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Original Research

The Formal Seed System and Seed Quality of Malt Barley in Northwestern Ethiopia: Implications for Reducing the Yield Gap

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Abstract

The formal seed distribution system plays an essential contribution in guaranteeing farmers' access to quality seed of malt barley. However, the role of formal seed systems in increasing the average malt barley produced in the country is not well documented. This paper focuses on examining the formal seed supply systems & their involvement in improved seed-to-malt barley yield increase in northwestern Ethiopia. The data were collected from secondary sources of information, investment, and inputs sector of Agriculture and public seed enterprises. Various analytical methods were applied to the gathered data according to their type. The highest adoption of improved seed and related management practices has led to increase yield in malt barley. Increased use of improved seed and associated management practices has contributed to the yield increase. For every 100 tons of additional malt barley-improved seed used by smallholder farmers, the regional average yield of malt barley increased by 2500 kg/ha (R sq=0.76). Therefore, alongside other yield-enhancing technologies and extension services, ensuring that farmers have access to improved seeds can play a key role in reducing the malt barley yield gap between the national average and the average yield achieved by farmers through on-farm demonstrations and supporting private seed enterprises.

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INTRODUCTION

Barley (*Hordeum vulgare L.)* is one of the most important staple foods and economically significant cereal crops in Ethiopia, following teff, maize, wheat, and sorghum in terms of widespread use (Tewabe et al., 2020). It is a crucial grain crop in Ethiopia, cultivated in a variety of ecological zones ranging from 1800 - to 3400 meters above sea level, across different seasons and production systems (Abebe et al., 2022). In the 2018/2019 main cropping season, Ethiopia's barley production was 1,767,518.447 tons, with a productivity of 2.177 tons per hectare (Abebe et al., 2022). In 2020/2021, barley production was assessed to

be 2.35 million metric tons. Similarly, malt barley covers 950,742.01 hectares of land in Ethiopia, with a productivity of 25.2 quintals per hectare. The Amhara Region covers 32,515.21 hectares of land, with a productivity of 23.3 quintals per hectare (Alemu et al., 2023). Between 2009 and 2013, farmers in Ethiopia received over 1932.1 tons of seeds from seed companies, covering 77,080 hectares of land (McGuire & Sperling, 2016). Malt barley makes up a small portion, not exceeding 10%-15%, of the overall share, but it remains a priority for malt factories, breweries, and policymakers (CSA, 2016; Abebe et al., 2022).

According to the level of complexity in agricultural production, crops, and the environment, a country's complete seed supply may come from a variety of sources, such as off-farm sources, it may come from on-farm savings made by the farmer (Bishaw, 2004, and Wegayehu & Derib, 2019).

The seed supplying system had a significant role for producers. Several institutions are involved in the malt-barley seed system. However, based on discussions and survey results, access to improved seeds has some limitations (Shimelis et al., 2024). First, there is resource waste due to duties being overlapped, gaps in, and repeated efforts by different institutions (Kebede et al., 2017; Wegayehu & Derib, 2019).

The use of seeds from formal seed suppliers by smallholder farmers in Sub-Saharan Africa is still restricted due to the Green Revolution (Ariga et al., 2019; Shimelis et al., 2024). Ethiopia was the first nation to adopt the Varied Seed System approach formally (Deme et al., 2020). As a substitute for the commonly employed formal seed system development or linear approach. Policymakers and people with agricultural backgrounds can share this information. As a result, the farmer can stop the crop from degrading and strategies can be created based on expected outcomes. Sustainable agriculture needs seeds, improved varieties, and other agricultural inputs to turn subsistence farming into a profitable industry.

The formal seed system and seed quality of malt barley in Northwestern Ethiopia face several challenges that contribute to a significant yield gap. These gaps hinder the full potential of malt barley production in the region. The key gaps identified in the formal seed system for malt barley in Northwestern Ethiopia are limited research on seed demand and supply dynamics, inadequate data on seed quality and certification processes, limited research and development for the region, inadequate seed distribution networks, limited attention to local adaptation and diversity, inadequate extension services and farmer training, underexplored socio-economic factors affecting seed adoption, inadequate assessment of seed system sustainability and limited government and private sector investment. Addressing these gaps in the study of formal seed systems can lead to a more effective and inclusive seed system that improves access to high-quality seeds, ensures better crop yields, and fosters agricultural sustainability. Hence this study aims to decide the role of a formal seed system and its contribution to malt barley productivity increase, guide investments, and help tailor seed systems to local needs.

