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Research Article

The Formal Seed System of Maize in Ethiopia: Implications for Reducing the Yield Gap

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Smallholder farmers' access to and use of quality seeds of improved varieties and hybrids is an integral component of sustainable maize production and the reduction of the yield gap in Ethiopia. Formal seed supply systems play a pivotal role in ensuring farmers' access to good quality seed and increasing the productivity of maize. However, the contribution of the formal seed system to the increase in the average national maize yield in the country is not well documented. This paper specifically analyzes the formal seed supply systems and contributions of improved seed to maize productivity increase in Ethiopia. Secondary sources of information, including published and unpublished data, were used. Analysis of the seed value chain from research to commercial seed producers indicated that public and private maize hybrids dominate the formal seed system. Increased use of improved seed and associated management practices has contributed to the yield increase at the national level. For every 10,000 MT of additional maize-improved seed used by smallholder farmers, the national average maize yield increased by 400 kg per hectare (*R* sq. = 0.59). Hence, in addition to other yield-increasing technologies and extension support, ensuring the availability of improved seed to farmers can significantly contribute to reducing the maize yield gap between the national average yield and the average yield from on-farm demonstrations already attained by farmers in Ethiopia. Various policy interventions are suggested to improve the maize seed system performance and increase the supply of maize improved seeds.

1. Introduction

Maize is a leading staple crop in the world in terms of production volume. Globally, maize is harvested from approximately 205 million hectares, and the total production is ca. 1.2 billion MT [1]. The global seed trade of maize accounts for approximately 3.56 billion USD [2]. Maize has the most advanced formal crop improvement and commercial seed production and distribution system across the world, and it is the key crop for most seed companies [3]. However, depending on the region and country contexts, the global maize yield gap ranges from 0 to 9 t/ha [4]. The maize yield gap is defined by the difference between potential yield and actual farmers' yields [5].

Maize remains crucial for food security in sub-Saharan Africa while the yield gap remains extreme in the region [4, 6]. In Ethiopia, maize is a staple crop grown on 2.5 million hectares in 2021 with a volume of production of 10.3 million MT [7]. While the national average yield of maize increased from 1.9 MT per hectare in 2003 to 4.2 MT per hectare in 2021 [7], there is a need to work towards reducing the maize yield gap to achieve sustainable food production for the ever-increasing population. Inadequate access to advanced technologies such as improved seed and fertilizer makes up the largest component of the maize yield gap in Ethiopia [8, 9] and the sub-Saharan Africa at large [5, 8, 10–12].

Similar to the global context [3], the maize seed industry in Ethiopia is also mostly formal, and out of the seeds required for planting the maize area in 2021, more than 80% was covered with improved seed [7]. The formal seed system of maize involves breeding institutions (the National Agricultural Research System, private breeding companies, and CGIAR centers), commercial seed producers (public seed enterprises and private seed companies), seed producer cooperatives/unions, the regulatory body (Ethiopian Agricultural Authority including regional entities), and the Ethiopian Biodiversity Institute.

As in other parts of the world [13–15], the introduction of hybrid maize has significantly contributed to changes in maize yield in Ethiopia. Although several maize varieties and hybrids have been released in Ethiopia over the years, currently, a total of 77 varieties are registered for production in the country, most of which are hybrids. For hybrids to impact maize yield, there is a need to have a sufficient quantity of the desired quality of seeds of new varieties produced and supplied to farmers. Hence, besides other yield-increasing factors, the increase in maize yield must be due to the increasing use of improved seeds [10, 16]. However, the separate contribution of the formal seed supply to the increase in maize yield in Ethiopia is not well distinguished to our knowledge. Hence, this study aims to specifically distinguish the contributions of formal seed supply to maize productivity increase, sort out the challenges faced by the formal seed system, and suggest possible policy interventions.

2. Study Methods

The source of data for production and farm management was the time series publications of the Ethiopian Statistical Service (ESS) [17] for the period from 2003 to 2020. In addition, improved seed demand, supply, and distribution data were obtained from unpublished data from the Agricultural Investment and Inputs Sector (AIIMS) of the Ministry of Agriculture (MOA). Information on improved seed production by public seed enterprises was obtained from the minutes of the Federal and Regional Public Seed Enterprises Forum (FRPSEF) for the years 2019–2022.

