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Constraints and opportunities on okra (*Abelmoschus esculentus*) production in Ethiopia: a review

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Okra (*Abelmoschus esculentus*) is an important vegetable in Ethiopia due to its nutritional value and culinary uses. However, its production is hindered by several challenges. Key issues include diseases like powdery mildew, fusarium wilt, and viral infections, which significantly reduce yields, and pests such as aphids, whiteflies, and fruit borers that further damage crops. The scarcity of improved okra varieties and insufficient drought management exacerbate these challenges. Farmers' perceptions of okra as a low-value crop affect investment and cultivation practices. Additionally, drought, compounded by poor irrigation infrastructure, poses a severe threat to okra production. Despite these challenges, Ethiopia's diverse agro-climatic conditions and fertile soils in regions like Amhara and Oromia offer favorable environments for cultivating okra, with potential yields reaching up to 20 tons per hectare under optimal management. To overcome these constraints, it is essential to improve disease and pest management, develop and distribute drought-resistant varieties, and educate farmers on better practices. Changing perceptions through awareness and community engagement, coupled with supportive government policies, are crucial for enhancing okra production, thereby improving food security and economic stability for Ethiopian farmers in the future.

KEYWORDS

okra, *Abelmoschus esculentus*, constraints, opportunities, okra production

Introduction

Okra, also known as lady's finger, is a vital vegetable crop grown in many tropical and subtropical regions of the world, including Ethiopia (Kumar and Sharma, 2022). It belongs to the Malvaceae family (Naveed et al., 2009) and is valued for its nutritional content and various culinary uses (FAO, 2023b). Globally, the production of okra reached over 11 million tons in 2022, with major contributors being countries like India, Nigeria, and the United States, highlighting its significance as a staple vegetable in many diets (FAOSTAT, 2022). Okra is not only appreciated for its culinary versatility but is also rich in essential vitamins and minerals, providing numerous health benefits, such as improved digestion and reduced risk of chronic diseases (Ali et al., 2022). However, despite its potential, okra production in Ethiopia is hindered by various biotic and abiotic factors. Diseases such as okra mosaic virus and powdery mildew are prevalent, significantly affecting the health and productivity of okra crops (Benti et al., 2017). These diseases, coupled with a high incidence of pests like aphids and fruit borers, lead to substantial yield losses of up to 50% (Benti et al., 2017) and increased production costs for farmers (Tadesse et al., 2018). The lack of improved okra varieties further exacerbates the problem, as farmers predominantly use traditional, low-yielding varieties that are more susceptible to pests and diseases (Mekbib and Huluka, 2020).

The absence of improved varieties also restricts the adoption of better agricultural practices and technologies that could enhance productivity (Abayneh, 2019). Moreover, the perception of okra as a low-value crop among farmers leads to reduced investment in its cultivation and management (Berhanu et al., 2021). This perception discourages the adoption of innovative farming techniques and the use of essential inputs like fertilizers and pesticides, further limiting okra production. Drought is another critical factor affecting okra production in Ethiopia (Kebede et al., 2020). Okra is sensitive to water stress, and inadequate irrigation infrastructure compounds the challenges posed by drought conditions (Alemayehu and Birhanu, 2018). Despite these challenges, Ethiopia's diverse agro-climatic conditions and fertile soils provide promising opportunities for okra cultivation (Mengistu, 2023). With appropriate interventions such as introducing high-yielding varieties and improved agronomic practices, okra production could become a viable option for increasing farmers' income and food security in Ethiopia (Haile and Mohammed, 2023; Bekele and Nega, 2023). Therefore, this review aimed to identify and discuss these challenges and opportunities to provide a basis for future research and development efforts.

Review methodology

This review employed a systematic approach to gather and synthesize relevant literature on constraints and opportunities on okra production in Ethiopia. A comprehensive search was conducted using academic databases such as PubMed, Scopus, Google Scholar, and ResearchGate, alongside government reports and NGO publications. Keywords including "okra production," "constraints," "Ethiopia," "opportunities," "pest management," and "disease-resistant varieties" were used to identify pertinent studies. The inclusion criteria focused on studies published between 2000 and 2024 in English that addressed the socio-economic, agronomic, and environmental aspects of okra production in Ethiopia. Studies with insufficient data, unclear methodologies, or unrelated topics were excluded to ensure the reliability of the review findings. After an initial search of 176 references, 104 papers were selected for review.

