiopia to guide research and development of the crop.

The sesame breeding research in Ethiopia was started in the late 1960s by the Ethiopian Agricultural Research Institute (EIAR) based at the Melka Werer Agricultural Research Centre (WARC) [20]. From 1960 to 1979, some introduced landrace collections were used to initiate the sesame breeding programme in the country. The local sesame breeding programme has mainly focused on characterization and mass selection of landrace collections for desirable traits for direct recommendation and large-scale production, marketing, and breeding. For instance, a total of 32 improved sesame verities were developed and released by the EIAR through mass selection from among the local germplasm collections [21]. The sesame varieties designated as Humera-1 and Setit-1 were released by the Humera Agricultural Research Centre (HuARC) in 2010. These varieties are widely grown by farmers for their early maturity, better yield response, and broad adaptability. The yield response of these varieties is low (<1.00 ton/ha), below the reportedly attainable yields of the crop at 2.53 and 1.62 tons/ha in Israel and China, respectively [14]. Therefore, sesame breeding programmes are required to select and identify desirable genotypes for practical breeding, genetic analyses, gene discovery, and developing high-performing and framer-preferred varieties. Sesame genetic improvement programmes should be guided by the prevalent production constraints of the growers as well as farmer- and market-preferred traits. These conditions will enable the development and deployment of new varieties according to the needs and preferences of the value chain, including participants such as farmers, traders, oil processors, and consumers.

Farmers are the main actors in agriculture enterprises, with a wealth of indigenous knowledge about their crops, farming systems, and constraints, and they have the means to adopt a technology [22]. Participatory rural appraisal (PRA) is a multidisciplinary research approach that aims to incorporate knowledge and opinions of farmers in the planning and management of research development projects and programmes [23]. PRA studies have been conducted in Senegal and Mali to initiate sesame research programmes and develop policies that optimized sesame production and improved farmers' livelihoods [10]. Through a PRA study, Dossa et al. [10] identified a lack of marketing, a decline in soil fertility, limited access to land, drought stress, backward agricultural implements, a lack of extension service, and limited access to agricultural inputs as most essential constraints on sesame production in Senegal and Mali. Myint et al. [24] reported insect pests, postharvest loss, drought, and salinity stresses as the overriding sesame production constraints in Myanmar. In Ethiopia, Abady et al. [25] used PRA tools. They reported drought stress, poor soil fertility, poor supply of improved seed, preharvest diseases (e.g., root rots and leaf spots), low-yielding varieties, poor access to extension services, poor access to credit, and limited availability of improved varieties as key challenges for groundnut production.

Additionally, in Ethiopia, Sori [26] reported limited access to credit and scarcity of land as affecting the magnitude of groundnut supply to the marketplace. In Ethiopia, no recent study has documented farmers' perceptions of the production constraints on sesame and the preferred traits that farmers, market, and the value chain require in a new sesame variety. Therefore, the objective of this study was to document sesame production opportunities and constraints and farmer- and market-preferred varieties and traits in eastern and southwestern Ethiopia as a guide for large-scale production and breeding. Consequently, this will serve as market research to guide variety design and development and to develop a successful marketing strategy.

2. Materials and Methods

2.1. Description of the Study Areas

The study was conducted in 2021 in two regions in Ethiopia: the Oromia region, in the Babile and Gursum districts in eastern Ethiopia, and in the Southern Nations, Nationalities, and Peoples' (SNNP) region in Melekoza and Basketo districts. The study areas are among Ethiopia's major sesame growing belts (Table 1 and Figure 1). Babile and Gursum have a predominantly well-drained sandy loam soil that is ideal for sesame production. The rainfall distribution of the areas is bimodal, with the main rain (locally referred to as Meher rain) received during July to October and short rain (locally known as Belg rain) during March to May [27]. The mean annual maximum and minimum temperatures are 28.1 °C and 15.5 °C, respectively, with the total annual rainfall ranging from 507 to 984 mm in the Babile district. The Gursum district receives an annual rainfall between 600 and 900 mm, with average temperatures varying between 25 and 33.5 °C. The predominant soil types of the Melekoza and Basketo districts are sandy soil with clay textures, ideal for sesame production. The rainfall distribution of the areas is bimodal, with the main rain received during July to October and short rain during March to May. The annual average rainfall is 750–1500 mm and 1000–1400 mm in the Melekoza and Basketo districts, respectively, during the primary cropping season (June to August) [28]. During the study, the minimum and maximum temperatures in Melekoza district were 15.1 to 27.5 °C, while those in Basketo were 15 and 27 °C, respectively [28].

Table 1. Agroclimatic and soil characteristics of the study areas.

Region	District	Villages	Altitude (Meter above Sea Level)	Geographic Coordinates	Annual Rainfall (mm)	Temperature (°C)	Soil Type
Oromia	Babile	Eibada Gemechu Ramata Salama	1642	9°13′09″ N, 42°19′25″ E	507–984	15.5–28.1	Sandy loam
	Gursum	Abadir Oda	1648	9°14′60.00″ N, 42°14′60.00″ E	600–900	25–33.5	Chromic vertisol
SNNP	Melekoza	Salaysh Mender 01 Salaysh Mender 03	1395	6°29′59.99″ N, 36°39′59.99″ E	750–1500	15.1–27.5	Sandy loam
	Basketo	Angela 03 Angela 04	1600	6°15′0.00″4 N, 36°34′59.99″ E	100–1400	15–27	Sandy loam

SNNP, Southern Nations, Nationalities, and Peoples'.