MATERIALS AND METHODS

The study was conducted during the 2021 and 2022 cropping seasons in the Amhara region of Ethiopia: The available data source for farming and agricultural management was from chronological data publication by the

Ethiopian Statical Service (ESS) from the years 2001-2020 and stakeholder interviews. Furthermore, enhanced seed demand, supply, and distribution data were gathered from unpublished sources within the agricultural sectors of the Amhara region. Data on improved seed production by public seed enterprises was collected from the national and regional seed enterprises and malt factories from the years 2018-2022 (Abebe et al., 2022).

Data analysis

Various analytical methods were applied to the gathered data according to their type. The data analysis included creating tables and applying simple linear regression. Estimating the rate of yield increases resulting from the use of improved seeds, and malt barley in the cultivated land cover (ha), the ESS yield information was regressed on year-on-year improved seed use and better-quality seed area coverage (Abate et al., 2015). The subsequent regression coefficients were considered as the rate of yield improvement per unit of improved seed use or unit area covered by improved seed. Furthermore, to assess the impact of extension services and fertilizer use on improved seed usage, the annual consumption of improved seed was regressed against the area covered by the extension package and the area with full fertilizer application. The resulting coefficients were interpreted as the increase in the quantity of improved seed used per unit area covered by the extension package or full fertilizer application. R and RStudio 4.7 software were used to create regression plots.

RESULTS AND DISCUSSIONS

Results

Formal Seed System of Northwestern Ethiopia

Demographic Features of the households sampled in the study area

Household factors such as gender, age, family size, degree of education, farming experience, and access to extension services are crucial for malt barley's seed and quality production. Based on the information displayed in Table 1.

Table 1

Distribution of household sex in Awi and South Gondar in %

Zone		Household sex distribution in Awi and S/Gondar				
		Male		Female		Total
	Districts	Frequency	%	Frequency	%	
Awi	Anksha	308	33.37	52	33.12	360
	Banja	316	34.24	44	28.03	360
	Guagusa	299	32.39	61	38.85	360
Total		923	100	157	100	1080
		Male		Female		
S/Gondar	Districts	Frequency	%	Frequency	%	Total
	Farta	299	35.89	61	24.7	360
	L/Gaynt	281	33.74	79	31.98	360
	Estie	253	30.37	107	43.32	360
Total		833	100	247	100	1080

The assessment is worked on the Awi zone of Anksha, Banja, and Guagusa woredas and the S/Gondar zone of Farta, L/Gaynt, and Estie woredas. The percentage of female and male heads made up roughly from each respective woredas were 33.12% 28.03%, and 38.85%, and males 33.37%, 34.24%, and 32.39% of the sample woredas as a whole in Awi zone and the Female 24.7%, 31.98%, and 43.32% and male 35.89%, 33.74%, and 30.37% of the south Gondar administrative zone of each selected respective woredas (Table 1). The head of the home had an average age of 47.6 years, with a range of 20 to 75 years (Table 2). With only a few duration of experience in irrigation production methods in the Awi zone, malt barley production averaged 20 years during the main season.

Table 2

Demographic and socioeconomic descriptive results of households

Variable	Number of respondents	Mean	SD	Min	max
Age of household head /year/	1080	47.6	4.25	20	75
Family size /number/	1080	5.36	1.08	2	13
Farming experience in main season/year/	1080	20	1.93	0	57
Farming experience within irrigation season /year/	1080	11.5	2.23	0	35

Formal seed system structure of malt barley

On average, 42% of the malting barley varieties grown in Ethiopia are introduced varieties. In Ethiopia, the primary sources of malt barley seed include the government seed supply, private seed producers, farmer-to-farmer seed exchange, cooperatives and NGOs, and research institutions. These sources help ensure a steady supply of malt barley seeds, which is essential for the growth of the malt barley industry in Ethiopia.

Many of the varieties come from germplasm donated by international organizations, primarily ICARDA and CIMMT. The three most important factors considered when allocating resources are its capacity to increase agricultural production in the area, the extent of the demand that has been identified, and impartiality. Certified seeds produced by the community commercial organizations are distributed by MoARD's Agricultural Marketing Sector. Although there is considerable variation, the distribution of seeds among zones is closely correlated with the size of the harvested areas and the capacity for production in various places.