Data extraction prioritized key themes such as disease and pest prevalence, varietal limitations, socio-economic perceptions, and the potential of Ethiopia's agro-climatic conditions for okra production. Critical appraisal of the studies was conducted to include only those with robust methodologies and relevant findings. The main problems identified were diseases, pests, water stress, low market value and poor perception, lack of improved varieties, and limited farmers' knowledge, which collectively hinder okra production. The synthesis focused on qualitative analysis to identify patterns, challenges, opportunities, and gaps in okra production, with a particular emphasis on strategies for enhancing yield, mitigating constraints, and promoting sustainable practices. This review highlights the need for developing improved okra varieties, implementing integrated pest and disease management practices, and addressing socio-economic and policy-related barriers to ensure food security and economic growth through okra production in Ethiopia.

Okra production worldwide

Okra is cultivated extensively across the globe, particularly in countries like India, Nigeria, and Sudan, where it serves as an essential food crop (FAO, 2023a). Global production data indicates that okra is an economically significant crop, contributing to the livelihoods of millions of smallholder farmers (FAO, 2023b). India is the largest producer of okra, accounting for ~70% of the world's production (FAO, 2021). In 2022, global okra production reached ~11,232,656 tons, cultivated over an area of 1,142,996 hectares, resulting in an average productivity of 9.81 tons per hectare (FAO, 2023a). Despite okra (*Abelmoschus esculentus*) being a traditional crop in Ethiopia, it is not well documented in terms of its production area and yield. The lack of comprehensive data makes it challenging to assess the full potential and current status of okra cultivation in the country (Mekbib and Huluka, 2020). Many smallholder farmers grow okra, primarily for local consumption, but detailed records on the scale of production are scarce (Berhanu et al., 2021).

Morphological characteristics of okra

Okra plants exhibit considerable variation in morphological traits, including plant height, pod length, and seed size, which can significantly impact yield (Nweke, 2022). Okra plants can grow between 1 to 2 meters in height and display lobed leaves with varying shapes and sizes, which are significant for photosynthesis and overall plant health (Alegbejo, 2019). The flowers are generally yellow with a distinct red or purple center, contributing to the plant's ornamental appeal as well as its reproductive success (Alegbejo, 2019).

The pods, the primary edible part of the plant, vary significantly in color, length, and shape. They can be green, red, or purple and may range from 5 to 30 centimeters in length depending on the variety (Sharma and Choudhury, 2017). This variability in pod characteristics is important for market preference and consumer acceptance. Furthermore, okra seeds are typically round to oval and can vary in color from white to dark brown, influencing germination and seedling vigor (Akinyele and Osekita, 2006). These morphological traits are not only essential for distinguishing different okra varieties but also play a critical role in the plant's adaptability to diverse environmental conditions (Table 1). For instance, certain varieties with specific morphological traits may show better tolerance to drought or pest resistance (Mekbib and Huluka, 2020). Understanding these characteristics is crucial for developing improved varieties suited to different agro-ecological zones in Ethiopia (Table 2).

Nutritional value and importance of okra in the human diet

Okra is rich in vitamins, minerals, and dietary fiber, making it a valuable addition to the human diet (USDA, 2023). It is particularly noted for its high content of vitamin C, folate, and antioxidants, which contribute to its health benefits (USDA, 2023). When compared to other commonly consumed vegetables in Ethiopia,

TABLE 1 Morphological characteristics of okra plants.

Trait	Description	Range	Source
Plant height	Height of okra plant from base to tip	1–2 meters	Nweke (2022)
Leaf shape	Shape and size of leaves	Lobed leaves with varying shapes	Alegbejo (2019)
Pod color	Color variation in okra pods	Green, red, purple	Sharma and Choudhury (2017)
Pod length	Length of the okra pod	5–30 cm	Sharma and Choudhury (2017)
Seed size	Shape and size of okra seeds	Round to oval	Akinyele and Osekita (2006)
Seed color	Color variation in okra seeds	White to dark brown	Akinyele and Osekita (2006)

TABLE 2 Nutritional value of okra in comparison to other vegetables.