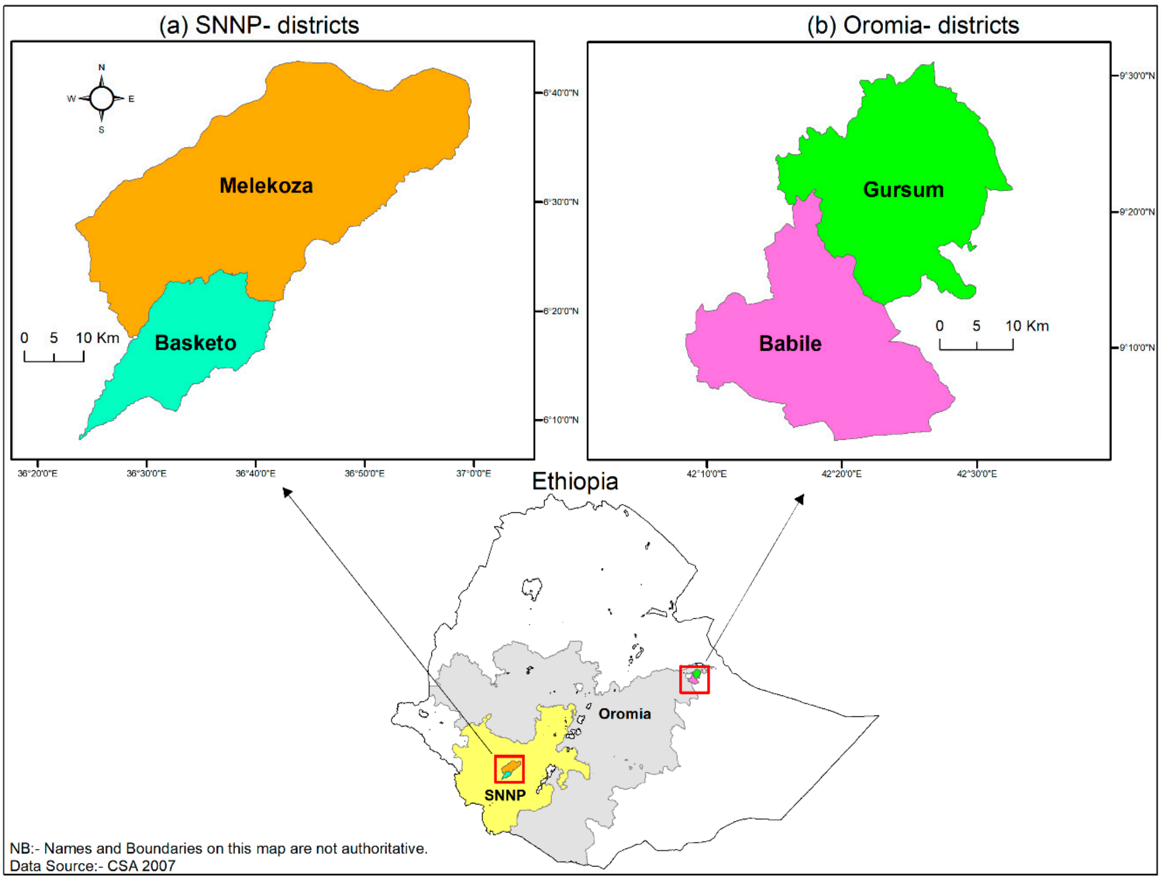

Figure 1. Map of Ethiopia showing the study sites shown with red squares: (**a**) SNNP districts (Melekoza and Basketo); (**b**) Oromia districts (Gursum and Babile). CSA, Central Statistical Agency; SNNPS, Southern Nations, Nationalities, and Peoples'.

2.2. *Questionnaire Design and Sampling Procedures*

A semistructured questionnaire and focused group discussions (FGDs) were used to collect data in the study areas. Data collected from FGDs were used to support and validate the information obtained from the semistructured questionnaire. A purposive sampling procedure was employed to select two sesame-growing regions, i.e., Oromia and SNNP, in Ethiopia. Figure 2 presents the sampling method, showing the selected regions, zones, districts, and villages for the study. From the Oromia region, two districts were selected from the east Hararghe zone (Babile and Gursum districts). In each district, two villages, locally referred to as 'kebeles', were subsampled, i.e., Eibada Gemechu and Ramata Salama in the Babile district and Abadir and Oda Oromia in the Gursum district. From the SNNP region, two districts were selected (Melokoza district from Gofa zone and Basketo district).

The Basketo district is a special district that is locally referred to as 'special wereda', and it does not have a zonal classification. In each district, two villages, i.e., Salaysh Mender 01 and Salaysh Mender 03 (Melekoza district) and Angela 03 and Angela 04 (Basketo district), were selected (Table 1). A random sampling method was used to select farmers from each village for interviews. Farmers were selected irrespective of wealth status and age group.