Three seed systems were used by most growers in the research area: integrated, informal, and traditional. Thus, even in cases when farmers were using good agronomic methods, the yield or production of malt barley declined throughout the year. More than 70% of farmers in the southern Gondar zone use formal seed systems; instead, the minority use informal seed systems; farmers exchange seeds with one another and even take seeds from factories without official inspector certification. About 30% of the practices were informal, with the formal seed systems in Farta and Estie weredas being

2.7% and 9.3% integrated, respectively. Formal seed system methods yielded significantly different malt barley production and quality. The informal seed system led to the rejection of the commodity crop in factories and a decline in its market value. Similar findings were found in the (Yohannes. 2021; Wegayehu & Derib, 2019) study, which showed that while integrated crop management technologies and improved malt barley varieties were successfully demonstrated to increase production levels and productivity in the project areas, smallholder farmers' partial acceptance of the full suite of better-quality commodities continues to be a notable and enduring cause of a sizable yield gap in farmers' fields.

Malt barley formal seed Sources in Northwestern Ethiopia

There are different varieties in the research area available for farmers the various amounts and percentages as shown in (Table 3) the most adaptable productive marketable Variety is Holker 31.48% and the next is Fatima 22.32% due to its available certified and basic seed sources, pest resistance, and productivity during the farmer assessment work. The other variety of production years is no longer due to different reasons such as market demand and productivity, pest resistance, and limited certified and basic seed sources.

Table 3

Seed system of malt barley varieties

Item Varieties	Frequency	Percentage (%)
Holker	340	31.48
Travler	138	12.78
Fatima	241	22.32
HB 1963	210	19.44
Miskal	109	10.09
Other	42	3.89
Total	1080	100
Seed generation used by sampled farmers		
Pre-basic	20	1.85
Basic seed	480	44.45
Certified	580	53.70
Total	1080	100

Formal seed delivery organizations in the study areas

The terms Pre-basic, Basic, and certified seeds refer to different categories of seed used in agriculture, each with a specific purpose, quality, and certification level to ensure the production of healthy, disease-free crops. These categories are part of a system designed to maintain and improve seed quality for commercial farming and large-scale crop production. Each country or region may have its own specific system and regulatory body for seed certification, such as the International

Seed Testing Association (ISTA), which sets global standards for seed quality.

The seed sources organization in the research area nearest agricultural offices, Seed Enterprises, Farmers Unions, and Malt Factories deliver to the local farmers (11.57%, 60%, 12.5%, and 15.93%) respectively (Table. 4). The Intermediate seed system Sources of improved malt barley seeds are NGOs, Research Center, and Universities deliver72.22%, 21.3%, and 6.48% respectively (Table 4).

The purpose of production within the total volume of output is to optimize efficiency and ensure that each unit contributes to the overall objectives of the production process. The Purpose of production from the total volume of production for own seed purposes, for selling, and for home consumption are 8.15%, 90.74%, and 6.48%, respectively (Table 4)

Table 4

Seed delivery organizations in Awi and south Gondar zone of Ethiopia

Items	Frequency	Percentage (%)
Farmers' formal seed system improved the variety of Seed sources.		
Nearest Office of agriculture	125	11.57
Seed Enterprises	648	60
Farmers Union	135	12.5
Malt Factories	172	15.93
Total	1080	100
Intermediate seed system Sources of improved malt barley	Frequency	Percentage
NGOs	780	72.22
Research Center	230	21.3
Universities	70	6.48
Total	1080	100
Purpose of production from the total volume of production in %	Frequency	Percentage
For own seed purpose	88	8.15
For selling	980	90.74
For home consumption	12	1.11
Total	1080	100

Public seed enterprise and its structure

The supply of seeds is heavily influenced by public seed enterprises of malt barley pre-basic, basic, and improved seeds. During the study time, more than six seed owners, namely, Amhara Seed Enterprise (ASE), Ethiopian Seed Enterprise (ESE), Malt factories, private seed enterprises, union and seed owners (Heineken, National Variety/ICARDA, and Soufflet, National, and Boort malt) are involved in the official supply of malt barley seed. The public seed enterprises together supplied a yearly average of 26.026 metric tons of malt barley improved seed between 2019 and 2022 (Table 5). Every public seed enterprise works within the regional state framework. From the late 2000s onwards, all public seed enterprises have created a dialogue platform. The EABC chairs

the forum, with the Ethiopian Institute of Agricultural Research (EIAR) and the Agricultural Investment and Input Sector of the MoA serving as observing members (Figure 1). The flow chart plays a significant role in terms of price setting for improved seeds of public varieties produced by enterprises.