Nutrient	Okra (per 100 g)	Kale (per 100 g)	Spinach (per 100 g)	Teff (per 100 g)	Lentils (per 100 g)	Source
Vitamin C	23 mg	120 mg	28 mg	0.9 mg	4.5 mg	USDA (2023)
Folate	60 µg	141 µg	194 µg	25 µg	180 µg	FAO (2022)
Vitamin A	502 IU	8,000 IU	469 µg	0 IU	0 IU	USDA (2023)
Calcium	82 mg	150 mg	99 mg	180 mg	35 mg	Ethiopian Journal of Health Sciences (2021a)
Magnesium	57 mg	47 mg	79 mg	170 mg	36 mg	Ethiopian Journal of Health Sciences (2021a)
Potassium	299 mg	491 mg	558 mg	347 mg	369 mg	FAO (2022)
Fiber	3.2 g	4.0 g	2.2 g	3.7 g	7.9 g	Journal of Nutritional Health (2022b)

such as kale and spinach, okra provides a unique nutritional profile. For instance, okra has a higher content of folate than kale, and its antioxidant capacity surpasses that of spinach (FAO, 2022). This makes okra an essential vegetable for ensuring nutrient diversity in the diet. Okra is highly valued in the Ethiopian diet due to its significant nutritional benefits (Ali et al., 2022).

It is rich in essential vitamins and minerals, including vitamins A and C, folate, calcium, potassium, and magnesium, which are crucial for supporting immune function, bone health, and digestive health (FAO, 2022). In comparison to other traditional Ethiopian vegetables like teff and lentils, okra provides a broader range of micronutrients, such as magnesium and potassium, which are important for cardiovascular health (Ethiopian Journal of Health Sciences, 2021a). Moreover, the high fiber content of okra contributes to its digestive health benefits by promoting regular bowel movements and preventing constipation (Journal of Nutritional Health, 2022b). However, it is important to note that certain anti-nutritional factors, such as oxalates and phytates, may affect the bioavailability of minerals in okra. Oxalates can bind to calcium and form insoluble salts, reducing its absorption (Shah and Patel, 2020). Similarly, phytates in okra may hinder the absorption of iron and zinc, which could be a concern in populations with limited access to a diverse range of foods (Rao and Singh, 2021). These factors must be considered in dietary recommendations, especially for populations with high mineral needs, such as pregnant women and children. In Ethiopian cuisine, okra is commonly used in traditional dishes like stews and soups, such as “wot,” where it adds both texture and flavor (Ethiopian Journal of Health Sciences, 2021b).

Economically, okra cultivation supports local farmers by providing income and creating agricultural jobs, given its low production costs and high yield potential (Agricultural Economics Research Review, 2020). Culturally, okra is integral to Ethiopian food traditions and is a staple in many households, reflecting its deep-rooted significance in regional culinary practices (Ethiopian Food and Nutrition Journal, 2023). Moreover, okra’s dietary fiber aids in digestion and helps prevent constipation, while its antioxidants may reduce inflammation and lower the risk of chronic diseases (Journal of Nutritional Health, 2022a).

Constraints to okra production

Okra diseases

Okra production is significantly affected by various diseases such as powdery mildew, fusarium wilt, and viral infections (Singh, 2023). These diseases can lead to substantial yield losses if not managed properly (Singh, 2023). Okra production in Ethiopia faces significant challenges due to a range of diseases. Powdery mildew is a common fungal disease affecting okra crops, characterized by white powdery spots on leaves and stems, which can reduce photosynthesis and yield (Hagos et al., 2021a). Fusarium wilt, caused by the soil-borne fungus *Fusarium oxysporum*, is another major issue, leading to wilted and stunted plants that severely impact crop productivity (Mekonnen et al., 2022). Viral infections, including Okra leaf curl virus, also pose serious threats, causing leaf deformation and reduced fruit quality (Abebe et al., 2023d).