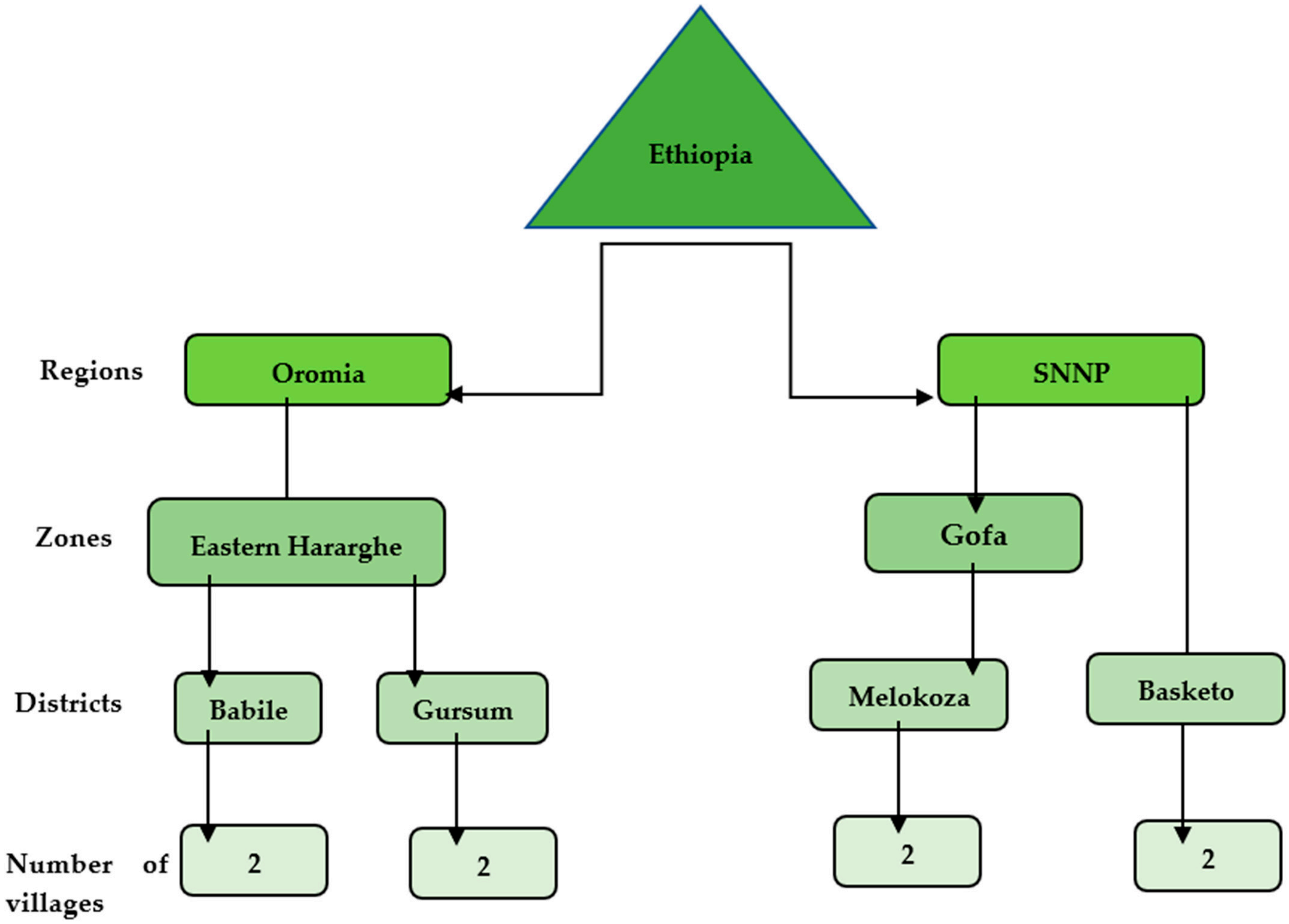

Figure 2. Sampling method cascading the selected regions, zones, districts, and villages for the study.

The farmers were selected with the assistance of the agricultural extension offices of the districts and villages. Based on the degree of homogeneity of the population, sesame production, and time and resource availability, 20 households from every eight villages were randomly sampled, providing a total of 160 respondents, of which only 14 (9%) were women-headed households (Table 2). FGDs were used to support and validate the interview data obtained from the semistructured questionnaire. The data collected from the FGDs included information on improved varieties, seed sources, seed and grain price, market information and challenges, and production constraints. The FGDs were held in four groups in six villages with 7 to 10 farmers per group across the four districts, except for Eibada Gemechu and Angela 03 villages in Babile and Basketo districts, respectively (Figure 3).

Table 2. Social and demographic information of respondent farmers in the study areas (%; n = 160).

Variable	Class	Districts				%Mean	* df	Chi-Square	*p*-Value
		Babile	Basketo	Gursum	Melokoza				
Gender	Female	7.5	17.5	2.5	7.5	9.00	3	5.949	0.114
	Male	92.5	82.5	97.5	92.5	91.00			
Family size	2–5	25.0	22.5	25.0	22.5	23.75	6	1.377	0.967
	6–10	67.5	70.0	72.5	70.0	70.00			
	11–15	7.5	7.5	2.5	7.5	6.25			
Age (years)	18–29	17.5	20.0	27.5	12.5	19.38	6	4.162	0.655
	30–50	72.5	75.0	62.5	80.0	72.50			
	52–65	10.0	5.0	10.0	7.5	8.13			
Education level	Illiterate	42.5	37.5	27.5	12.5	30.00	12	20.319	0.061
	Read and write	20.0	15.0	20.0	10.0	16.25			
	Primary school (Grade 2 to 8)	35.0	42.5	50.0	67.5	48.75			
	Secondary school (Grade 9 to 12)	2.5	2.5	2.5	10.0	4.38			
	College	0.0	2.5	0.0	0.0	0.63			

* df, degrees of freedom.

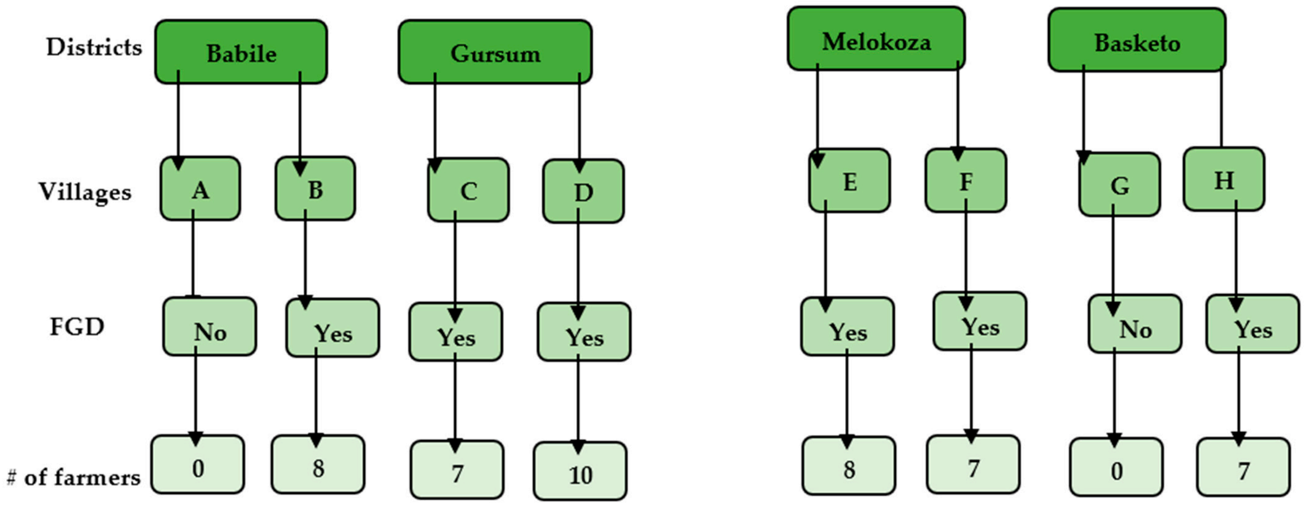

Figure 3. Sampling structure for the focused group discussions (FGDs) in study districts. Villages are denominated as follows: A, Eibada Gemechu; B, Ramata Salama; C, Abadir; D, Oda; E, Salaysh Mender 01; F, Salaysh Mender 03; G, Angela 03; and Angela 04.

