

The Emerging Challenge of Seed Counterfeiting: Empirical Evidence from Ethiopia

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Abstract

Seed counterfeiting is becoming a serious concern and a discussion agenda, as it threatens the growing seed industry in Ethiopia. However, information on the extent, drive practices, and prevention measures of counterfeit seed is scarce. Based on 48 semi structured interviews with representatives from regulatory agencies, seed companies, and government offices, we have identified the causes, sources, practices, consequences, and combating measures of seed counterfeiting in the country. Hybrid maize is the primary crop highly affected by counterfeiting, followed by vegetable seeds. We found that dressing grains with artificial color, adulteration, label imitation, package reuse, and mislabeling are the most common practices of seed counterfeiting. Local grain traders and agro-dealers are the top seed counterfeiters. Coordinated efforts are essential for awareness creation and timely information about the effect of counterfeit seeds to stakeholders, including farmers, seed companies, regulatory agencies, law-enforcing offices, and policymakers, to combat counterfeiting. Moreover, the study suggests improving the seed supply, enforcing measures, using digital technologies, strengthening regulatory systems, and effectively coordinating among relevant actors to address counterfeit seeds in Ethiopia.

Keywords: Counterfeit seed, Ethiopia, seed regulation, seed sector, smallholder farmers

Introduction

The seed industry, both in the world and in Africa, has grown steadily in recent decades. Africa's seed market size is estimated at 2.99 billion USD in 2024 and is expected to reach 3.99 billion USD by 2030 (Mordor Intelligence, 2024). Hybrids dominate the African seed market, sharing 60% of the market, and the remaining is covered by open-pollinated varieties and hybrid derivatives (Mordor Intelligence, 2024). The seed industry, through the formal sector, addresses the seed demand of smallholder farmers in Africa, although farmers in the region still access most seeds from the informal sector (Bishaw and Atilaw, 2016; McGuire and Sperling, 2016; Sperling *et al.*, 2020).

The major constraints to addressing farmer seed demand through formal systems include a shortage of quality seeds, a lack of access to credit (Langyintuo *et al.*, 2010), the transfer of genetic materials between the public and private sectors (Das *et al.*, 2019, Langyintuo *et al.*, 2010), restrictive legislation (Kuhlmann *et al.*, 2023),

and limited companies' capabilities (Pedrini *et al.*, 2020), variety registration procedures (Holubowicz, 2008), the limited use of modern technologies (Afzal *et al.*, 2020), and the challenge of counterfeit seeds (de Boef *et al.*, 2014). Some of the challenges are internal and can be managed by industry actors. However, some other challenges are external and require the intervention and collaboration of diverse stakeholders.

Seed counterfeiting is a common challenge worldwide (OECD/EUIPO, 2021) and in Africa (AU, 2021; de Boef *et al.*, 2014; Kuhlmann *et al.*, 2022; TASAI, 2024). The level and intensity of the challenge vary among countries (Bishaw *et al.*, 2021; Izuogu *et al.*, 2023; Longley *et al.*, 2021; Machibya *et al.*, 2021; Mmboga, 2023), which depend on the specific country context and efforts to address the challenge (TASAI, 2024). Reports from other countries have indicated that up to 30–40% of all seeds offered for sale in Uganda (Longley *et al.*, 2021), and up to 40% of seeds in Kenya (de Boef *et al.*, 2014) are counterfeit. The use of counterfeit seeds has a significant negative effect at different levels, from individual farmers to the overall economic performance of a country. The use of counterfeit seeds can bring significant risks to farmers, consumers, and the environment (de Boef *et al.*, 2014). Counterfeit seeds are low in quality and are usually far below the required minimum seed quality standards (Barriga and Fiala, 2020; Gharib *et al.*, 2021). Furthermore, the use of counterfeit seeds places farmers' livelihoods and families at risk (ISF, 2018).

In addition to their negative adverse effects on the livelihoods of farmers, the continuous sales of counterfeit seeds threaten the entire seed industry (Mmboga, 2023) and the economic development of a country (Kuhlmann *et al.*, 2023). Counterfeit seeds affect the adoption rates of improved crop varieties by farmers and disrupt the effort of breeding activities (Derwisch *et al.*, 2016). Moreover, the practice of seed counterfeiting potentially undermines innovations (OECD/EUIPO, 2021).

In different countries, several efforts have been made to combat seed counterfeiting and minimize its effect. Hoecht and Trott (2014) suggested different strategies for the same purpose. Timely and accurate awareness creation for all actors, including farmers, is a common way of addressing counterfeit seeds (de Boef *et al.*, 2014; Kassem *et al.*, 2021). The use of advanced technologies is also in place to combat counterfeiting (Chistruga, 2023), although authentication technologies are contingent upon consumer access (de Boef *et al.*, 2014). The development of appropriate legal frameworks and enforcement measures also contributes to effective anticounterfeiting measures. There has been positive progress in Africa regarding the government's concerted efforts to combat the sale of counterfeit seeds, although the effort has been largely ineffective (TASAI, 2024).