Data analysis involved tabulations and simple linear regression. To calculate the rate of yield gains over the improved seed use (MT) and maize area coverage (ha), the ESS productivity data were regressed on yearly improved seed use and improved seed area coverage [10]. The resulting regression coefficients were taken as the rate of increase in yield per unit amount of improved seed use or unit area coverage by improved seed use. In addition, to understand the impact of extension and fertilizer use on improved seed use (MT), the yearly consumption of improved seed was regressed over the area coverage by extension package and the area coverage with full fertilizer (DAP/NPS/mixed + urea). The resulting coefficients were taken as a unit increase in the quantity of improved seed use per unit area of the extension package or the full fertilizer application. SigmaPlot 12.5 software was used to generate regression plots.

3. The Formal Maize Seed System of Ethiopia

3.1. The Maize Formal Seed System Structure of Ethiopia. The formal maize seed system of Ethiopia is characterized by an active engagement of the public and private sector actors participating at various levels of the value chain. Figure 1 shows the links among major entities at different levels along the maize value chain. Public research institutes and universities are involved in germplasm and variety development and maintenance of breeder/prebasic seeds. Currently, multinational seed companies in Ethiopia import maize parents to multiply improved seeds locally.

The emergence of regional public seed enterprises together with the increasing role played by the private sector in hybrid maize seed supply might have contributed to the significant changes in improved seed supply and increased maize yield. In hybrid maize, the private sector has a stronger role compared to other field crops. The roles played by major entities of the formal seed system are depicted in the following sections.

3.2. The National Agricultural Research System. In the formal seed system of maize, in addition to variety development, the National Agricultural Research System (EIAR, RARIs, and Universities) plays a pivotal role in maintaining public varieties and supplying their early generation seed [17–19]. The EIAR (through its subsidiary research centers, namely, Melkassa, Bako National Maize, and Ambo) maintains and supplies the early generation seed for lowland, midaltitude, and highland public maize varieties [19]. Based on an initiative of a decentralized early generation seed production scheme, RARIs are also playing a vital role in the production and maintenance of parental lines (breeder and prebasic seeds). The Amhara Agricultural Research Institute (Adet Agricultural Research Center) and Oromia Agricultural Research Institute (Bako) are participating in the production of breeder and prebasic seeds of parents of hybrid maize varieties. The research system is also involved in the demonstration and popularization of the newly released varieties through preextension and large-scale demonstrations.

3.3. Public Seed Enterprises. Public seed enterprises play an important role in the supply of maize prebasic, basic, and improved seed [20, 21]. Currently, five seed enterprises, namely, Amhara Seed Enterprise (ASE), Ethiopian Agricultural Business Corporation (EABC), Oromia Seed Enterprise (OSE), Somali Seed Enterprise (SoSE), and South Seed Enterprise (SSE), are operating in the formal supply of maize seed. Public seed enterprises together supplied a yearly average of 12,953 MT of maize-improved seed between 2018 and 2022 (Table 1). Except for EABC, all public seed enterprises operate at the regional state scale. Since the late 2000s, all public seed enterprises have established a dialog forum. The forum is chaired by the EABC, and the Ethiopian Institute of Agricultural Research (EIAR) and the Agricultural Investment and Input Sector of the MoA are observing members. The forum plays an important role in terms of price setting for improved seed of public varieties (both hybrids and OPVs) produced by the enterprises.