2.3. Data Collection

Both primary and secondary data were collected. Primary data were collected through interviews using a semistructured questionnaire and focus group discussions. The responses of the selected farmers were based on their 2020 sesame farming experience. Enumerators were well-trained, and the questionnaires were pretested to ensure that enumerators understood the subject area, to create a clear awareness among the interviewees, and to improve the clarity of questions for proper data collection. Data were collected through the semistructured questionnaire on demographic characteristics of the households, farm sizes, the farming systems used, the sesame area cultivated and the productivity status thereof, seed systems, production constraints, important crop traits preferred by farmers, and market accessibility. Secondary data, such as area coverage, production, and productivity of the crop, were collected from the respective districts of agricultural offices used in the study.

2.4. Data Analysis

Both quantitative and qualitative data were coded and subjected to analysis using the Statistical Package for the Social Sciences (SPSS) software version 20 [29]. The quantitative data were coded before analysis. Descriptive statistics, such as frequencies and percentages, were calculated. In addition, chi-square and t-tests were performed using the cross-tabulation procedure of SPSS.

3. Results

3.1. Sociodemographic Description of Respondent Farmers

One hundred sixty smallholder farmers were interviewed individually using semistructured questionnaires; of these, 46 participated in focus group discussions. Table 2 shows the demographic characteristics of the participants. Of the 160 smallholder farmers interviewed, 91% and 9% were males and females, respectively. Gursum district had a relatively higher number of male respondents (97.5%), followed by Babile and Melokoza districts (92.5% each), while Basketo district had 82.5% male participants.

Seventy percent of the households had a family size of 6 to 10 individuals, while 24% had 2 to 5 individuals. Polygamy is a common culture in the study areas and is linked with the high population growth rate in the rural areas. The majority (73%) of the households were between 30 and 50 years of age, indicating that the middle-aged adult farmers were highly engaged in sesame production in the study areas. Nineteen percent of the participants ranged from 18 to 29 years of age, while eight percent were between 51 and 65 years of age. About 49% of the respondents had attended primary school, while 30% of the participants could not read and write. The rest of the respondents were able to read and write (16%) or had attended secondary school (4%) and college (0.6%) (n = 160).

3.2. Main Socioeconomic Activities in the Study Districts

Off-Farm Income Sources of Farmers

Table 3 presents the off-farm income sources of the respondent farmers. The result showed that about 4% of the respondents earned off-farm income, most frequently through a daily labourer wage and trading, followed by carpentry, serving in churches, construction sectors, and pensions. The majority (88%) of the households did not have off-farm income sources except for crop production and livestock rearing.

Table 3. Off-farm income sources of participants in the study areas (%; n = 160).

Income Sources	Districts				%Mean	* df	Chi-Square	*p*-Value
	Babile	Basketo	Gursum	Melokoza				
None	95.0	78.0	90.0	88.0	87.500	18	23.410	0.175
Daily labour	5.0	5.0	5.0	0.0	3.750			
Trader	0.0	5.0	0.0	10.0	3.750			
Builder	0.0	0.0	3.0	0.0	0.625			
Carpenter	0.0	5.0	3.0	0.0	1.875			
Church employ	0.0	5.0	0.0	3.0	1.875			
Pension	0.0	3.0	0.0	0.0	0.625			

* df, degrees of freedom.

3.3. Farmers' Awareness of Sesame Varieties

About 62% of the farmers had information regarding improved sesame varieties. Framers received information about the new varieties via development agents (34%) and local radio programmes (25%). About 38% of participant farmers were not aware of the improved varieties (Table 4). The following sesame varieties were known and cultivated in the study areas: Humera-1, Abasena, Wollega, Adi, and unnamed. There was a highly significant difference ($p < 0.00$; $\chi^2 = 158.71$) in the sesame varieties cultivated among the four districts. The majority (56%) of the farmers cultivated sesame using unnamed varieties. About 38% of respondent farmers sourced sesame seeds from neighbours through farmer-to-farmer exchange and farm-saved seeds, while 19% of respondents sourced from local markets and 6% from nongovernment organizations such as Self Help, the Hararghe Catholic Secretariats (HCS), and the Catholic Relief Service (CRS) (Table 4). There were no government-linked sesame seed enterprises or cooperative seed production in the study areas. Also, there were no formal seed systems to support sesame production in the study areas except those provided by nongovernment organizations, which provided seeds for demonstration purposes some long years ago. In Melokoza and Basketo districts, 30% of the respondent farmers reported using sesame variety Humera-1, acquired through farmer-to-farmer exchange, farm saving, or the local market. During the FGDs, participants stated that Humera-1 was their chosen variety for its white seed colour, high oil content, and yield potential, fetching reasonable market price compared to other cultivars in the study areas. Sixty percent of the respondent farmers reported participating in technology transfer activities. About 38%, 14%, and 8% of farmers participated in farmer training centres (FTC), on-farm trials, and farmers' field days, respectively, and thereby received technical backstopping in sesame production (Table 5). About 38% of the respondent farmers reported that FTCs were the main sources of information and technology transfer methods.