In Ethiopia, counterfeit seeds are becoming a common concern (Kuhlmann *et al.*, 2023). Hassena *et al.* (2020) reported that counterfeit seed marketing practices are common in some areas and more common for hybrid maize varieties. The limited reach of the regulatory system is considered one of the main challenges associated with fake seeds (Hassena *et al.*, 2020). However, consolidated information on the extent of seed counterfeiting in Ethiopia, the prevalence, common drivers, sources, and common practices is scarce. In Ethiopia, well documented evidence is not available how and when seed counterfeiting is practiced. The practice might have been in place for a long period. Currently, however, there are some indications of its presence and effects associated with the expansion of the seed industry in the country (Hassena *et al.*, 2020). The scarcity of evidence-based information hinders timely decision-making practices, the use of solution-oriented best approaches, and the development of appropriate legal frameworks and enforcement measures. Using individual interviews with major seed business actors, including regulatory experts, representatives from both public and private seed companies, and government professionals, the present study aims to address (1) the extent, major causes, main sources, and common practices of seed counterfeiting in Ethiopia; (2) the consequences of counterfeiting seeds in Ethiopia; and (3) potential interventions for combating counterfeit seeds in Ethiopia. In this study, we use counterfeit seeds, illegal seed trade, and fake seeds interchangeably for ease of communication.

Methodology

Data collection

The data collection was organized using individual interviews with resource people. The study approached people with strong experience in seed production, marketing, and inspection. We purposely approached key informants with good experience in dealing with counterfeit seed in the country. A total of 48 respondents who showed interest in participating in the interview responded. The respondents were from private and public seed companies (6), seed regulatory authorities (36), the bureau of agriculture (3), research institutes (2), and development partners (1) working on seed projects. The respondents were individually approached for their availability and willingness to participate. They were informed about the study objectives and were granted anonymity of their responses. The interview questions were distributed to interested respondents via email and hard copies. The respondents who accessed the internet connection returned their responses via email; others sent their responses through available means.

The interview document was organized in a logical order. The flow of interview questions started from general perspectives about counterfeiting in agricultural products and then focused specifically on seeds. The interview questions were designed both from the literature and from context-specific practices in Ethiopia.

The questions were prepared to gather information about the extent, the main causes and common forms of seed counterfeiting, and suggestions for responsible actors to address seed counterfeiting in Ethiopia.

Data analysis

The data were analyzed using full documents from all individual interviews. A line-by-line review of the document was applied to the interviews. With careful reading of the documents, we used deductive data analysis for coding and capturing the key topics. The repeated responses by the respondents were further consolidated to reflect the specified key topics. The responses of the respondents are displayed in expressive quotes and are presented in italics. Furthermore, the responses were analyzed quantitatively and expressed as percentages.

Results and Discussion

Counterfeiting in agricultural inputs in Ethiopia

Respondents mentioned several reasons for the prevalence of counterfeiting agricultural inputs. Some are common for all, whereas others are relevant for specific inputs. Limited awareness or correct information about the products, limited enforcement of the regulations, and weak coordination among relevant actors were the most common reasons reported. An expert indicated that *seed regulatory bodies are limited with manpower, facilities, and logistics to cover a wide geographical location*. These limitations directly affect the enforcement of the regulations. Weak coordination, as explained by a few experts, among actors weakens the availability and distribution of products. One expert mentioned that *the not well-organized coordination among relevant stakeholders, including policymakers, producers, inspectors, and distributors, takes the major responsibility for the limited availability of products to farmers, which aggravates the prevalence of counterfeiting agricultural inputs*. The coordination issue is a common seed sector challenge in Ethiopia (Alemu et al., 2021).

With respect to seeds, experts have repeatedly mentioned the significant mismatch between demand and supply as a key reason for prevalence of counterfeit seed. The formal seed supply accounts for only 10–20% of the actual seed demand of the country, which varies among crops. A greater economic return of fake seeds also aggravates their prevalence. One expert explained that *reuse of the packaging material of the reputed company and filling it with adulterated or substandard seed is a common practice, particularly for hybrid crops, to maximize a higher economic return with a lower cost*. A limited understanding by users of the negative effects of agrochemicals and their malfunctional practices contributes to the use of fake products. One of the respondents described the complexity of this product from the quality and timely information flow perspective, as *traders engaged in the*

agrochemical business do not regularly check the registration status of the chemicals along with their correct trademarks. The flow of information from regulatory agencies to traders and users is weak. In addition to the higher prices of inorganic fertilizer, its limited availability and delay in distribution also contribute to counterfeiting fertilizers in Ethiopia. In general, *the counterfeiting of inorganic fertilizers is less subject to adulteration than are that of seeds and agrochemicals, as the business is still under public domain.*