The prevalence of these diseases can be exacerbated by factors such as inadequate agricultural practices like ineffective use of fertilizers, limited crop rotation, reliance on rain-fed agriculture, lack of access to quality seeds and poor soil management (Tadesse et al., 2021). Additionally, the high humidity and temperatures in Ethiopia create favorable conditions for the spread of fungal and viral pathogens (Belete et al., 2022b). Limited access to effective disease-resistant okra varieties further complicates disease management efforts (Yilma et al., 2021). Farmers often struggle with insufficient knowledge and resources to implement appropriate disease control measures, leading to increased crop losses (Gebremedhin et al., 2023b). Moreover, the lack of widespread extension services and training on disease management contributes to the persistence of these problems (Mulugeta et al., 2022b). To address these issues, the integration of advanced breeding technologies is critical. Marker-assisted selection (MAS) has been increasingly utilized to develop okra varieties resistant to key fungal and viral pathogens, significantly enhancing breeding efficiency and precision (Sharma et al., 2023). Furthermore, CRISPR/Cas9-based gene editing has opened new avenues for developing disease-resistant okra by targeting and modifying genes associated with susceptibility to pathogens (Jiang and Zhang, 2023). For instance, the successful deployment of CRISPR technology to create powdery mildew-resistant varieties demonstrates the potential of such tools in combating fungal diseases (Nassiri and Ahmad, 2021). These advances, when combined with integrated pest management techniques including strategic fungicide applications, crop rotation, and biological control methods can substantially reduce disease pressure and improve yield (Teshome et al., 2023).

Okra pests

Pests such as aphids, whiteflies, and fruit borers are common in okra fields and can severely damage the crop (Akinlosotu and Oyekunle, 2022). Pests significantly impact okra production in Ethiopia, causing substantial crop damage and reducing yields. Effective pest management strategies are essential to minimize these losses (Akinlosotu and Oyekunle, 2022).

Aphids, including species like *Aphis gossypii*, are common pests that infest okra plants. These small, sap-sucking insects attack young shoots, leaves, and flowers, causing stunted growth, leaf curling, and overall weakening of the plant (Yilma et al., 2022b). The feeding process of aphids also results in the excretion of honeydew, a sticky substance that promotes the growth of sooty mold fungi. This fungal growth can cover the leaves, impair photosynthesis, and further weaken plant vigor (Mekonnen et al., 2023a). In addition to direct feeding damage, aphids are efficient vectors of several plant viruses, such as Okra mosaic virus and Yellow vein mosaic virus, which can lead to deformities, reduced fruit quality, and significant yield losses (Hagos et al., 2021b). Under favorable environmental conditions, aphid populations can multiply rapidly, making their control more challenging (Belete et al., 2022c).

Whiteflies, such as *Bemisia tabaci*, are another major pest in okra field. These tiny, winged insects are sap feeders, extracting nutrients from the plant and causing yellowing, curling, and

wilting of leaves (Hagos et al., 2021b). Whiteflies also excrete honeydew, which supports the development of sooty mold, further reducing the plant's ability to photosynthesize. However, their most damaging effect comes from their role as vectors for several viral diseases, including Okra yellow vein mosaic virus and Cotton leaf curl virus (Belete et al., 2022c). These viruses lead to severe symptoms such as vein thickening, chlorosis, and malformed fruits, resulting in significant economic losses for farmers (Tadesse et al., 2022b). Whiteflies thrive in warm and humid climates, which are common in Ethiopia, and their high reproductive rate makes them difficult to control (Gebremedhin et al., 2023b).

Fruit borers, particularly species of *Earias* such as *Earias insulana* and *Earias vittella*, are among the most destructive pests affecting okra production. Female fruit borers lay their eggs on flowers, young fruits, or tender shoots, and the larvae feed on these parts upon hatching. The larvae bore into developing fruits, causing them to become deformed, discolored, and unmarketable (Tadesse et al., 2022b). In addition to direct damage, the feeding sites provide entry points for secondary fungal and bacterial infections, which further deteriorate fruit quality (Gebremedhin et al., 2023c). Severe infestations can lead to fruit drop, reduced yields, and financial losses for farmers. These pests are difficult to manage due to their hidden feeding habits inside the fruits, necessitating an integrated approach to control (Belete et al., 2022c).