3.4. Sesame Cropping System and Production Status

Sesame cropping systems and perceptions of production trends in the four districts are summarized in Table 5. There was a highly significant difference ($p < 0.00$; $\chi^2 = 108.542$) in sesame cropping systems among the four districts. Sixty percent of the farmers cultivated sesame as a sole crop, while 40% intercropped sesame with sorghum (37.5%), groundnut (8.75%), or maize (3.75%) (n = 160) (Figure 4). Most of the respondent farmers (41.88%) in the study areas practiced crop rotation of sesame with maize, followed by mung bean (18.75%), haricot bean (17.50%), and groundnut (9.38%). Crops and their areas of production in the study areas are summarized in Figure 5. Sesame had the most significant area coverage, followed by maize and sorghum (Figure 5). During the FGDs, the majority (46%) of the households reported the trend that sesame production areas had decreased, while 34% and 19% reported increasing and constant trends, respectively, for the last five years. The decreased area of sesame production was mainly attributed to a lack of improved varieties, abiotic and biotic stresses, and a lack of extension services and market linkage.

Table 4. Farmers' awareness about improved sesame varieties, seed sources, and participation in technology transfer activities in the study areas (%; n = 160).

Variable	Category	Districts				%Mean	* df	Chi-Square	*p*-Value
		Babile	Basketo	Gursum	Melokoza				
Seed source	Local market	22.5	10.0	40.0	2.5	18.75	9	84.000	0.000
	NGOs	12.5	12.5	0.0	0.0	6.25			
	Farmer to farmer	50.0	2.5	57.5	40.0	37.50			
	Farm saved	15.0	75.0	2.5	57.5	37.50			
Information about improved varieties	Yes	25.0	80.0	45.0	97.5	61.88	3	54.976	0.000
	No	75.0	20.0	55.0	2.5	38.13			
Source of information	No	75.0	20.0	55.0	2.5	38.13	9	97.809	0.000
	Local radio programme	20.0	17.5	37.5	25.0	25.00			
	Developmental agent	0.0	62.5	0.0	72.5	33.75			
	Farmer to farmer	5.0	0.0	7.5	0.0	3.13			
Varieties grown	Unnamed	100.0	57.5	65.0	2.5	56.25	12	158.711	0.00
	Humera-1	0.0	35.0	0.0	85.0	30.00			
	Abasena	0.0	5.0	0.0	0.0	1.25			
	Wollega	0.0	2.5	0.0	12.5	3.75			
	Adi	0.0	0.0	35.0	0.0	8.75			
Participation in technology transfer	Yes	35.0	80.0	35.0	90.0	60.00	3	42.500	0.000
	No	65.0	20.0	65.0	10.0	40.00			
Methods of technology transfer	No	65.0	20.0	65.0	10.0	40.00	9	67.323	0.000
	On-farm trials	20.0	7.5	22.5	7.5	14.38			
	Field days	2.5.0	10.0	2.5	15.0	7.50			
	FTC	12.5	62.5	10.0	67.5	38.13			

NGOs, nongovernment organizations; df, degrees of freedom, FTC, farmer training centre.

Table 5. Farmers' sesame cropping systems and perceptions of production trends in the study areas (%; n = 160).

Variable	Category	Districts				%Mean	* df	Chi-Square	*p*-Value
		Babile	Basketo	Gursum	Melokoza				
Cropping system	Sole cropping Inter cropping	12.5 87.5	100.0 0.0	27.5 72.5	100.0 0.0	60.00 40.00	3	108.542	0.000
Sesame intercropping with	Sorghum Groundnut Maize NA	80.0 12.5 7.5 0.0	0.0 0.0 0.0 100.0	28.0 9.0 3.0 0.0	0.0 0.0 0.0 100.0	37.50 8.75 3.75 50.00	9	162.819	0.000
Sesame rotation with	Maize Mung bean Haricot bean Groundnut None	17.5 0.0 25.0 25.0 32.5	42.5 45.0 10.0 0.0 2.5	40.0 0.0 35.0 12.5 12.5	67.5 30.0 0.0 0.0 2.5	41.88 18.75 17.50 9.38 12.50	12	98.490	0.000
Sesame production status in the last 5 years	Constant Increasing Decreasing	17.5 17.5 65.0	25.0 47.5 27.5	22.5 60.0 17.5	9.0 24 7.0	19.38 34.38 46.25	6	40.809	0.000

* df, degrees of freedom; NA, not applicable.

Figure 4. (**A**)—a sole crop of sesame; (**B**)—sesame intercropped with sorghum in Babile district; (**C**)—white seeded sesame preferred mainly by farmers (photos by Desawi H.).

3.5. Constraints to Sesame Production in Ethiopia

Farmers identified the major abiotic, biotic, and market constraints affecting sesame production in the study areas (Table 6). There was a highly significant difference ($p < 0.00$; $\chi^2 = 30.204$) among districts' access to improved seeds. Farmers' perceptions in regard to the assessed production constraints were further explored through FGDs. About 83% of households reported that lack of access to improved seeds was ranked as a leading constraint of sesame production. This was mainly attributed to the lack of government-linked sesame seed enterprises and cooperative seed production in the study areas. About 87.5 to 90% of the households reported low yield gains by the existing varieties as the second most crucial yield-limiting factor in the study areas.

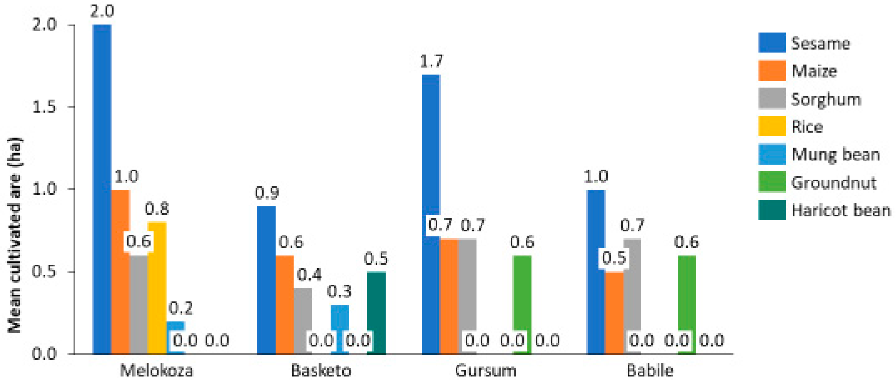

Figure 5. Mean cultivated area (ha) allocated for different crops grown in the study districts in the 2020/2021 cropping season.