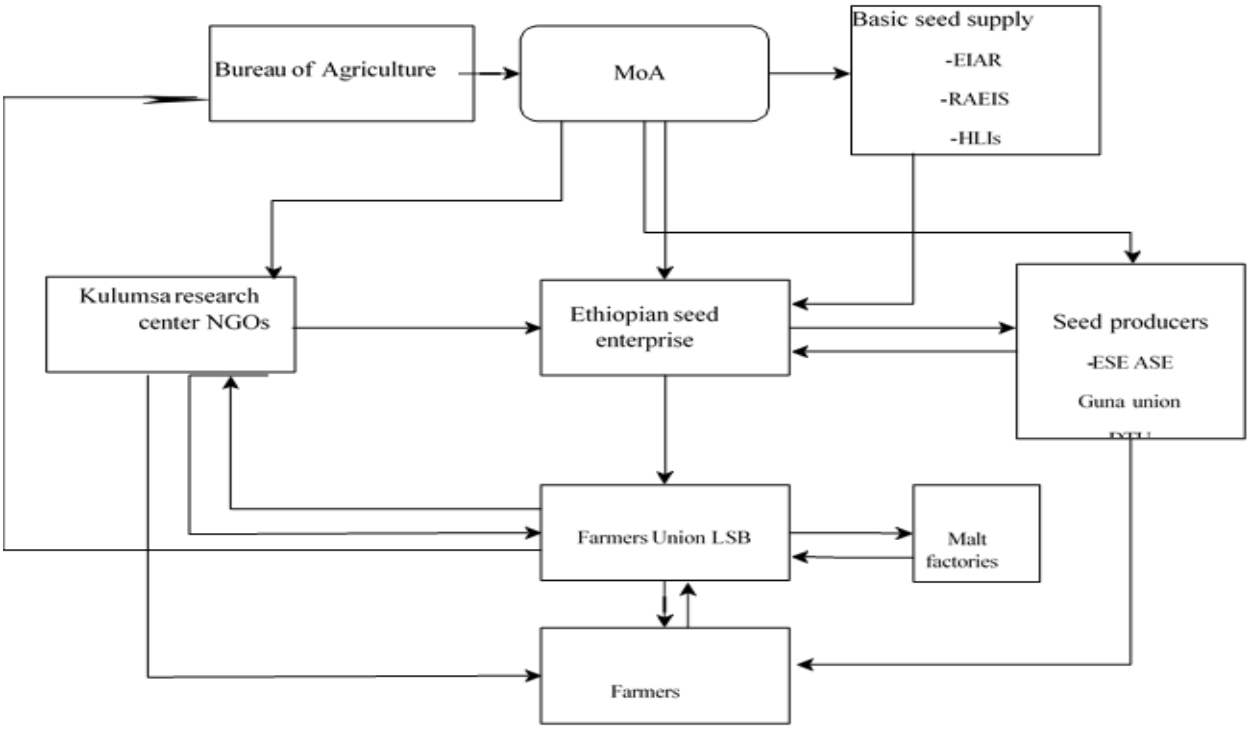

Figure 1. *The official malt barley seed distribution system flow charts in northwestern Ethiopia*

National and Multinational Private Companies

Dashin malt factory does not receive high-quality products from farmers, despite their factory's demands for high-quality row seeds. Ethiopia was previously importing 70% of the barley needed by its brewing industry, while more than 80% of Ethiopia's barley is used for food, and the remaining 15 to 20% is for malt production (Deme et al., 2020). However, in recent times, Ethiopia has since become almost fully self-sufficient in barley production. Common varieties including the Holker factory's demands for high-quality row seeds, Ibone Travller, and the recently introduced Fetima variety in the southwestern Amhara region are all permanently grown and supplied by one-acre fund, which distributes malt barley seed throughout the region. The manufacturer, though, aspires to be the sole Travller variety. Standard varieties qualified for different quality percentages, according to the Dashin Malt Factory; for example, Travller 95%, Holker 75%, and Ibon 72% are qualified. For several reasons, including disease, the farmer is defended by the factory, which is why they wish to grow the farmer's Travller variety for their animal feed. The manufacturer and farmer failed to meet their objectives as a result of this conversation. Factory expectations are too high for local farmers to meet due to quality-based production. Western nations like France and

other European nations supply more than 80% of the grain used in manufacturing.

This study similar to Kassie et al. (2019), studied the effect of different seed sources on malt barley production in the Amhara region of Ethiopia. The findings compared the performance of malt barley varieties sourced from formal and informal seed channels.

Kassie et al. (2019) found that malt barley varieties obtained from formal seed sources exhibited higher yields, better uniformity, and improved quality compared to those sourced from informal channels. Formal seed sources also contributed to higher nitrogen content in malt barley grains.

There are four certified seed production groups: public seed enterprises, seed producer cooperatives, seed producer clusters, and commercial farmers. The national as well as regional seed enterprises contribute to over 80% of malt barley seed multiplied and distributed to the different channels stated in the sections below. The enterprises acquire their basic seed from research centers and malt factories/breweries, mainly Soufflet and Boortmalt (Table 5).