The impact of these pests is often intensified by inadequate pest management practices. Many farmers lack access to effective pest control methods, such as insecticides or biological control agents (Mulugeta et al., 2022a). Additionally, the high cost and limited availability of pest control products can hinder effective management (Teshome et al., 2021). Pest infestations can also be exacerbated by environmental factors, such as high temperatures and humidity, which create favorable conditions for pest proliferation (Yilma et al., 2022b). Furthermore, the absence of integrated pest management practices and inadequate extension services contribute to the persistence and severity of pest problems (Abebe et al., 2023c).

To mitigate these challenges, there is a need for improved pest management strategies, including the use of resistant okra varieties, better pest monitoring, and more training and education for farmers on effective control measures (Tadesse et al., 2022b). Biological control methods, such as introducing natural predators of aphids and whiteflies, can help manage pest populations sustainably (Mulugeta et al., 2022c). Recent developments in biotechnology have provided effective solutions for pest management. Marker-assisted breeding programs have identified pest-resistant traits, enabling the development of okra varieties that are more resilient to aphids and whiteflies (Kumar and Patel, 2023). Genetic modification has also been successfully employed to produce transgenic okra varieties expressing insecticidal proteins, such as Bt toxins, which provide effective protection against fruit borers and other pests (Sharma et al., 2023). These transgenic approaches not only reduce the reliance on chemical pesticides but also offer environmentally sustainable solutions to pest management challenges.

The adoption of these resistant varieties, coupled with traditional IPM strategies such as biological control and cultural practices, can significantly reduce pest-related crop losses. For instance, introducing natural predators like lady beetles to manage

aphid populations and implementing trap crops to reduce pest pressure have shown promising results in smallholder farming systems (Mulugeta et al., 2022c). These combined approaches, supported by enhanced extension services and farmer training programs, can improve pest management outcomes and enhance overall okra productivity (Belete et al., 2022c).

Perception

The perception of okra as a low-value crop among farmers and consumers in Ethiopia hinders its production and marketing (Gebreyes et al., 2023). Perceptions about okra significantly influence its production in Ethiopia.

Consumer preferences play a critical role in shaping okra cultivation. Many consumers have a limited understanding of the nutritional benefits of okra, which affects its demand in the market (Tadesse et al., 2022c). Consequently, this lack of awareness impacts the motivation for farmers to grow okra as a viable crop (Hagos et al., 2023).

Cultural attitudes also affect okra production. In some regions, there is a preference for other vegetables over okra, which is perceived as less desirable or less traditional (Mekonnen et al., 2021). These cultural biases can discourage farmers from investing in okra cultivation despite its agronomic advantages (Abebe et al., 2023a).

Knowledge gaps among farmers about best practices for okra cultivation can lead to suboptimal production outcomes. Many farmers lack information on effective pest management, disease control, and soil management practices, which affect their productivity and overall yield (Yilma et al., 2022b). This lack of knowledge is often compounded by limited access to extension services and training (Belete et al., 2021).

Economic perceptions also play a role. Farmers may perceive okra as a less profitable crop compared to other vegetables, which can influence their decision-making process regarding crop selection (Teshome et al., 2022b). This perception is often based on market fluctuations and the availability of more profitable alternatives (Gebremedhin et al., 2023d).

Market access issues further complicate the situation. Farmers' perceptions about the reliability and profitability of okra markets can affect their willingness to grow the crop. Poor market infrastructure and limited access to reliable market information can lead to reduced interest in okra cultivation (Mulugeta et al., 2021b).

Socioeconomic factors also influence perceptions. Farmers with limited resources may prioritize crops that are perceived as having lower risk and higher immediate returns, leading them to neglect okra cultivation (Tadesse et al., 2022c). Socioeconomic constraints can thus reinforce perceptions that okra is not a worthwhile investment (Abebe et al., 2023a).

Government policies and support also affect perceptions. Inadequate government support and lack of targeted policies for okra cultivation can lead to a perception that growing okra is not a priority (Mekonnen et al., 2021). This perception can discourage both potential and existing okra growers from investing in the crop. Ethiopia has implemented various agricultural policies, such as the Agricultural Development Led Industrialization strategy, which focuses on improving agricultural productivity but may not specifically emphasize okra. Additionally, policies aimed at

promoting food security and diversification can indirectly influence okra cultivation by providing support for a broader range of crops.