Table 6. Percentage of farmers and reported sesame production constraints in the study areas.

Traits	Rank	Districts				%Mean	* df	Chi-Square	*p*-Value
		Babile	Basketo	Gursum	Melekoza				
Lack of access to improved seed	1st 2nd 3rd 4th	95.0 0.0 2.5 2.5	75.0 12.5 0.0 12.5	97.5 2.5 0.0 0.0	62.5 27.5 2.5 7.5	82.50 10.60 1.30 5.60	9	30.204	0.000
High cost of seed	1st 2nd 3rd 4th	65.0 7.5 25.0 2.5	37.5 20.0 10.0 32.5	80.0 12.5 0.0 7.5	17.5 25.0 30.0 27.5	50.00 16.25 16.25 17.50	9	52.019	0.000
Low-quality seed	1st 2nd 3rd 4th	37.5 7.5 30.0 25.0	50.0 20.0 0.0 30.0	55.0 10.0 20.0 15.0	25.0 45.0 15.0 15.0	41.88 20.63 16.25 21.25	9	36.955	0.000
Low yield	1st 2nd 3rd 4th	90.0 2.5 5.0 2.5	70.0 12.5 2.5 15.0	87.5 5.0 2.5 5.0	47.5 30.0 15.0 7.5	73.75 12.5 6.25 7.5.0	9	32.538	0.000
Climate change (Drought)	1st 2nd 3rd 4th	52.5 12.5 25.0 10.0	32.5 45.0 10.0 12.5	42.5 20.0 17.5 20.0	32.5 30.0 25.0 12.5	40.00 26.88 19.38 13.75	9	16.394	0.059
Insect pests	1st 2nd 3rd 4th	57.5 5.0 15.0 22.5	80.0 2.5 10.0 7.5	52.5 7.5 15.0 25.0	47.5 30.0 15.0 7.5	59.38 11.25 13.75 15.63	9	28.654	0.001
Diseases	1st 2nd 3rd 4th	77.5 0.0 17.5 5.0	82.5 7.5 2.5 7.5	65 12.5 22.5 0.0	52.5 30.0 10.0 7.5	69.38 12.50 13.13 5.00	9	8.726	0.001
Weeds	1st 2nd 3rd 4th	32.5 7.5 27.5 32.5	50.0 25.0 10.0 15.0	42.5 20.0 25.0 12.5	65.0 22.5 5.0 7.5	47.50 18.75 16.88 16.88	9	25.715	0.002
Lack of market information	1st 2nd 3rd 4th	42.5 5.0 25.0 27.5	87.5 5.0 2.5 5.0	30.0 15.0 27.5 27.5	60.0 17.5 12.5 10.0	55.00 10.63 16.88 17.50	9	37.449	0.000
Low market price	1st 2nd 3rd 4th	57.5 12.5 12.5 17.5	90.0 5.0 5.0 0.0	62.5 12.5 17.5 7.5	65.0 15.0 12.5 7.5	68.75 11.25 11.88 8.13	9	15.972	0.067

* df, degrees of freedom

3.6. Market-Preferred Traits of Sesame

Farmers identified white seed colour, increased seed size, true-to-type seed, high oil content, and increased thousand-seed weight as the most critical sesame market-preferred traits in the study areas (Table 7). Farmers in all the districts ranked true-to-type seed as the first market-preferred trait, followed by white seed colour and high oil content (n = 160). During the FGDs, farmers stated that the middlemen and district trade offices mysteriously engaged in market price fixing without farmers involvement. This indicates that there are no price regulations favouring the framer's involvement in sesame market systems in the study areas. Therefore, it is essential for the Ministry of Trade and Industry (MoTI) through the Ethiopian Commodity Exchange (ECX) to strengthen sesame marketing regulations and to avail farmers of market information.

Table 7. Percentages of farmers reporting sesame market-preferred traits in the study areas.

Traits	Rank	Districts				%Mean	* df	Chi-Square	*p*-Value
		Babile	Basketo	Gursum	Melekoza				
White seed colour	1st	27.5	37.5	17.5	32.5	28.75	12	25.624	0.012
	2nd	15.0	5.0	10.0	17.5	11.88			
	3rd	15.0	42.5	17.5	20.0	23.75			
	4th	20..0	12.5	30.0	17.5	20.00			
	5th	22.5	2.5	25.0	12.5	15.63			
High seed size	1st	10.0	0.0	12.5	5.0	6.88	12	29.69	0.003
	2nd	25.0	7.5	37.5	20.0	22.50			
	3rd	27.5	15.0	15.0	27.5	21.25			
	4th	25.0	55.0	32.5	27.5	35.00			
	5th	12.5	22.5	2.5	20.0	14.38			
True-to-type seed	1st	12.5	45.0	25.0	62.5	36.25	12	65.989	0.000
	2nd	27.5	22.5	20.0	22.5	23.13			
	3rd	27.5	30.0	35.0	10.0	25.63			
	4th	22.5	2.5	7.5	5.0	9.38			
	5th	10.0	0.0	12.5	0.0	5.63			
High oil content	1st	52.5	2.5	35.0	5.0	23.75	12	65.989	0.000
	2nd	2.5	0.0	15.0	17.5	8.75			
	3rd	7.5	12.5	7.5	25.0	13.13			
	4th	25.0	27.5	27.5	30.0	27.50			
	5th	12.5	57.5	15.0	22.5	26.88			
High 1000-seed weight	1st	10.0	20.0	5.0	0.0	8.75	12	72.709	0.00
	2nd	12.5	67.5	7.5	32.5	30.00			
	3rd	37.5	5.0	30.0	37.5	27.50			
	4th	10.0	2.5	22.5	22.5	14.38			
	5th	30.0	5.0.	35.0	7.5	19.38			

* df, degrees of freedom.

3.7. Farmer-Preferred Traits

In the present study, farmers selected sesame cultivars for production based on reasonable market price, resistance to diseases, drought tolerance, resistance to insect pests, high yield, increased 1000 seed weight, high oil content, and white seed colour, in that order (Table 8). During the FGDs, farmers described reasonable market price, high oil content, white seed colour, and high thousand-seed weight as market-preferred traits. These attributes attracted premium prices for sesame farmers.