Table 5

Amount of improved malt barley seed by Ownership/Exclusive right in Ethiopia.

Year	Ownership/Exclusive right					
	Variety	Heineken	National variety/ICARDA	Soufflet	National Variety	Boort malt
2019 - 2022	Traveler	3.324	-	-	-	-
	IBON	-	3.214	-	-	-
	Fatima	-	-	3.096	-	-
	HB1963	-	-	-	2.743	-
	Holker	-	-	-	2.815	-
	Sabin	-	-	-	2.202	-
	Miskal	-	-	-	2.442	-
	Explorer	-	-	-	-	3.04
	Henrike	-	-	-	-	3.15
Total		3.324	3.214	3.096	10.202	6.19
Subtotal		26.026 tone				

In many cases, seed enterprises give more attention to food security crops as instructed by the government. As such there are challenges for companies to secure their plots regularly for malt barley seed multiplication. Cooperatives contribute 5% of the seed multiplication. They are often specialized farmer organizations with the sole purpose of the seed business. The commercial seed producers and producer clusters contribute a respective share of 10% and 5% of the seed multiplied.

For instance, the BOOST project uses all possible seed multiplication approaches. It is working with 8 seed multiplying cooperatives (5 In Oromia and 3 In Amhara), 14 seed clusters, 16 commercial farms, and OSE farms. Below is an estimate of certified malt barley seed injected into the market by major actors over the last five years (HEINEKEN, SOUFFLET, OSE, OACF, Boortmalt, AMF,

and Unions). There has been a significant increase in seed volumes over the years. Over 60% of this volume was contributed from Heineken (before 2019) and Soufflet (after 2019) and the role of other actors like OSE, Boortmalt, OACF, AMF, and unions has also increased over time. In 2023, the total seed sold out was reduced due to the regional agricultural office's decision on seed COC transfer between OSE and Soufflet. Over 5,000 tons of seed are left unsold during the year due to these changes in approach. Added to this, the demand of farmers and aggregators for fresh seed purchase has decreased compared to the previous years due to the stable grain price in 2022/2023 throughout the year (low future price increase expectation), the high price of wheat (encourages farmers to produce wheat), the price gap between barley grain and seed and high rain in some areas.

Formal seed suppliers and their distribution system

The Federal Ethiopian Institute of Agricultural Research (EIAR), regional agricultural research institute, the Ministry of Agriculture (MoA), A regional Bureau of Agriculture (BoA), and an extension system at the zonal, district, and kebele levels. The primary partners carrying out the production in their respective target regions were Kulumsa Agricultural Research Centers (ARCs) from EIAR, adet, Gondar, and Sirinka, ARCs from ARARI; these PSEs included regional public seed enterprises (PSEs) like Amhara seed Enterprise (ASE), LSB, unions, and NGOs, as well as Federal Ethiopian Seed Enterprise (ESE) (Figure 2). Three seed producers, and marketing cooperatives; more than five farmers' cooperative unions; regional seed regulatory and quality control and quarantine agencies of respective regions; farmers in the Agricultural Growth Programme (AGP); and Productivity Safety Net Programme (PSNP) districts are examples of private seed producers, farmers' cooperative unions, and associations. Malt Factories; breweries like Dashen, Habesha, Heineken, Meta, and Raya; and development NGOs working in study locations, such as Agricultural Transformation Institute (ATI), Integrated Seed Sector development-Ethiopia, and ICARDA-Austrian Development Agency project, were involved in promoting and scaling improved technologies. Farmers were engaged as the primary actors in the seed industry, hosting demonstrations, and producing, and marketing seeds. According to Bishaw (2004), the formal seed system comprises institutional and organizational frameworks that include businesses, organizations engaged in to transfer of contemporary varieties from agricultural research to farming communities.

Improved seed demand and supply dynamics in malt barley

Malt barley seed demand and requirements

Currently, there is a high gap between the amounts of Malt Barley seed required to cover the Malt Barley potential zone and the quantity of demand collected. Furthermore, the gap between the amount of improved seed used by farmers and the required quantity or collected demand does not exceed 19%. In 2021, 83% of farmers acquired malt barley seeds from cooperatives, while 4% got them from their stores, 8% from nearby farmers, and 5% from markets. The malted barley cultivated land in 2021 was around 261750 ha, with an improved seed requirement of 9262.5 metric tons at a seed rate of 150 kg ha^{-1} (Table

6). In 2020/21, only 6% of Ethiopia's barley growing areas were planted with improved seed, while the remaining 94% was planted with farmers' saved seed. The demand for improved seed collected by the Ministry of Agriculture was around 5103 metric tons of different varieties. This denotes that the collected demand and the necessary amount of malt barley seed were nearly accurate.