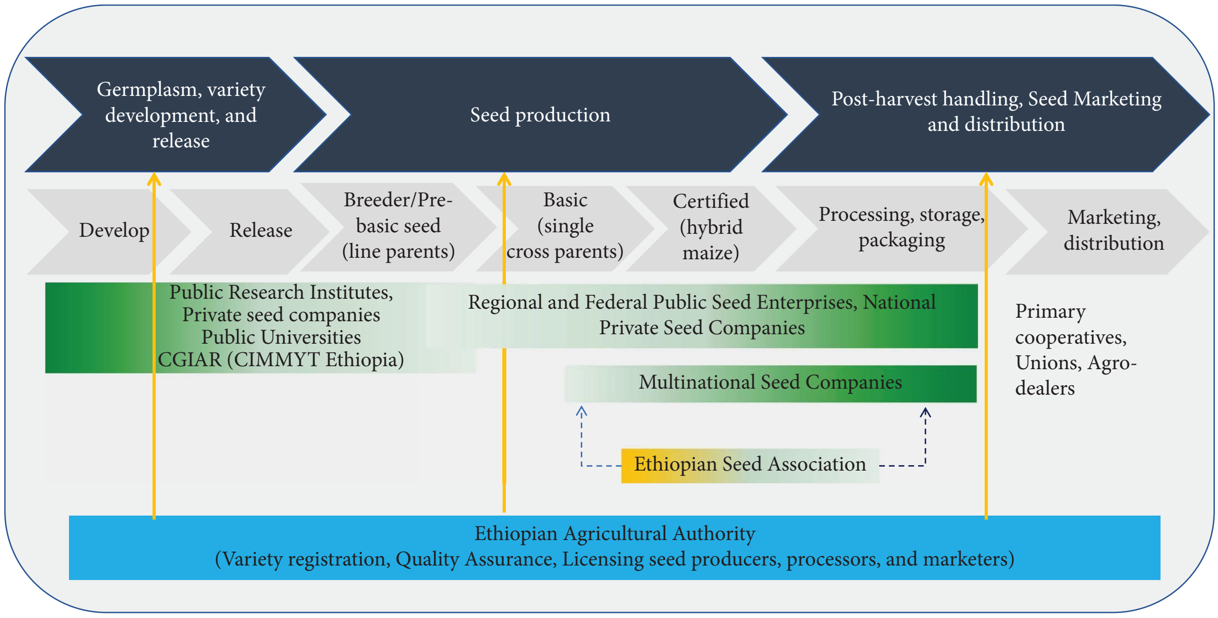

Figure 1: The maize seed industry structure in Ethiopia.

Table 1: Amount (MT) of improved seed of maize produced by public enterprises in Ethiopia.

Year	OSE	ASE	SSE	EABC	SoSE	Total
2019	5797.7	1331.8	3303.6	3867.2	750.0	15050.3
2020	9718.4	1614.6	3878.8	6649.7	1034.2	22895.7
2021	10521	2757.2	550	2295.1	989.4	17112.7
2022	10521.0	1627.9	550.0	1639.2	1221.5	9707.4
Total	30729.4	7331.5	8258.9	14451.2	3995.1	64766.1

*OSE = Oromia Seed Enterprise; ASE = Amhara Seed Enterprise; SSE = South Seed Enterprise; EABC = Ethiopian Agricultural Business Corporation; SoSE = Somali Seed Enterprise (source: Federal and Regional Public Seed Products Forum (unpublished data)).

There are recent moves to establish public seed enterprises under newly established regional states such as Central Ethiopia and South Western Ethiopia and former ones, namely, Afar and Tigray Regional States (source: author assessment). Operationalization of those public seed enterprises will surge the number of parastatals.

3.4. National and Multinational Private Companies. The Ethiopian Seed Association (ESA) has registered two members as multinational (a multinational company is a company that does business in other countries around the world) (Pioneer Hi-Bred Seeds Ethiopia PLC now Corteva Agriscience and Bayer Crop Science PLC) and 25 members as national (national private companies are those registered within Ethiopia and have no business in another country) private seed companies [22], while there are still emerging companies that are not yet affiliated with the ESA. Private seed companies that entered the maize seed market with their varieties included Corteva Agriscience (Pioneer Hi-Bred Seeds, Ethiopia), Syngenta, Red Speckled Ethiopia, Seed Co, GCT Trading, CPP Seeds PLC, and Bayer Crop Science PLC (Monsanto/Makobu) [23]. The presence of multinational private seed companies in the formal seed supply system of maize dates back to the 1990s with the release of the first private hybrid Jabi by Corteva Agriscience (Pioneer Hi-Bred Seeds Ethiopia). During the early 2000s, Syngenta entered the Ethiopian maize seed market with two hybrids, namely, Bereda and Beles. However, Corteva Agriscience remained the major player in the private seed supply side of maize in Ethiopia. The demand for Corteva hybrids is increasing, but there is a limited supply. In 2022, only 25% of the demand for Corteva Agriscience hybrids (mainly for the hybrids Damote, Limu, and Shone) was supplied, and it was approximately 27% of the national hybrid maize seed supply during the same year (MoA, unpublished data).