Table 8. Farmer-preferred traits (% farmers) in sesame varieties in the study areas.

Traits	Districts				Mean
	Babile	Basketo	Gursum	Melekoza	
Yield potential	11.45	7.04	11.24	5.89	8.91
High oil content	9.63	3.45	8.73	3.52	6.33
High oil quality (e.g., aroma and taste)	6.97	4.21	6.98	4.74	5.73
Good market price	12.64	9.82	12.82	10.00	11.32

Table 8. *Cont.*

Traits	Districts				Mean
	Babile	Basketo	Gursum	Melekoza	
White seed colour	5.80	5.47	6.56	6.66	6.12
High 1000-seed weight	6.56	7.66	7.03	7.61	7.22
Tall plant height	5.44	1.43	5.31	2.69	3.72
High number of capsules	2.47	5.56	2.62	5.39	4.01
High number of branches per plant	5.70	6.47	4.73	4.89	5.45
Resistance to insect pests	7.26	10.65	7.24	11.52	9.17
Resistance to disease	9.42	12.19	9.31	12.60	10.88
Drought tolerance	9.00	11.06	8.94	12.37	10.34
Early maturity	3.95	10.57	4.47	5.41	6.10

4. Discussion

4.1. Sociodemographic Description of Respondent Farmers

The participation of male (91%) farmers was higher than female (9%) farmers in sesame production in the study areas (Table 2). The disparity indicates that male households dominated sesame production. In agreement with this finding, Dossa et al. [10] reported that more male than female farmers were involved in sesame production in Senegal and Mali. Gender imbalance also occurred in the findings of Abady et al. [25] on groundnut production in similar study areas of Ethiopia.

Most of the households had a family size of 6 to 10 individuals (Table 2). Mendola [30] suggested that the household is a significant source of labour in smallholder farming communities, suggesting that the larger the household size, the greater the labour force available to operate farming activities and minimize the cost of production.

The majority of the households were between 30 and 50 years of age (Table 2). It is believed that this active age group plays a crucial role in decision-making, improving the local economy, adopting improved technologies, and conducting farm operations. Previously, these demographic groups were reported in the sesame production areas in Senegal and Mali [10].

About 49% of the respondents had attended primary school, followed by 30% who were unable to read and write. A household's education level has a great impact on the management of the family's livelihood and active participation in decision making, adoption of technologies, and farm operations [31]. Farmers with no formal education are unwilling to adopt improved technologies and extension services and rely on traditional farming practices in Burkina Faso [32]. Therefore, enrolling children in the local schools is most vital to help households adopt improved technologies, extension services, and access to information that will improve the production and productivity of the crop, thereby improving the livelihood of the family. Further, developmental agents or any service providers need to use vernacular language during the implementation of technology transfer activities. Local language would improve the level of understanding of illiterate households towards adopting improved technologies in the study areas.

4.2. Main Socioeconomic Activities in the Study Districts

Off-Farm Income Sources of Farmers

Most of the studied households did not have off-farm income sources (Table 3). Typically, the income sources of households in developing countries are dependent on agriculture, as favoured by the agricultural-led industrialization policies of said countries. Abady et al. [25] and Daudi et al. [33] reported that most of groundnut farmers' livelihoods were derived from agriculture in Ethiopia and Tanzania, even more so in the former. Different sources of income for farmers can help ensure their livelihoods. Therefore, it is essential to design and introduce projects to diversify farmer's portfolios of income sources in the study areas to mitigate the impacts of crop failure and livestock death due to abiotic and biotic stresses.

4.3. Farmers' Awareness of Sesame Varieties

The study showed that most farmers had information about improved varieties through development agents (extension workers at village level), radio programmes, and farmer-to-farmer information exchange in the study areas (Table 4). Even though the farmers had information, they cultivated varieties often sourced from the informal sector in the study areas. The farmers cultivated improved sesame varieties, but there were no government-linked sesame seed enterprises or cooperative seed production in the study areas. Thirty percent of the respondents in Melokoza and Basketo districts adopted the Humera-1 variety, developed and released by Humera Agricultural Research Centre (HuARC) in 2010. This variety was developed through mass selection from among local germplasm collections. Most farmers in Ethiopia and Tanzania used seed of groundnut landraces for multiple benefits such as good oil quality, grain yield, adaptability to environmental stresses, drought tolerance, seed availability, and the ability to adapt to adverse climatic conditions and to retain seeds for the next cycle of planting [25,33]. The study areas' farmers classified Humera-1 and Adi as early-maturing cultivars and Abasena and Wollega as medium-maturing cultivars with relatively better bacterial blight resistance. High thousand-seed weight, high oil content, and white seed colour are among the most essential traits considered in the export standards of sesame [34]. The findings of this study show the need to design and introduce government-assisted sesame seed enterprises and cooperative seed production and to strengthen the extension service delivery system to enhance the dissemination and adoption of improved sesame agricultural technologies and enhance the livelihoods of the farmers in the study areas.

Most of the respondent farmers (60%) participated in technology transfer activities in the study areas. Chi-square analysis revealed the presence of highly significant differences among the four districts in methods of technology transfer ($p < 0.000$; $\chi^2 = 67.323$) (Table 5). The majority of the farmers reported that FTCs were among the main information and technology dissemination centres through demonstrations of methods to the farmers. Therefore, demonstrating improved varieties with the full package of agronomic practices through on-farm trials and FTCs, strengthening the extension services, and increasing availability of sesame seeds through engaging government seed enterprises and private seed producers would boost sesame production and productivity in the study areas.

4.4. Sesame Cropping System and Production Status

Most respondent farmers in the study areas grew sesame as a sole crop (Table 5). Farmers in Babile and Gursum districts intercropped sesame with sorghum, maize, and groundnut crops to diversify their cash income and mitigate the adverse effects of crop failure associated with growing sesame as a sole crop. In line with the current findings, Mesfin et al. [35] reported sesame intercropping with sorghum and millet in the study areas. Some farmers practiced sesame intercropping with sorghum and millet crops in Senegal and Mali [10]. Furthermore, Mkamilo [36] reported sesame intercropping with maize in southeast Tanzania.