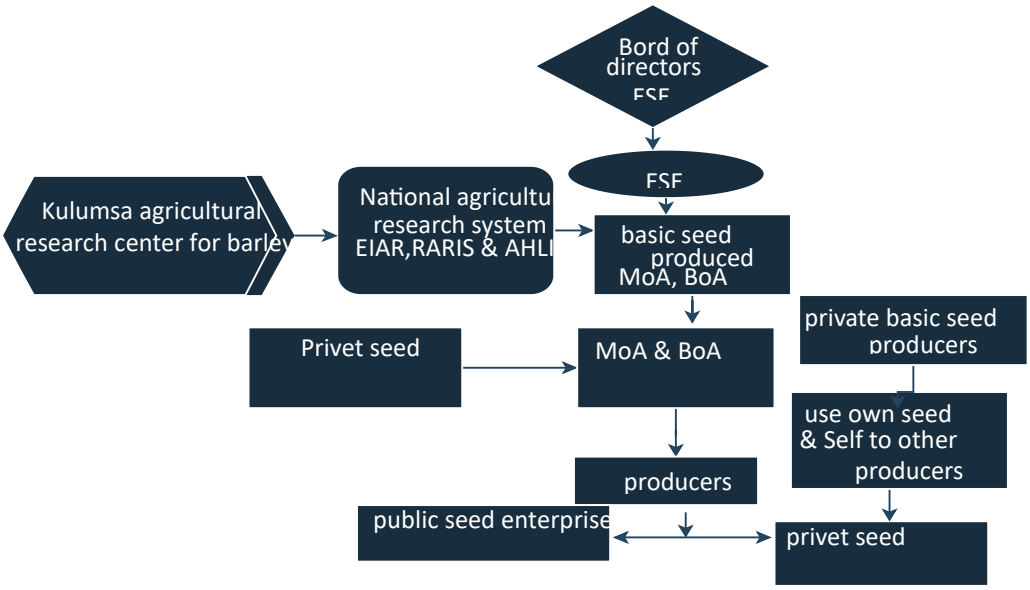

Figure 2. *Ethiopian malt barley distribution and basic seed production actors and links*

However, there is a significant gap between the quantities used, the required amount, and the collected demand (Table 6). For example, in 2021, the demand for improved seed was 5103 metric tons, whereas the domestically produced improved seed amounted to 6591 metric tons. This suggests that the additional improved seed used by farmers in the same year comes from other sources.

Table 6

Improved seed demand, utilization, and requirement of malt barley in Ethiopia

year	Improved seed demand t/ha	Improved seed used (MT)	Area of production	Improved seed requirement (MT)*	Demand-to-requirement ratio (%)	Utilization-to-requirement ratio (%)	Utilization-to-demand ratio (%)
2018	4350	3072	384001	5760	75.5	53.3	70.6
2019	4700	4550	568750	8531.25	55.06	53.3	96.8
2020	23780	9507	478620.5	7179.375	65.5	50.9	81.3
2021	20000	6563	959273..4	9262.5	55.09	52.7	96.8
2022	66000	4313	2024921.7	25386.875	65.54	54	81.38

Source: - regional yield data from Amhara region Bureau of Agriculture and book of And Ethiopia malt barley sector evidence-based assessment and recommendation, Calculated based on the total area of malt barley production and the seed rate (150 kg per ha).

Changing patterns of improved seed demand by variety.

The demand for improved seed was reliably below 50% of the total demand between 2018 and 2022 (Table 6). From the nine varieties Traveler, Holker, Ibone, Fatima, HB1963, and Miskal accounted for more than 40% of the total demand for improved variety seeds of malt barley. Other varieties, Sabin, explorer, and Henrike were reliably higher than 25% of the total malt barley seed demand of the total improved seed demand in 2021 and 2022. While Local malt barley varieties only cover about 35% of the production demand.

The demand for malt barley varieties like IBON is high in Ethiopia due to the increasing number of breweries and the need to meet the quality and quantity requirements of the malting industry. This variety is disease-tolerant, adapts well, and is productive. It has a yield advantage over the national average yield of malt barley. Farmers like this variety because of its productivity and early maturity. Other high-yielding and high-quality malt barley varieties include Travler and Holker. The analysis of long-term national data revealed a strong connection between extension services and the use of improved seed. Due to insufficient extension and promotion, farmers, awareness of newly introduced malt barley varieties remains limited (Alemu et al., 2021).