Prevalence of crops for counterfeit seeds

All the respondents agreed that counterfeiting is more prevalent for hybrid maize in Ethiopia (Figure 1). The limited availability of farmers preferring certified seeds of improved varieties is the main factor for the higher prevalence of fake seeds in the maize seed market. *The limited capacity of seed companies, both public and private, to provide large volumes of maize seeds to the market is the determining factor.* The annual average maize seed supply (between 2019 and 2022) by Ethiopian public seed companies was 12,953 MT (Kalsa *et al.*, 2024). The engagement of private companies in hybrid maize seed supply has increased over the years due to the comparative advantage of the hybrid maize seed business. However, their contribution is limited by various factors, including a limited policy environment (investment incentives, tax exemption) and weak production capacities (Kifle and Atilaw, 2018; Lemma and Admasu, 2018). For example, Corteva AgroSciences, the main maize seed supplier company in the country, provided only 25% of the demand for its maize varieties in 2022 (Kalsa *et al.*, 2024). In most cases, both public and private seed companies engage in the production of a few maize varieties (Kalsa *et al.*, 2024), although there are numerous released varieties in the country. The greater shortage of maize seed supply from companies, coupled with its attractive market price and limited regulatory mechanisms, aggravates the engagement of illegal actors in the maize seed business. The respondents explained that *the higher profit margin of counterfeit maize seeds encourage some traders and producers to engage in illegal practices.*

The results also confirmed that tomato, onion, pepper, and cabbage are the most common vegetables with relatively high counterfeit seed prevalence in Ethiopia. This might be associated with their largely imported seeds. Repackaging and labeling expired vegetable seeds are common forms of counterfeiting seeds that illegal traders are practicing in Ethiopia. Farmers usually require small quantities of vegetable seeds, which local companies usually do not make available with the required packaging size. *One reason is that the vegetable seed market is almost entirely dominated by imported products.* This demand for smaller quantities of vegetable seeds by farmers has led traders to practice selling small quantities of seeds from open packages. *This makes regulatory measures difficult to differentiate authentic seeds from fake seeds.*

For other crops, including wheat, tef, barley, haricot bean, and fruit seedlings, the limited availability of seeds contributes to illegal seed marketing practices in Ethiopia. Seed shortages are particularly common, with seed companies producing seeds with outgrowing farmers via contractual arrangements. Companies do not collect all the seeds because of the large volume of side-selling seeds by out growers, which is due mainly to price disagreements with contracting companies. Side selling by farmers is a concern in Ethiopia, both for contract-based seed and grain production (Alemu *et al.*, 2021).

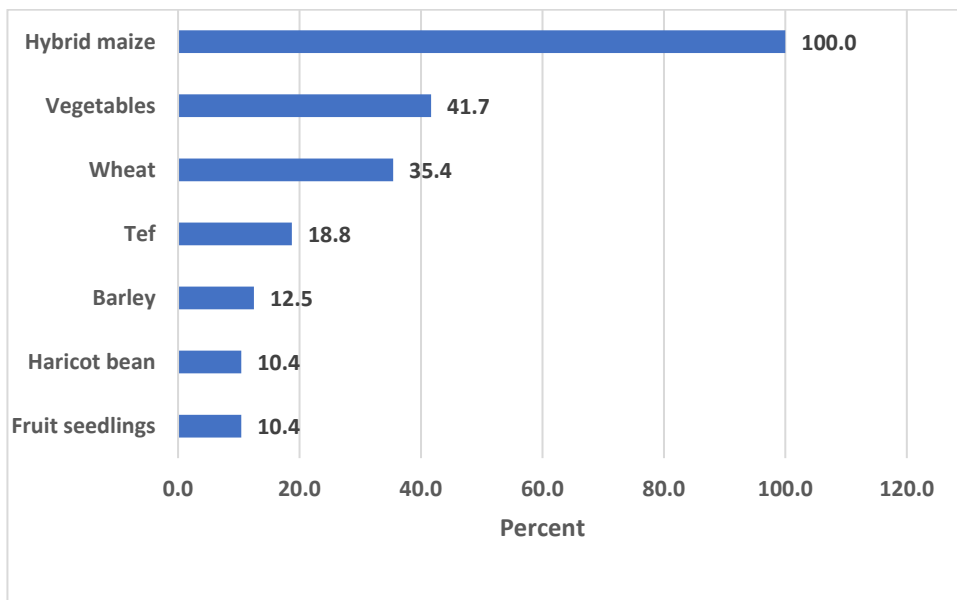


Figure 1. Crop seeds with a prevalence of counterfeit seeds (% respondents; n=48)

Common practices of seed counterfeiting in Ethiopia

Table 1 presents the extent of seed counterfeiting practices in Ethiopia. The respondents were asked to determine the extent to which the practices were most common, less common, and not common. Dressing grains with artificial color is the most common seed counterfeiting practice in Ethiopia, as reported by 83% of the respondents. It is a practice whereby producers or sellers buy and/or prepare ordinary grains, dye them with a similar color, and then sell them to farmers as genuine seeds. An expert further explained that *people practice such illegal acts, aiming to equate fake seeds with genuine seeds. This practice is most common for hybrid maize and imported vegetable seeds because they are treated with chemicals.* Of course, it is sometimes difficult to differentiate the fake color. However, most colors used by fake seed suppliers tend to stick to the fingers during handling, as discussed by respondents.