Recently, Bayer Ethiopia has been pushing into the maize seed market of the country, with 74 MT, 54 MT, and 156 MT improved seeds of its hybrids during 2020, 2021, and 2022, respectively (Jemal Mussa, personal communication).

The strong seed extension and marketing strategy followed by private seed companies is creating an increasing demand for private varieties (key informant discussions). Providing adequate support to private sector players can improve market competition and farmers' choice of varieties with genuine merits. While multinational companies have their varieties, the domestic private sector relies on public varieties. Improving the access of domestic private seed companies to public varieties through licensing and variety designation can be a way to bring fair competition in the maize seed market of Ethiopia.

3.5. Seed Producer Cooperatives and Unions. In the formal maize seed system, while there are some unions that produce their own improved hybrid seed, seed producer cooperatives and unions are involved mostly as out-growers. Their involvement is mainly in contractual seed production arrangements with public seed enterprises [24]. Self-pollinated crop seed producer cooperatives play a key role in meeting seed demand and contribute greatly to seed supply improvement for farmers.

4. Improved Seed Demand and Supply Dynamics in Maize

4.1. Improved Seed Demand and Requirements. Different authors have lamented that the lack of realistic demand is one of the major challenges in the formal seed system of Ethiopia [18, 25, 26]. In self-pollinated crops, changes in the demand in terms of variety or quantity of seed cannot be estimated from the demand collection system, and there are always mismatches in demand and supply on the ground. Unlike self-pollinated crops, however, the demand for maize hybrids is nearly realistic despite mismatches in some of the varieties.

Currently, there is little difference between the quantity of maize seed required to cover the maize area and the quantity of demand collected. In addition, the difference between the quantity of improved seed utilized by farmers and the quantity required or the collected demand is not more than 19%. The maize production area in 2021 was approximately 2.5 million ha, with an improved seed requirement of 63,155.3 MT at a seed rate of 25 kg per ha (Table 2). The improved seed demand collected for the same year by the Ministry of Agriculture was approximately 63,896.5 MT of different varieties. This implies that the collected demand and the required quantity of maize seed were nearly realistic.

However, there is a large difference between the quantity utilized and the quantity required or the collected demand (Table 2). For instance, in 2021, the demand for improved seed was 63,896.5 MT, while the improved seed produced in the country was 32,518.3 MT. This indicates that the remaining improved seed utilized by farmers in the same year was from other sources.

4.2. Varietal Dynamics of Improved Seed Demand. Except for a few varieties, the demand for improved seed was consistently below 1% of the total demand during the period between 2020 and 2022 (Table 3). Six hybrids dominated the improved seed demand. The demand for improved seeds of Limu, BH661, Shone, BH540, Damote, and BH546 accounted for more than 90% of the total demand for improved hybrid seeds of maize. The demand for the private variety, Limu, was consistently higher than 20% of the total maize seed demand. Likewise, the public variety BH661 accounted for approximately 17.5–2% of the total improved seed demand in 2021 and 2022.

The relatively high demand for private varieties such as Limu and Shone could be attributed to the supply of high-quality seed and strong extension systems (including after-sales service) adopted by the seed company. It was learned from the analysis of long-term national data that there is a strong relationship between extension service and the use of improved seed. With inadequate extension and popularization, farmers' knowledge of newly released maize varieties remains low [27].

In recent years, the demand for BH546 has increased, while that for BH660 has slightly diminished. The recent increase in the demand for BH546 might be due to the expanding knowledge by farmers on its yield advantages over the long-existing BH540. A recent extensive demonstration by ACDI/VOCA across Amhara, Oromia, SNNP, and Tigray in 2022 indicated that the average yield over 1223 plots of BH546 was approximately 64 Q/ha (Getahun Alemu, personal communication, and unpublished data).