At the current time, the demand for the HB 1963 variety is high, whereas the IBON variety is somewhat reduced. The current situation in the Demand for HB 1963 might be due to the expanding knowledge by farmers and the malt quality standard of the factory on its yield advantage over the long-existing variety Miskal variety. A new large protest by One Acre Fund all over the malt barley potential zone of the Amhara, region in 2022 showed that the average product was more than 2520 kg/ha (Getie Melese, personal communication, and unpublished data).

Contribution to improved seed

The average national malt barley yield in Ethiopia increased by more than 68% between 2003 (1.7 t/ha) and 2022 (2.5 t/ha) (ESS 2021). The increase is due to several factors, including breeding and extension programs, market demand, and the introduction of new varieties. However, Ethiopia's barley yield per hectare is still lower than the top 20 global producers. Some reasons for this include limited availability of improved seed, Low soil fertility and plant nutrition, limited availability of quality agrochemicals, biotic stress, such as weeds, disease, and insects, lack of appropriate extension services, and high harvesting and post-harvest losses. Ethiopia’s malt barley productivity had been unimpressive at 2.1 metric tons per hectare, compared with 2.93 metric tons in South Africa, 3.26 in Kenya, and more than 6 metric tons in France, Germany, and the Netherlands (Tadesse, 2020; Tewabe et al., 2020).

It is imperative, hence, that the formal seed supply system play a fundamental role in terms of increasing malt barley 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 should be considered in the increase in malt barley production and productivity in the country.

There was a strong relationship between the application of fertilizer, use of extension packages, malt barley yield, and quantity of improved seed used. As expected, malt barley productivity was positively influenced by the malt barley area receiving all fertilizer

categories and the extension packages' area coverage. An increase in the area of malt barley receiving all categories of fertilizer by 10,000 ha increased malt barley yield by 0.2 tons per ha. Similarly, an increase in the malt barley area that received full extension packages by 1,000 ha increased the yield per ha by 2.5 tone/ha. With no extension package, malt barley yield could remain at only 1.5 t/ha. Not only malt barley yield but also the use of improved seed is dictated by access to extension packages and fertilizer use (Figure 3). As the malt barley 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 malt barley varieties and vice versa.

Similarly, an increase in the area receiving full extension packages also positively influenced the quantity of improved seed used. Malt barley has been an essential component of the extension package in recent years. With no use of complete fertilizer and extension packages, the use of malt barley-improved seed was observed to be nil (Figure 3). This implies that farmers' use of malt barley improved seed is highly dictated by access to fertilizer.

Seed quality verification, and market

In the southern Gondar zone, over 97% of cooperatives still lack the fundamental infrastructure needed to generate high-quality seeds that satisfy requirements recognized by seed-certifying organizations. Threshers are one of these facilities' features, allowing farmers in L/Gaynt Wareda and Farta to harvest their crops in time to avoid unpredictable rains. This took place in February and March. The crops' seed quality was impacted by these spoils. Poor yields, off-type crops, and other weed varieties, particularly in Estie, diminish the quality of agronomic techniques, as the respondent noted. I determined and respondents informed me of these as the main issues with the research area's quality. Even if stakeholders and development agents don't follow up, this is still the case. For the malting and brewing sectors, malt barley quality is still a major issue.

Discussions

Farmers have to make careful decisions about which crops to cultivate based on various issues like climate, soil type, market demand, as well as available resources. This study is similar to the findings of Bowman et al.(2013) and Tewabe et al. (2020) who showed that the choice of crop can significantly impact the success and profitability of the farming operation. The formal seed system directly affects the quality and yield of the crop. This study is in agreement with Kebede et al. (2017) and Terefe et al.(2018) which found that increased diversity is essential for lucrative and sustainable malt barley production and information on crop responses to agricultural inputs such as N fertilizer rates. The quality of the malt barley seed is vital for obtaining high-quality grains (CSA, 2016; Abebe et al., 2022).