Seed adulteration is the second most common counterfeiting practice, as explained by 79% of the respondents. This is a practice whereby growers or sellers mix substandard seeds or grains with excellent-quality seeds to increase their quantity. *This is a common practice when there is a critical seed shortage. Producers and illegal traders blend grain or poor-quality seeds with genuine seeds, pretending to be good-quality seeds to gain unfair advantages at the expense of farmers. This practice is more common for hybrid maize than for other crops.* Label imitation, package reuse, and mislabeling are other common practices.

Table 1. Extent of counterfeit seed practices in Ethiopia (n= 48)

Seed counterfeiting practice	Most common (%)	Less common (%)	Not at all (%)
Mislabeled	50.0	35.7	14.3
Label imitation	57.1	28.6	14.3
Repackaging rejected seed	19.0	52.4	28.6
Stealing seed on farm	33.3	47.7	19.0
Adulteration	78.6	16.7	4.7
Dressing grain with artificial color	83.3	14.3	2.4
Package reuse	54.8	31.0	14.2

Main sources of counterfeit seeds in Ethiopia

The respondents were asked to prioritize the three most common seed counterfeiters in Ethiopia in order of importance. Table 2 presents the percentage of respondents who mentioned the specific counterfeiter ranks between one and three. The numbers in parentheses refer to the percentage of respondents who ranked the specific counterfeiter as the top source. About 96% of the experts mentioned that traders are among the top three seed counterfeiters in Ethiopia. Among them, 73% indicated that traders are more responsible than others. Studies in Kenya have indicated that small traders are the predominant source of fraudulent seeds (Gharib *et al.*, 2021). *Some local traders are supplying fake hybrid maize seeds by dyeing the grain with resembling dye, packing it, and selling it to farmers.* The supply of fake seeds by traders, mainly for hybrid maize in Ethiopia, is rampant. This is common during high demand by farmers for specific crops and varieties, for which companies do not supply sufficiently.

About two-thirds of the respondents included agro-dealers among the top three sources of seed counterfeiting in Ethiopia. None of the respondents ranked public seed enterprises as a top source. They are the main producers and suppliers of certified seeds of improved varieties. Around 86% of early-generation seeds (EGS) are produced by public seed enterprises (Hassena *et al.*, 2022). This shows that public seed enterprises are in a good position to be responsible for tackling the counterfeit seed. Moreover, a summary of the responses also revealed the limited contribution of farmer cooperative unions to seed counterfeiting. Respondents also mentioned the large number of farmers as a source for seed counterfeiting. *The phenomenon may be associated with some farmers who may be involved in*

disseminating fake seed that was provided by local grain traders without their knowledge.

Table 2. Seed counterfeiters in Ethiopia

Counterfeiters	Percent (n=44)
Private companies	27.3 (15.9)
Traders	95.5 (72.7)
Farmers	29.5 (2.3)
Agro-dealers	68.2 (15.9)
NGOs	9.1 (6.8)
Public seed enterprises	2.3 (0)
Farmer cooperative unions	6.8 (2.3)

Major causes of seed counterfeiting in Ethiopia

The experts were asked to list the top three causes or driving forces of counterfeit seeds in Ethiopia, and a summary of their responses is presented in Figure 2. Most of the respondents (83.3%) indicated that the limited availability of certified seeds to farmers is one of the three determining factors for the prevalence of counterfeit seeds in Ethiopia. Almost two-thirds of the respondents reported it as the top factor. The limited (non)availability of appropriate legal documents is not a primary problem for addressing seed counterfeiting, as was reported by a few respondents. The legal framework for addressing counterfeit seeds in Ethiopia is addressed by Seed Proclamation No. 1288/2023. The proclamation is granted the power to the Ethiopian Agricultural Authority (EAA) and regional state regulatory authorities to control illegal seed trade and is stated as *“To control illegal seed trade by the regional authority and as deemed necessary by the EAA.”* This shows that the implementation of anticounterfeit seeds is primarily performed at the regional state level, and when necessary, the EAA is engaged in enforcement. Moreover, the EAA establishment legislation (Regulations No. 509/2022), as well as the establishment of regional regulatory authorities, gives power and duties to them *to confiscate agricultural inputs and products that are counterfeit, out of date, of unknown origin, mixed with foreign matter, or do not meet the requirements.* Instead, the respondents emphasized the weak implementation of existing seed legislation is one cause. One expert indicated that *the existing legal documents are adequate for addressing the issue of counterfeit seeds. We can minimize the distribution of fake seeds if there is strong coordination among relevant stakeholders at all levels and commitment to implementation.* Weak enforcement of legislation is a prevalent challenge in Ethiopia and Africa and is associated with several factors, including a lack of awareness among relevant actors, inadequate resources, and poor coordination (Kifle et al., 2022; Komen and Wafula, 2021; Kuhlmann et al., 2023).