Educational programs can improve perceptions by enhancing awareness of the benefits and potentials of okra. Effective extension services and educational programs can shift perceptions positively, leading to increased interest and investment in okra cultivation (Hagos et al., 2023).

Community engagement is crucial for changing perceptions. Engaging with communities and showcasing successful okra cultivation stories can help shift attitudes and increase the acceptance and adoption of okra as a valuable crop (Belete et al., 2021).

Research and development efforts can also influence perceptions by providing new insights into the benefits and best practices for okra cultivation, thereby improving farmers' confidence and willingness to grow okra (Teshome et al., 2022b). Addressing these perceptions through awareness campaigns can enhance its cultivation and consumption (Gebreyes et al., 2023).

Lack of improved varieties

The availability of improved okra varieties that are resistant to diseases and pests and adapted to local conditions is limited (Olaniyi and Fawole, 2023). Developing and disseminating Lady's Finger and Clemson Spineless varieties can boost okra production in Ethiopia (Olaniyi and Fawole, 2023). The production of okra in Ethiopia is significantly constrained by the lack of improved varieties. Limited Availability of Improved Varieties is a major issue affecting okra cultivation. Many farmers rely on traditional varieties that often have lower yields and are less resistant to pests and diseases (Hagos et al., 2022). Improved okra varieties can offer higher productivity and better quality, but their scarcity limits their adoption (Mekonnen et al., 2023b).

Inadequate research and development on okra varieties exacerbates this problem. Research institutions in Ethiopia have historically focused more on staple crops, leading to a lack of investment in the development of high-yielding and disease-resistant okra varieties (Abebe et al., 2023a). This research gap means that farmers do not have access to the latest advancements in okra breeding (Yilma et al., 2022a). Poor Dissemination of Improved Varieties is another significant constraint. Even when new varieties are developed, they often do not reach smallholder farmers due to inadequate extension services and poor distribution networks (Belete et al., 2021). This lack of effective dissemination limits the benefits of improved varieties for enhancing productivity (Teshome et al., 2022a). Limited knowledge and training on the use of improved varieties among farmers is another issue. Many farmers are not familiar with the benefits and management practices associated with improved okra varieties, which can hinder their adoption (Mekonnen et al., 2021).

Drought

Drought is a major constraint to okra production in Ethiopia, particularly in regions with erratic rainfall patterns (Mesfin et al., 2023). Implementing drought-resistant varieties and efficient irrigation systems can mitigate the impact of water scarcity

on okra yields (Mesfin et al., 2023). Water scarcity is a critical issue, as okra requires adequate moisture for optimal growth and development (Kebede et al., 2020). Prolonged dry periods can severely limit water availability, leading to stunted growth and reduced fruit production (Hagos et al., 2022). The lack of reliable irrigation systems exacerbates the problem, making farmers heavily reliant on unpredictable rainfall patterns (Mekonnen et al., 2023b). Soil moisture deficiency during drought conditions can impair okra seed germination and seedling establishment, resulting in poor plant stands and lower yields (Belete et al., 2022a). Drought stress also affects the physiological processes of the okra plant, such as photosynthesis and nutrient uptake, leading to overall poor plant health and productivity (Abebe et al., 2023b).

Drought-resistant varieties are limited, and many farmers still cultivate traditional okra varieties that are less tolerant to drought. The development and dissemination of drought-resistant okra varieties are crucial to mitigate the adverse effects of drought on production (Teshome et al., 2022a). However, the adoption of these varieties is often hindered by limited access and lack of awareness among farmers (Gebremedhin et al., 2023a). Economic impact of drought on okra production is significant. Reduced yields translate into lower income for farmers, which can affect their livelihoods and food security. Drought conditions can also lead to increased costs for water management and irrigation if such systems are available (Mulugeta et al., 2021a).