While newly registered public hybrids such as BH661, BH546, BH547, and BH549 are well known for their superior performance, there is always demand for the outdated varieties in some areas because of limited awareness of the farmers about the existence of new varieties and lack of seeds of the new varieties. BH661, BH546, and BH547 are combination hybrids developed by EIAR breeders using CIMMYT and EIAR parental inbred lines, while all parents of BH549 have been developed by EIAR breeders. The maize seed demand for decades-old public varieties such as BH140, BH660, and BH540 is surprising and an issue that the formal maize seed system could not revert to until recently. However, the maintenance of parental materials for those hybrids is nearly unavailable at the research centers. The hybrids BH546 and BH547 have yield advantages of 30% and 26.4%, respectively, over BH540 [28–30]. The former two are three-way cross hybrids (CML395/CML202/BKL001 and BKL002/CML312/BKL003, respectively) [23] released for high-potential maize growing areas and adapted to the same agroecology where BH540 had been widely grown. Promotion of these high-yielding modern varieties is highly needed to increase farmers' awareness. However, the return for investment on variety promotion by commercial seed companies is very minimal because any commercial company can take the market advantage of a well-promoted public variety. This can be properly handled through licensing public varieties to commercial seed producers.

A deeper investigation was performed on the surprisingly high demand for the extremely old BH540 hybrid, while its parental materials are not yet maintained at the research centers. Discussion with key informants from South Seed Enterprise, Southern Agricultural Research Institute, and former SNNPR Bureau of Agriculture indicated the drivers. The high demand by farmers for the hybrid seed of BH540 could be attributed to its yield, white flour color of the grain, and water absorption capacity of the flour. Farmers perceived that the comparative advantages/disadvantages of BH540 should be carefully specified through participatory variety trials and farinographic tests. On the other hand, from the key informant discussion, it was also learned that hybrid seed production of BH540 is a challenge because the male parent has a low yield and the female parent has lodging problems when improved seed is produced. This makes the $F1$ yield of BH540 low (<20 Q/ha) and unattractive to seed producers. This in turn has reduced access to improved seeds of BH540. Replacing BH540 with recent hybrids of comparable end-use quality is an essential step to be taken by the formal seed system in Ethiopia.

Table 2: Improved seed demand, utilization, and requirement of maize in Ethiopia.

Year	Improved seed demand (MT)*	Improved seed used (MT)**	Area of production (ha)**	Improved seed requirement (MT)***	Demand-to-requirement ratio (%)	Utilization-to-requirement ratio (%)	Utilization-to-demand ratio (%)
2013	45,600	17,210	2,013,045	50,326	90.6	34.2	37.7
2014	46,605	20,129	1,994,814	49,870	93.5	40.4	43.2
2015	49,255	23,381	2,110,209	52,755	93.4	44.3	47.5
2016	48,399	22,895	2,111,518	52,788	91.7	43.4	47.3
2017	50,226	30,522	2,192,572	54,814	91.6	55.7	60.8
2018	44,692	31,569	2,128,949	53,224	84	59.3	70.6
2019	39,210	NA	2,367,797	59,195	84.0	NA	0
2020	45,195	43,758	2,274,306	56,858	79.5	77.0	0.0
2021	63,897	52,000	2,526,212	63,155	101.2	82.3	81.4

*Source: administrative data from the Ministry of Agriculture. **Source: https://www.statsethiopia.gov.et/our-survey-reports/. ***Calculated based on the total area of maize production and the seed rate (25 kg per ha). NA, data not available for improved seed utilization. (), data for actual improved seed produced in the year.

Table 3: Percentage share of maize hybrids in the national demand for improved seed of maize (source: MoA, unpublished data).