A higher profit margin from selling fake seeds is another important cause reported by respondents. The profit potential of selling fake seeds is greater, particularly at times of critical seed shortages. *Seed shortages may arise from the limited supply of seed companies, and in some areas, socioeconomic factors also significantly*

hinder the transportation of seeds to the farming community. Illegal traders understand the situation and analyze the profit margin of selling fake seeds. One-third of the respondents mentioned limited support from legal actors. This is associated mainly with the limited awareness of legal actors about the effect of fake seeds that makes control difficult. Regulatory agencies do not have clear procedures or active platforms such as task forces and committees at different levels to create awareness for the causes and consequences of fake seeds to diverse stakeholders, including legal actors.

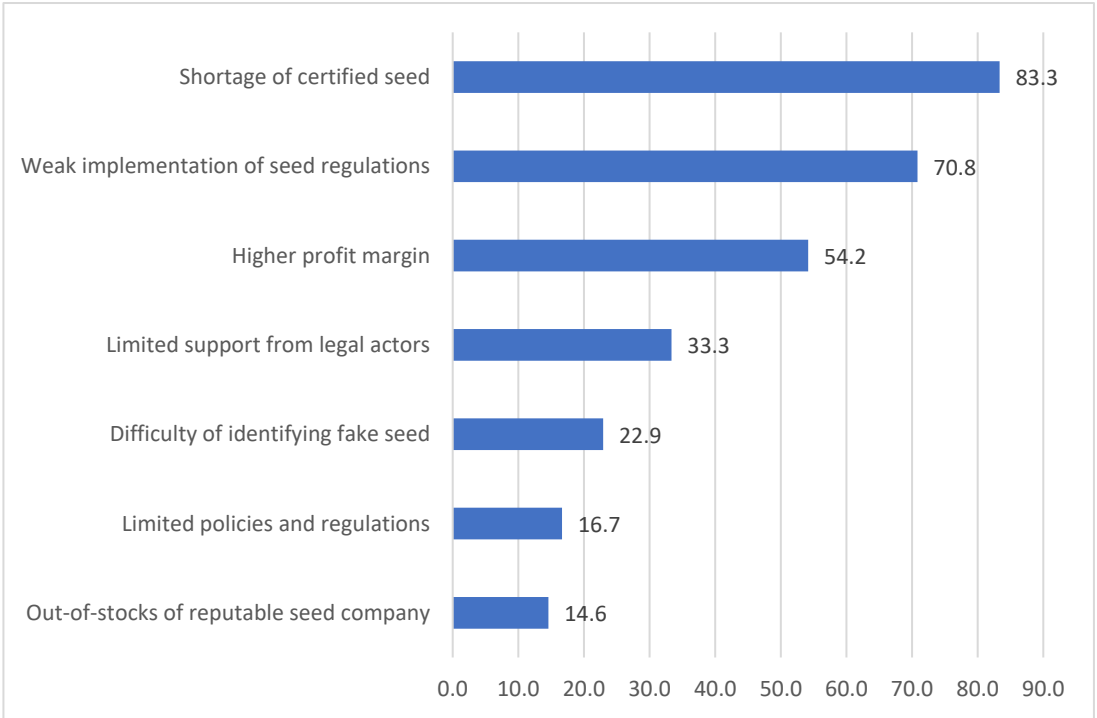


Figure 2. Major causes of seed counterfeiting in Ethiopia (% respondents; n=48)

Impact of counterfeit seeds in Ethiopia

The consequences of seed counterfeiting practices are manifold. It has a significant effect on a wide range of stakeholders and beneficiaries along the seed supply chain (de Boef *et al.*, 2014). In this section, we summarize the responses of the respondents at four different levels: individual farmers, seed companies, regulatory systems, and the seed sector.

Individual farmers

Counterfeit seeds are generally characterized by their poor quality. Poor-quality seeds are associated with poor germination, poor vigor, and weak crop stands. Experts explained that counterfeiting seeds significantly reduces crop productivity, from lowering the plant density to complete crop failure. Poor plant density is

commonly associated with yield and yield-related traits (Barnard and Calitz, 2011; Zaimoglu et al., 2004). Good-quality seeds, together with the recommended specific cultural practices, are responsible for increasing crop yield by up to 15–20% (Prasad et al., 2017).