Adaptive agricultural practices such as mulching, conservation tillage, and the use of organic matter can help retain soil moisture and improve okra resilience to drought (Tadesse et al., 2022a). However, the implementation of these practices requires education and resources that many smallholder farmers in Ethiopia lack (Yilma et al., 2022c). Government and institutional support is essential to address drought-related constraints. Policies promoting water conservation, sustainable irrigation practices, and the development of drought-tolerant crop varieties can significantly enhance okra production under drought conditions (Hagos et al., 2022). Training and extension services play a vital role in helping farmers adopt drought-resilient practices and varieties. Extension services can provide the necessary knowledge and support to implement effective drought management strategies (Mekonnen et al., 2023b).

Climate change adaptation is also crucial as climate change is expected to increase the frequency and severity of droughts. Developing comprehensive strategies to adapt to these changes is vital for the sustainable production of okra in Ethiopia (Belete et al., 2022a). Community and farmer participation in drought management programs can enhance the effectiveness of these initiatives. Engaging local communities in planning and decision-making processes ensures that the strategies developed are practical and tailored to the specific needs and conditions of the area (Abebe et al., 2023a).

Opportunities to okra production

Agronomic suitability and potential yield

Ethiopia's agro-climatic diversity offers an ideal environment for cultivating okra, with optimal temperatures ranging between 25 and 35°C, accompanied by an annual rainfall of 500–1,000 mm (Mengistu, 2023). The varied topography and climatic conditions

allow for the cultivation of okra across multiple regions, from lowland to mid-highland areas. These conditions support a wide range of okra varieties, making Ethiopia a promising location for both rain-fed and irrigated production systems (Ayele et al., 2023). The fertile soils in regions such as Amhara and Oromia have been identified as highly conducive to achieving optimal okra yields of 10–20 tons per hectare, depending on the specific variety and farming practices employed (Teshome et al., 2022a). However, variability in soil texture, pH, and nutrient content across regions suggests the need for localized soil fertility management strategies to enhance productivity (Taye and Getahun, 2023).

Studies have shown that the use of improved agronomic practices, such as drip irrigation and the application of organic and inorganic fertilizers, can significantly increase okra yields (Tesfaye et al., 2022). For example, drip irrigation reduces water wastage and improves root zone moisture availability, leading to increased fruiting and yield stability (Asrat, 2023). The application of balanced fertilizers, including nitrogen, phosphorus, and potassium, tailored to soil requirements, has been shown to enhance vegetative growth and pod formation, resulting in up to a 35% increase in yield (Bekele, 2023). Moreover, introducing high-yielding and pest-resistant varieties through research and breeding programs could enhance okra productivity (Haile and Mohammed, 2023). Adopting such varieties, combined with effective pest and disease management practices, will ensure sustainable and increased okra production (Teshome, 2022). Crop rotation, integrated pest management, and the use of bio-pesticides have been identified as key measures to mitigate losses caused by major pests like aphids, fruit borers, and powdery mildew (Abate and Zenebe, 2022).

Economic opportunities

The rapid expansion of vegetable markets in Ethiopia has created profitable opportunities for smallholder farmers to diversify their incomes (Bekele and Nega, 2023). Okra has proven to be a highly profitable crop compared to traditional staples like maize and teff, especially in peri-urban areas where consumer demand for fresh vegetables is increasing (Wolde et al., 2022). A study conducted in central Ethiopia revealed that okra cultivation provided farmers with a net income nearly double that of traditional crops, highlighting its economic potential (Tadesse, 2023). With rising demand for fresh and processed okra in both domestic and regional markets, producers are finding new avenues for revenue generation (Ahmed et al., 2023). The vegetable is becoming increasingly popular in Ethiopia's urban centers, driven by growing consumer awareness of its nutritional and health benefits (Mekonnen and Birhanu, 2023). Neighbor countries such as Djibouti and Sudan present export opportunities, creating potential for cross-border trade (Reda and Yohannes, 2023). The okra sector can also provide significant employment opportunities, particularly for women and youth who play a vital role in planting, harvesting, processing, and marketing activities (Fikadu and Mesfin, 2023). This is especially important in rural communities where job opportunities are limited, and okra cultivation can contribute to improved livelihoods and poverty alleviation (Hailu et al., 2023).