Maize hybrid	Institution/Company	Year of release	Adaptation	2020	2021	2022	Average
Limu/P3812W	Corteva Agriscience™	2012	Midaltitude	28.6	35.7	32.4	32.3
BH661	EIAR/Bako NMRC	2011	Mid to Highland	23.2	17.5	19.6	20.1
Shone/P30G19	Corteva Agriscience™	2006	Midaltitude	16.1	18.7	19.2	18.0
BH540	EIAR/Bako NMRC	1995	Midaltitude	12.9	9.5	10.9	11.1
Damote/P3506W	Corteva Agriscience™	2015	Midaltitude	4.3	7.2	5.6	5.7
BH546	EIAR/Bako NMRC	2013	Midaltitude	2.1	4.6	5.6	4.1
BH660	EIAR/Bako NMRC	1993	Midaltitude	5.8	2.9	2.5	3.7
BH140	EIAR/Melkasa ARC	2013	Low land	4.0	1.6	2.4	2.7
Kortu/P2809W	Corteva Agriscience™	2017	Midaltitude	0.2	0.9	0.3	0.5
BH547	EIAR/Bako NMRC	2013	Midaltitude	0.5	0.2	0.8	0.5
BH545	EIAR/Bako NMRC	2008	Midaltitude	0.8	0.2	0.1	0.3
MH140	EIAR/Melkasa ARC	2013	Low land	0.4	0.2	0.0	0.2
Leku/DK777	Bayer Ethiopia	2017	Low land	0.1	0.1	0.3	0.2
Jibat/AMH851	EIAR/Ambo ARC	2009	Highland	0.1	0.1	0.3	0.2
BH543	EIAR/Bako NMRC	2005	Midaltitude	0.2	0.1	0.1	0.1
BH541	EIAR/Bako NMRC	2002	Midaltitude	0.2	0.1	0.0	0.1
Shallaa/P2859W	Corteva Agriscience™	2011	Midaltitude	0.2	0.0	0.0	0.1
Aba Raya	Syngenta	2006	Midaltitude	0.1	0.0	0.0	0.1
MH138Q	EIAR/Melkasa ARC	2012	Low land	0.1	0.0	0.0	0.1

5. Contribution of Improved Seed Use to the National Maize Yield

The average national maize yield in Ethiopia increased by more than 121% between 2003 (1.9 t/ha) and 2020 (4.2 t/ha) [7]. A regression analysis of maize national yield over the years 2003–2020 showed that the average yearly change was approximately 160 kg per ha. In line with this, the quantity of maize-improved seed utilized by smallholder farmers in Ethiopia during the years between 2005 and 2020 increased by 343.4% [7]. It was observed that there is a direct relationship between the quantity of maize-improved seed used by farmers and the national yield average (Figure 2). For every 10,0000 MT of additional maize-improved seed used by smallholder farmers, there was an increase of 0.4 MT per ha in the national average maize yield (Figure 2(a)). In addition, for every additional 100,000 ha of maize area covered with improved seeds, there was an increase of 0.2 MT per ha in the national average maize yield. Figure 2(c) shows that for every 10% increase in the area covered by the improved seed of maize, there is an increase of 46 MT per ha of the national average yield. A study on the impact of the direct seed marketing (DSM) approach in Ethiopia indicated that there was a 26% increase in maize yields due to DSM [31]. Such evidence shows that improving farmers' access to maize hybrid seeds can enhance national maize productivity [16].

It is imperative, hence, that the formal seed supply system played a fundamental role in terms of increasing maize production and productivity in Ethiopia. However, the role of other inputs, although their impacts highly depend on the availability of quality seed and the contribution of favorable policy (leadership and extension service), should be considered in the increase in maize production and productivity in the country.

There was a strong relationship between the application of fertilizer, use of extension packages, maize yield, and quantity of improved seed used (Figure 3). As expected, maize productivity was positively influenced by the maize area receiving all categories of fertilizer and the area coverage of the extension packages. An increase in the area of maize receiving all categories of fertilizer by 100,000 ha increased maize yield by 0.2 MT per ha. Similarly, an increase in the maize area that received full extension packages by 100,000 ha increased the yield per ha by 0.16 MT. With no extension package, maize yield could remain at only 1.5 t/ha. It is well documented that access to extension services determines improved seed use [14, 32].