In addition to the immediate low crop productivity, the use of fake seeds has other economic, health, and social impacts. The use of poor-quality seeds costs African farmers hundreds of millions of dollars annually (AGRA, 2020). The interviewees explained that using fake seeds is a waste of resources for farmers and affects the financial income of the household. *Using fake seeds has double penalties for farmers, i.e., unnecessary costs for fake seed purchase and low productivity and income.* The losses from crop failure and financial losses may risk farmers' livelihoods (ISF, 2018). Farmers' food and feed security could be at risk, which further affects both the food and feed value chains. This further aggravates the unreliability of farmers to shocks. *Fake seeds may have a high impact on farmers who use the seed; productivity declines, which puts the whole family at risk.*

Counterfeit seeds also adversely affect farmers' trust in seeds from the formal channel (ISF, 2018). Farmers may lose trust and hesitate to purchase seeds. They are forced to use their own saved seeds, and their demand for certified seeds will gradually decline. *Farmers might refrain from using seeds delivered through a formal system in the future because they lose what they expect from the seeds.* The expected yield of quality seeds is a key factor for farmers to purchase seeds from producers (Agossou et al., 2023). One expert mentioned that *farmers may not be willing to pay for better inputs, including seeds.*

Seed companies

All seed companies, regardless of their scale of production and type, face challenges from counterfeiting seeds. Its effect is multifold, from influencing the reputation of the company to total bankruptcy. This undermines fair competition among seed companies. *Unfair competition and market imbalance affect the benefits of seed companies and their sustainability in the seed sector.* Counterfeiting affects Kenyan seed businesses in terms of market penetration, market development, product development, and diversification (Mmboga, 2023).

Counterfeiting also affects the business profitability of seed companies and their sustainability in the market. Companies sometimes cannot sell their certified seeds in places where seed counterfeiting is common. Illegal actors may pack counterfeit seeds in packets that completely resemble the genuine seed of a company for which farmers face difficulty in distinguishing the fake seed from the real seed. The interest of companies in investing in seed businesses decreases when the counterfeit seed dominates the market. *In Ethiopia, the absence of effective anticounterfeiting measures discourages private companies from further investment.*

Counterfeiting also affects the credibility of seed companies to customers. Furthermore, it puts the seeds of genuine producers at a lower level of acceptance. The gradual increase in the degree of trust erodibility of buyers toward seed producers affects the seller–buyer relationship. *The low seed market (reduction in seed sales) resulted from the lack of an established relationship between the farmers and the seed producers.* Seed brand counterfeiting is also becoming a common practice in Ethiopia, mainly for hybrid maize and vegetable seeds. Illegal actors use very close branding of the genuine producers by repacking the rejected seed and sometimes even the grain. Brand counterfeiting can change the behavior of customers (Trott and Hoecht, 2007), and customers may lose their trust in seed producers.

Regulatory systems

A strong seed regulatory system is one of the most important success factors for a robust seed sector in any country (TASAI, 2024). It plays a significant role in reducing and controlling the effect of counterfeit seeds. The level of participation of stakeholders actively engaging in each node of the seed value chain depends on the efficiency of the country's seed regulatory system. *Weak seed regulation results in poor recognition of the regulatory system.* The excessive presence of fake seeds in the market may undermine the efforts of seed regulation. The respondents mentioned that *regulatory authorities may have lost their legal mandates and responsibilities.*

The existence of a high level of seed counterfeiting is an indication of the presence of negative externalities associated with a weak regulatory system in the country. *This is associated with the failure to create a strong regulatory system and coordinate institutions.* The absence of strong regulatory systems for combating negative externalities encourages the entry of substandard seeds into the market, which eventually discourages competitive seed market development and private sector investment (Louwaars and Manicad, 2022). Furthermore, the experts mentioned that the controlling effort demands extra costs and workload, as the system is not yet well developed. *The underdeveloped regulatory system increases the unnecessary workload on regulatory experts and makes the identification of counterfeit seeds complex.*

Seed sector

The respondents explained that the presence of uncontrolled counterfeit seeds in the market is one indicator of the presence of a weaker seed sector. They further stressed that the effect could also disrupt and weaken the formal seed supply system. Continued sales of illegal seeds threaten farmers' confidence in the seed sector (ISF, 2018). Moreover, the weaker seed sector has adverse consequences in limiting the private sector's involvement in seed businesses. It also disheartens investors from looking for better opportunities in the sector. An expert mentioned that *private*

investors may be discouraged from investing in innovation, research, and new technologies. The weak seed sector ultimately affects the efforts of the government in ensuring productivity and overall economic growth. A recent report indicated that counterfeiting seeds is a challenge in Ethiopia and requires enhanced support and enforcement of regulations (TASAI, 2024).

Understanding of seed counterfeiting by stakeholders

Combating counterfeit seeds requires the commitment and coordination efforts of several stakeholders. These include farmers, producers, inspectors, traders, law enforcement officers, and policymakers. However, the success of anticounterfeiting depends on the level of understanding by each stakeholder regarding its negative consequences for productivity and the livelihoods of farmers, seed companies, and the seed sector in general. Nearly 85% of the respondents feel that stakeholders, other than regulatory bodies, do not clearly understand the extent of seed counterfeiting in Ethiopia. The experts mentioned that the level of understanding also varies among stakeholders. This limitation may have contributed to the inadequacy of efforts to combat the sale of counterfeit seeds in Ethiopia (TASAI, 2024).