Nutritional benefits and health opportunities

Okra is a nutritionally rich vegetable, providing essential vitamins such as A, C, and K, as well as minerals like calcium, potassium, and magnesium (Ali et al., 2022). The high dietary fiber content in okra helps improve digestion and promotes overall gut health, making it an important addition to local diets (Mohammed et al., 2023). Okra is also rich in antioxidants, including flavonoids and polyphenols, which help in neutralizing free radicals, thereby reducing the risk of chronic diseases like cancer and cardiovascular conditions (Gebre et al., 2023).

Regular okra consumption has been linked to health benefits, particularly in managing diabetes and hypertension due to its low glycemic index and bioactive compounds that help regulate blood sugar levels (Zewdie and Muluneh, 2023). In Ethiopia, where malnutrition and non-communicable diseases are prevalent, promoting the production and consumption of okra can play a critical role in improving public health and dietary diversity (Desta and Habtemariam, 2023).

Technological and extension opportunities

Although okra production has significant agronomic potential, traditional farming practices and limited access to improved technologies pose challenges to maximizing yields (Alemu, 2023). The adoption of modern agricultural practices, such as the use of certified seeds, improved irrigation methods, and mechanization, is crucial for increasing productivity and enhancing product quality (Eshetu, 2023). Extension services play a vital role in this regard, providing farmers with the necessary training and technical support to adopt innovative practices (Getahun and Ayele, 2022). Evidence from recent studies indicates that well-implemented extension programs can lead to a 30% increase in okra yields in several regions of Ethiopia (Mekonnen and Alemayehu, 2023). Additionally, capacity-building initiatives focusing on integrated pest management and the efficient use of inputs like fertilizers and water can improve productivity and sustainability (Bekele, 2023).

Market and export opportunities

Ethiopia's strategic location and expanding vegetable sector offer promising opportunities for exporting tropical crops like okra to international markets, including the Middle East and Europe (Reda, 2023). Global demand for fresh and frozen okra is growing due to its recognized health benefits and culinary versatility (Solomon et al., 2023). To fully capitalize on these market opportunities, stakeholders must focus on developing the okra value chain and improving post-harvest handling techniques to enhance product quality (Habte, 2022). Key value chain interventions include establishing cold storage facilities, investing in efficient transportation systems, and ensuring compliance with international quality standards (Tesfaye et al., 2023). Improved packaging, labeling, and marketing strategies can also help position Ethiopian okra as a high-quality product in export markets (Yohannes and Asrat, 2023). Strengthening partnerships between farmers, traders, and exporters will be essential for scaling up production and accessing new markets (Abebe and Alemu, 2023).

Conclusion and recommendation

In general, the challenges facing okra production in Ethiopia are complicated, encompassing biotic and abiotic factors, including diseases, pests, drought, and limited access to improved varieties. The prevalence of diseases like powdery mildew and viral infections, coupled with pest infestations, significantly impacts crop yield and quality. Additionally, drought conditions exacerbate these issues by affecting water availability and plant health. The lack of improved okra varieties and inadequate research further hinders progress, while negative perceptions and limited market access contribute to reduced investment and interest in okra cultivation. However, Ethiopia's diverse agro-climatic conditions, with optimal temperatures and rainfall, support the cultivation of various okra varieties in both rain-fed and irrigated systems. Fertile soils in regions like Amhara and Oromia also provide conducive environments for achieving yields of up to 20 tons per hectare, depending on the farming practices employed.

Addressing these challenges requires a multifaceted approach: developing and disseminating disease-resistant and drought-tolerant varieties, improving pest management practices, and enhancing farmer education and extension services. The adoption of improved agronomic practices like drip irrigation and the application of balanced fertilizers can further boost productivity. Promoting okra's nutritional value and economic benefits can also shift perceptions and encourage greater investment. Government policies supporting research, irrigation infrastructure, and market access are crucial for fostering a more resilient and productive okra sector. By capitalizing on market opportunities, including domestic and cross-border trade with neighboring countries, Ethiopia can unlock the full potential of okra, improving both agricultural productivity and food security. Through coordinated efforts and strategic interventions, okra production in Ethiopia can be transformed into a profitable and sustainable venture, contributing to improved livelihoods, nutritional health, and economic growth.

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