The present study revealed that most of the farmers practiced sesame rotation with maize, mung bean, haricot bean, and groundnut, mainly to restore of soil fertility and reduce pest pressure in the four districts (Table 5). Conversely, most interviewees practiced the monoculture of sesame in Senegal and Mali [10]. The majority of the farmers explained that the trend of sesame production in the study areas was decreasing, mainly attributing this trend to a lack of improved varieties, abiotic and biotic stresses, a lack of better agronomic practices, and poor extension services and market linkages in the study areas. This result corroborated the findings of Abady et al. [25] in regard to groundnut production in the same study areas in Ethiopia.

4.5. Constraints to Sesame Production in Ethiopia

Farmers identified lack of access to improved varieties, high cost of seeds, low quality of seeds, low yield, climate change, insect pests, diseases, weeds, lack of market information, and low market price as the most critical constraints affecting sesame production (Table 6). Most households reported a lack of access to improved seeds as the most crucial constraint on sesame production due to the lack of a formal seed sector. The majority of the farmers identified low yield as the second most important constraint in sesame production in the study areas, suggesting that farmers grow unimproved varieties often sourced from the informal sector. Similarly, Teklu et al. [37] reported that the low productivity of sesame was due to a lack of improved and high-yielding varieties, traditional production technologies, and abiotic and biotic stresses, among other constraints. The authors also reported that landrace varieties were the primary sources of seed for cultivating the crop in Ethiopia. The low yield of sesame in SSA is mainly attributable to a lack of high-yielding, well-adapted varieties and shattering-tolerant cultivars, the prevalence of biotic and abiotic stresses, and the use of traditional production and harvesting systems [6,10,16–19,37,38]. The respondent farmers also identified low-quality and expensive sesame seeds sourced from the local market as one of the important production constraints. For instance, farmers in Basketo and Melokoza districts bought 1 kg of improved seed with a monetary value of 60 Birr (1.30 USD). Farmers expressed poor seed systems and lack of quality seed producers as a bottleneck in sesame production.

Climate change and insect pests are among the most essential yield-limiting factors mentioned by the sesame growers in the study areas (Table 6). Insect pests primarily cause yield reduction. A mean yield loss of 25% has been reported due to insect pest attacks [39]. Similarly, Myint et al. [24] reported that drought and insect pests were among the major sesame production constraints in Myanmar. Therefore, the development and introduction of drought-tolerant and insect pest-resistant varieties to the seed system is crucial to minimize the risk of crop failure due to abiotic and biotic stresses and increase the crop's productivity.

Furthermore, farmers in the study areas mentioned a lack of market information and low market price as among the most critical challenges in sesame production. In the study areas, there were no market infrastructures or market information delivery systems, and the growers were forced to sell their produce at a lower price. The market value chain is not well-developed, which often highly discourages farmers from producing the crop. For instance, farmers in Basketo and Melokoza districts sold 100 kg of their products with 1000–3000 Birr (about 22.3–67 USD) at farm gate price but at 3000–3500 Birr (about 67–78 USD) during the study period. The lack of an encouraging production environment in the study areas highly affected farmers and discouraged them from producing the crop in a larger quantity and with better quality. In agreement with the current findings, Myint et al. [24] reported that lower production and productivity in some areas of Myanmar was due to a lack of market for the farmers. There is a need to improve the sesame value chain through incorporating improved and high-yielding varieties into the formal seed system, more expansive use of the best agronomic practices, strengthening the extension services, and developing market infrastructure and on-time market information delivery. These attributes can motivate farmers to produce higher quantities of better-quality seed to the market.

4.6. Market-Preferred Traits of Sesame

Sesame is an important oilseed crop serving various value chains globally. In the present study, farmers identified white seed colour, higher seed size, true-to-type seed, higher oil content, and increased thousand-seed weight as the most crucial sesame market-preferred traits (Table 7). Farmers ranked true-to-type seed as the first most crucial market-preferred trait, followed by white seed colour and higher oil content. Higher thousand-seed weight, higher oil content, and white seed colour are among the most critical traits considered in the export standards of sesame [34]. Therefore, introducing improved, higher-yielding, higher-thousand-seed weight, higher-oil content, and white-seeded sesame varieties is considerably important to increasing the crop's market value.

4.7. Farmer-Preferred Traits

Farmers identified reasonable market price, resistance to disease, drought tolerance, resistance to insect pests, high yield, high 1000-seed weight, high oil content, and white seed colour as the most important traits in the study areas (Table 8). Most of the respondent farmers ranked reasonable market price as the most important trait, followed by resistance to diseases, drought tolerance, and resistance to insect pests. The ultimate goal of farmers when engaging in crop production is to increase productivity and obtain better income from the market, thereby improving their livelihood. Farmers in the study areas suggested that varieties with high yield, drought tolerance, and insect pest and disease resistance were highly preferred. These varieties avert the risks of crop failure due to abiotic and biotic stresses.

5. Conclusions

Farmers identified limited access to improved seeds as the most critical production constraint, followed by low yield gains, diseases, and low market price. Other production constraints included insect pests, lack of market information, and high cost of seed. These constraints were attributable to the absence of a dedicated breeding programme, lack of a formal seed sector, poor extension services, and underdeveloped pre- and postharvest infrastructures. The essential market-preferred traits of sesame included true-to-type seed, white seed colour, and high seed oil content. The vital farmer-preferred attributes included reasonable market price, resistance to crop diseases, drought tolerance, resistance to crop insect pests, high seed yield, high thousand-seed weight, high oil content, white seed colour, early maturity, and good oil quality in areas such as aroma and taste. Therefore, there is a need for a dedicated sesame genetic improvement programme that would integrate the above key production constraints and market- and farmer-preferred traits to develop and deploy new-generation varieties to enhance stable production, productivity, and adoption of sesame cultivars in Ethiopia.

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