The respondents were asked for their suggestions toward the improvement of a common understanding for relevant stakeholders. Most respondents suggested regular awareness-creation activities through diverse platforms. *Awareness should be created about the extent of the problem and discussions among stakeholders to ensure that coherent strategies and actions are in place.* In addition to massive and continuous awareness creation, they suggested improving the coordination among stakeholders by forming a task force or committee at various administrative levels. Coordinated efforts by stakeholders are necessary to focus more attention on public awareness and effective control measures. Law enforcement officers should work together with seed inspectors for legal measures. *Tackling seed counterfeiting requires strong and coordinated collaboration among all stakeholders across the entire seed value chain.*

Combating counterfeit seeds in Ethiopia

The respondents suggested possible strategies to address seed counterfeiting in Ethiopia. We summarize their suggestions, and this section presents improvement in seed supply, enforcement measures, the application of technologies, the strengthening of regulatory mechanisms, and the improvement of the coordination system.

Improving the seed supply: About 95% of the respondents believe that it is possible to address seed counterfeiting in Ethiopia. Improving the seed supply is the most mentioned option by many of the respondents. *The presence of counterfeit seeds will decline in the market when there is a greater supply of certified seeds of*

improved varieties in the market in sufficient quantities with acceptable qualities. The seed supply system in Ethiopia is dominated by the public sector (Mulesa *et al.*, 2021). In Ethiopia, public seed enterprises are the major suppliers of seeds of improved crop varieties (Hassena *et al.*, 2022; Kalsa *et al.*, 2024; Kifle and Atilaw, 2018). Although they have contributed to the greater supply of seeds to the formal market, they cannot satisfy the diverse seed demands of farmers. Private companies, both national and multinational, have been engaging in formal seed systems. They focus only on a few crops, mainly hybrid maize and vegetables (Ayana *et al.*, 2014; Lemma and Admasu, 2018). However, the problem of counterfeit seed is more prevalent on crops where the private sector has an interest. In recent years, the contribution of cooperative unions to seed supply improvement has increased (Gebrehiwot *et al.*, 2024; Sisay *et al.*, 2017). One expert mentioned that *there must be an enabling environment for private seed companies to increase their number and have access to farmland, credit access, and early-generation seeds to improve the quantity and quality of the seed supply in Ethiopia.*

Enforcement measures: The enforcement of anticounterfeiting measures is also suggested by respondents to combat counterfeit seeds. Taking anticounterfeiting measures is a pressing challenge for many countries, including Ethiopia (Kuhlmann *et al.*, 2022). Ethiopia has a legal framework for addressing counterfeit seeds, giving more responsibility to regional regulatory bodies, as stated in Seed Proclamation No. 1288/2023. However, there are gaps in the implementation. The small amount of attention given by stakeholders coupled with limited progress in the implementation of legal procedures is a challenge in addressing counterfeit seeds. Several respondents believed that *strict law enforcement with meaningful penalties and proper monitoring of the implementation can reduce the challenges of counterfeiting seeds in the country.* The enforcement measures in Ethiopia are critical for preventing seed counterfeiting, and enforcement should include the implementation of penalties and punitive measures (Kuhlmann *et al.*, 2022). Experience from other countries shows that there are different types and levels of measures, such as enforcement actions. For example, in Kenya, the Kenya Plant Health Inspectorate Service, a legal entity for the seed regulatory system, confiscated the bags of seeds and empty packages and closed the shop to conduct further investigations (NTV Kenya, 2019).

Use of technologies: The use of technologies to prevent or limit counterfeit seeds on the market was also proposed by the respondents. Kuhlmann *et al.* (2020) reported that some countries used technologies for combating seed counterfeiting and established a system for verification by farmers. de Boef *et al.* (2014) also summarized the different market-based good practice solutions for tackling seed counterfeiting. These include, among others, e-verification (Ashour *et al.*, 2017), seed coating agents using polymer hydrogels (Gao *et al.*, 2020), blockchain-based traceability (Lee and Yeon, 2021), digital images (Chen *et al.*, 2019), tags with

physically unclonable functions (Arppe and Sørensen, 2017), the use of digital platforms such as SMS (Kuhlmann et al., 2018), and barcode use for seed certification. Some of these technologies may demand skilled manpower and resources. Regulatory experts have suggested the use of barcode systems to address the proliferation of counterfeit seeds. *Innovations, such as the use of secured barcode systems and the use of digital technology with authenticated codes for better traceability of seeds, are important in seed packaging.* In Ethiopia, the use of technologies for addressing seed counterfeiting is not well practiced. Recent interventions regarding the use of barcode systems for seed certification aimed at combatting counterfeit seeds were practiced in the Amhara, Oromia, and Central Ethiopia regional states of Ethiopia (<https://ensp-seed.org/2024/06/04/tackling-counterfeit-seed-lessons-from-amhara-region/>).

