Sesame

Subjects: Anthropology
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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 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.

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

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][2][3][4][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][7][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][17][18][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 varieties 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 the 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.

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

2.1. Off-Farm Income Sources of Farmers

Most of the studied households did not have off-farm income sources. 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. [27] 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 areas to mitigate the impacts of crop failure and livestock death due to abiotic and biotic stresses.

2.3. 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 areas. Even though the farmers had information, they cultivated varieties often sourced from the informal sector in the areas. The farmers cultivated improved sesame varieties, but there were no government-linked sesame seed enterprises or cooperative seed production in the 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 the 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][27]. The 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 [28]. 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 areas.

Most of the respondent farmers (60%) participated in technology transfer activities in the areas. Chi-square analysis revealed the presence of highly significant differences among the four districts in methods of technology transfer ($p < 0.000$; $\chi^2 = 67.323$). 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 areas.

2.4. Sesame Cropping System and Production Status

Most respondent farmers in the areas grew sesame as a sole crop. 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. [29] reported sesame intercropping with sorghum and millet in the areas. Some farmers practiced sesame intercropping with sorghum and millet crops in Senegal and Mali [10]. Furthermore, Mkamilo [30] 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 soil fertility and reduce pest pressure in the four districts. 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 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 areas. This result corroborated the findings of Abady et al. [25] in regard to groundnut production in the same areas in Ethiopia.

2.5. 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. 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 areas, suggesting that farmers grow unimproved varieties often sourced from the informal sector. Similarly, Teklu et al. [31] 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][17][18][19][31][32]. 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 areas. Insect pests primarily cause yield reduction. A mean yield loss of 25% has been reported due to insect pest attacks [33]. 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 areas mentioned a lack of market information and low market price as among the most critical challenges in sesame production. In the 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 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.

2.6. 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. 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 [28]. 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.

2.7. Farmer-Preferred Traits

Farmers identified reasonable market price, resistance to diseases, 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 areas. 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 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.

3. 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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