Not only maize yield but also the use of improved seed is dictated by access to extension packages and the use of fertilizer (Figure 3). As the maize area receiving all categories of fertilizer (DAP/NPS/blended + urea) increased, the quantity of improved seed used also increased. Farmers' investment in yield-increasing technologies might be influenced by their access to improved seeds of improved varieties of maize and vice versa.

Similarly, an increase in the area that received full extension packages also had a positive influence on the quantity of improved seed used. Maize hybrids have been essential components of the extension package in recent years. With no use of complete fertilizer and extension packages, the use of maize-improved seed was observed to be nil (Figure 3). This implies that farmers' use of maize-improved seed is highly dictated by access to fertilizer

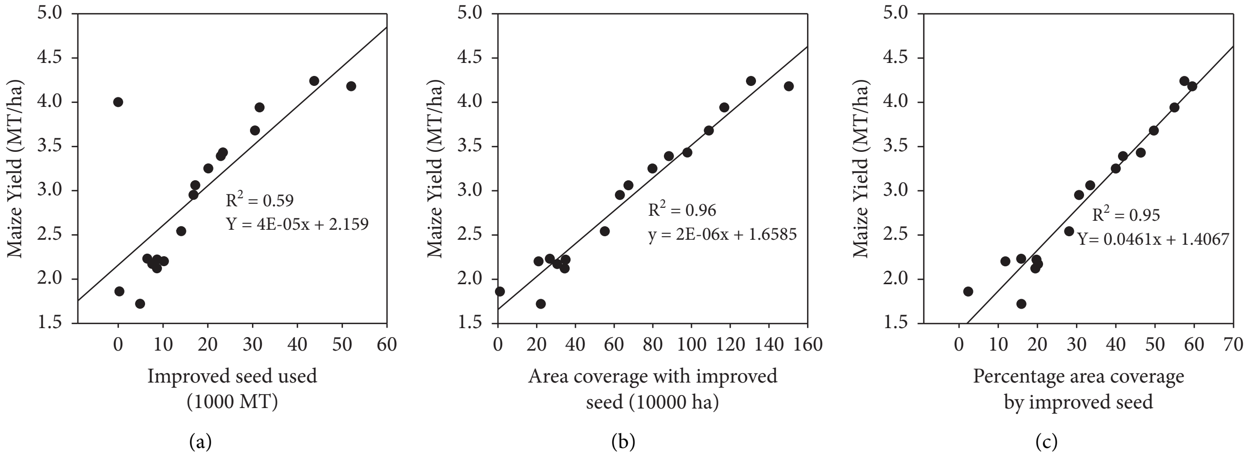

Figure 2: The relationships between maize yield (MT/ha) and the volume of improved seed used (a), maize area covered with improved seed (b), and percentage share of maize area covered with improved seed (c) during 2004–2021 (source: author analysis).