Strengthening the regulatory systems: Strengthening the regulatory systems at both the regional and federal levels is suggested by most of the respondents to combat seed counterfeiting. Regional regulatory authorities are responsible for controlling illegal seed trade in their respective regions. The structure of regional regulatory authorities varies among regions. Some regions have independent regulatory authorities, and in other regions, a specific department under the regional bureau of agriculture manages seed regulatory activities. The success of anti-seed counterfeiting depends on the availability of strong legal frameworks and the implementation capacity of those legislative measures. *The Ethiopian Seed Proclamation includes several elements related to seed regulation and illegal seed control, and further specific directives are under development for efficient implementation.* However, regulatory bodies are currently constrained by important capabilities such as staffing, facilities, and logistics (Hassena et al., 2020; Kuhlmann et al., 2022). Experts have suggested that *anticounterfeiting can be successful when there are strong, capable, and responsive regulatory authorities in the country.*

Coordinated efforts: Almost all the respondents believed that anti-counterfeiting efforts can be successful when there is strong and effective coordination among relevant stakeholders. *There should be a strong system that coordinates all the seed value chain actors and stakeholders well to address counterfeiting.* The Ethiopian seed sector in general faces challenges related to coordination and collaboration among seed sector actors and stakeholders (Alemu et al., 2023; MoA, 2019). It is characterized by the lack of a unified government-led coordination mechanism (AGRA, 2022). The loose coordination also affects anti-counterfeiting efforts (Kuhlmann et al., 2022). *The limited commitment by stakeholders to strengthening and capacitating the regulatory system through a decentralized approach is a challenge in tackling counterfeiting problems.* The need to strengthen coordination and leadership is timely and critical to profoundly transform the seed sector of Ethiopia (AGRA, 2022).

Conclusions and Policy Implications

The present study revealed hybrid maize is the primary crop highly affected by counterfeiting, and its prevalence is the highest in Ethiopia. Counterfeit seeds are also common in vegetables, particularly tomatoes, onions, peppers, and cabbage. Therefore, special regulatory emphasis should be given to hybrid maize and vegetables. Regulatory authorities should work with local companies and other relevant actors in ensuring the supply of vegetable seeds with correct information.

Dressing grains with artificial color, adulteration, label imitation, package reuse, and mislabeling are the most common practices of seed counterfeiting in Ethiopia. The efforts of regulatory authorities in tracking rejected seeds are well recognized. Both seed companies and seed regulatory authorities should use technologies for labeling to avoid label imitation and appropriate sealing of approved seed lots. This study also identified traders as the greatest seed counterfeiters in Ethiopia, followed by agro-dealers. Regulatory authorities should strengthen the certificate of competence requirements for agro-dealers and regularly monitor the activities of agro-dealers and the seed companies for which agro-dealers sell their seeds.

This study identified the major driving forces for counterfeiting seeds in Ethiopia. Shortage of certified seed supply, weak law enforcement, and higher profit margins of the fake seed are the major causes of seed counterfeiting. Moreover, limited awareness and loose collaboration among stakeholders are the other driving forces. The significant mismatch between demand and supply is a key reason for seed shortages. The government should encourage and create conducive environments for seed producers, both public and private, to engage in EGS production to improve the quantity of certified seeds. Quality-based seed pricing can inspire companies to involve themselves more in EGS production and supply. Strengthening the capacity of regulatory authorities (staffing, facilities, logistics) is suggested to improve the effective implementation of seed regulations.

This study also described the consequences of counterfeiting seeds at different levels: individual farmers, seed companies, regulatory systems, and the seed sector. At the individual level, it affects the immediate economic and social benefits (e.g., complete crop failure) of households. At the macroeconomic level, it also affects the economic development of the country (e.g., weakening private investment). Moreover, this study suggested improvements in the seed supply, enforcement measures, innovations, strengthening regulatory systems, and coordination to address seed counterfeiting in Ethiopia. Furthermore, it is suggested that awareness creation and timely information delivery to diverse stakeholders, including farmers, seed companies, regulatory experts, law-enforcing officers, and policymakers, are crucial in combating counterfeiting.

The present study has certain limitations. This study gathered information from resource people who have immense experience in the seed business. The present study didn't include the total volume or percentage of counterfeit seed in the country due to a lack of well-documented information. Moreover, it didn't collect sample seed from the market or from the production field for checking variety identity and varietal purity. The study also didn't include many respondents from the private sector due to the lower response rate. Acknowledging the limitations of the study, we suggest an in-depth survey by addressing diverse stakeholders who have a stake in the seed sector, including producers, regulatory experts, law enforcement officers, farmers, and policymakers. We suggest further research into investigating the prevalence of counterfeit seed through proper seed quality analysis from sample seed.

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