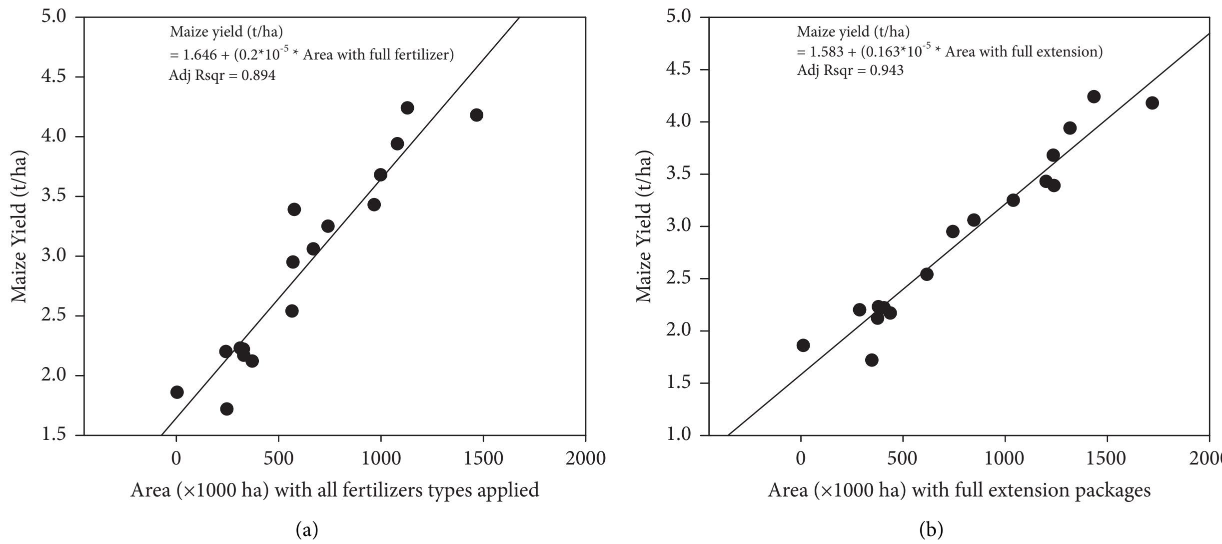

Figure 3: The relationships between maize yield (MT/ha) and total maize area that received all types of fertilizer (a) and total maize area that farmers implemented full extension packages (b) during 2004–2021 (source: author analysis).

and extension packages. Similarly, earlier studies also showed that there is a strong relationship between fertilizer and improved seed use by farmers [32].

6. Conclusion and Policy Implications

6.1. Conclusion. The maize seed system in Ethiopia is predominantly formal. According to data from the Ethiopian Statistical Service [7], in recent years, improved seed use by maize farmers has reached approximately 82% of the total requirement. A production pathway analysis also indicates that there is sufficient prebasic seed being produced for public hybrids. However, the production of improved seed from the early generation seed supplied to seed producers is not as expected. This indicates that there is a loss of EGS at certain points and mismatches between the produced and demanded varieties, which need adequate planning and an adequate tracking mechanism that extends from breeder seed multiplication to improved seed marketing.

There is adequate evidence that improved seed use by farmers from formal seed sources has positively influenced maize productivity in Ethiopia. Improved seed and fertilizer use and other improved agronomic management practices are complementary agricultural inputs that can positively influence maize yield. To enhance maize-improved seed use, there is a need to improve the access of farmers to fertilizer. In addition, improved seed use is associated with farmers' access to extension packages and services. Maize extension packages consider improved seeds as an important component of the menu.

6.2. Policy Implications. The maize production increase remains an important component of food system resilience in Ethiopia. In addition, the demand for maize grain for feed is expected to increase as the country is developing. Therefore, the government can positively influence improved seed use for maize through different policy interventions.

6.2.1. Hybrid Maize Seed Promotion. Seed producers should be adequately encouraged to adequately promote improved seed use of newly developed better-performing hybrids. This will in turn increase maize seed marketing and improve varietal choice for farmers. This is especially important for public maize hybrids and those companies that use the hybrids. Promotions of public varieties can be strengthened through the transfer of the right of use to commercial entities. Public maize hybrids can be transferred to commercial entities through variety licensing through exclusive or nonexclusive rights.

6.2.2. Increase Private Sector Role. Currently, the private sector's role is increasing in the maize seed industry of Ethiopia. The government can promote more private investment in hybrid development and seed production through the operationalization of the legal frameworks of plant breeders' rights. However, the land shortage, which is very important in terms of breeding stations and early generation seed production, should be adequately addressed for the private sector to participate in maize hybrid seed value chain activities. Moreover, the private sector needs support from the government structure (all from federal to woreda admin) to establish fair play in terms of early generation seed allocation of public varieties, shortening lengthy licensing processes, improving infrastructure and security, and improving access to foreign currency allocation for the importation of maize parents.

6.2.3. Maize Farm Management. In addition to the use of hybrid maize seed, the national average yield increase is also due to the increasing use of fertilizer and agrochemicals. In addition to encouraging farmers to increase fertilizer use per unit area, there is a need to improve farmers' access to fertilizer (in terms of availability, affordability, and quality). It is also important to increase the maize area that receives full recommendations through a vibrant maize extension service.

Data Availability

The datasets during and/or analysed during the current study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

KKK led data collection and wrote the manuscript. SA reviewed the manuscript and contributed to the regional data collection. MW, TA, and AT provided insights.

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