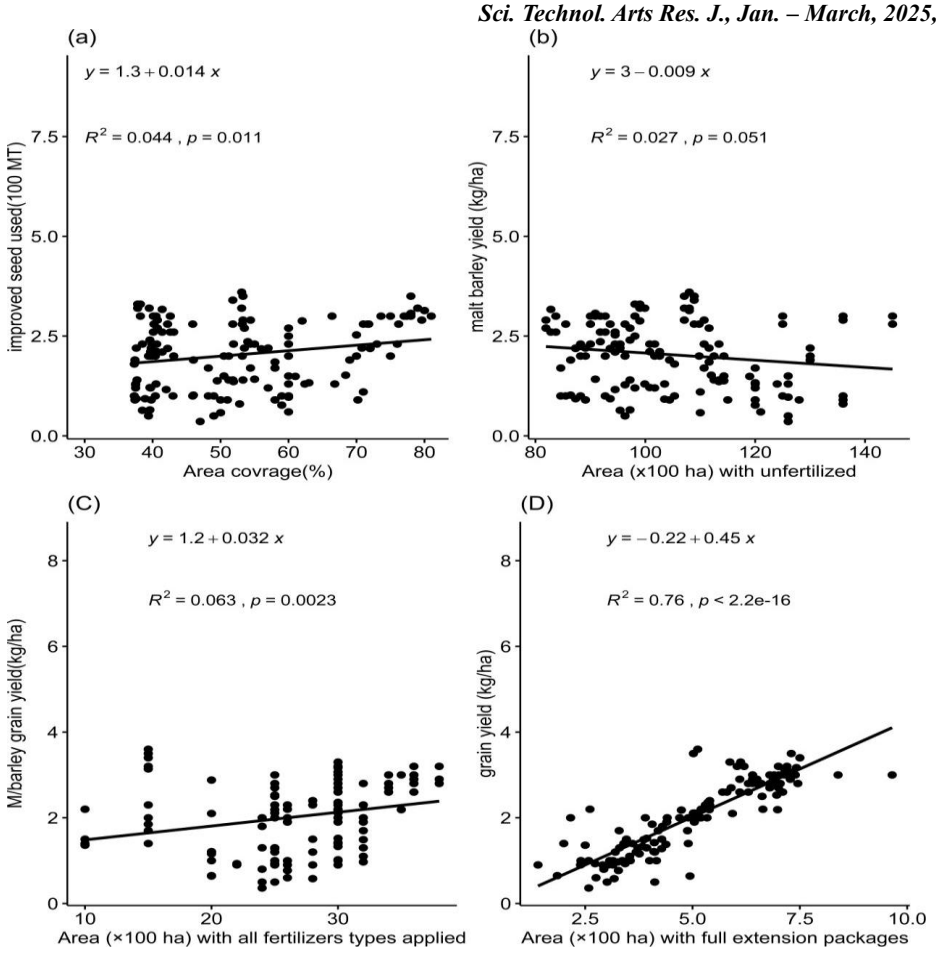

Figure 3. *Relationship between malt barley yield (ton/ha) and total area with all fertilizer types unfertilized area, and full extension packages (2005–2020).*

The formal seed system should ensure that the seeds have high germination rates, and genetic purity, and are free from diseases or contaminants. Seed quality can greatly influence crop establishment, vigor, and overall yield. Similar to (Bishaw, 2004; Assefa et al., 2021), this study found that farmers may have chosen and collected seeds from their yield for planting for the next year, which is produced informally, even though they may have embraced a newer variety produced by the formal sector. The choice of proper varieties of malt barley is essential for consistent quality and yield. The formal seed system should provide farmers with access to a diverse range of suitable barley varieties that are specifically bred for malt production (Bishaw, 2004; Ebone et al.,2019; Shimelis et al., 2024). These varieties should have desirable traits such as high malt extract, good agronomic performance, disease resistance, and adaptation to local conditions (Abebe et al., 2022; Ganewo et al., 2022). The formal seed system should ensure that farmers have sufficient access to high-quality malt barley seeds (Bishaw, 2004; Abebe et al., 2022). This includes efficient distribution channels, availability of certified or improved seed varieties, and affordable pricing (Abebe et al., 2022). Accessible seed systems are crucial for enabling farmers to adopt improved varieties and technologies positive finding with (Engel et al., 2008). The formal seed system should have effective mechanisms for seed

multiplication to produce sufficient quantities of quality seeds (Yohannes, 2021; Ganewo et al., 2022). This involves the production of foundation and certified seeds through controlled environments and strict quality control measures. Regular monitoring and testing of seed lots help ensure accurate labeling, genetic purity, and acceptable quality standards. This is in agreement with (Pinto et al., 2015; Ganewo et al., 2022) who showed formal seed system should provide necessary training and support to farmers regarding seed selection, handling techniques, and best practices for seed establishment. Educating farmers on the importance of using quality seeds and proper seed management techniques can greatly enhance crop performance and yield. This study is comparable to that of (Kassie et al., 2019), which revealed the main factor limiting improved varieties' output across Ethiopia's agroecologies is poor crop management.

CONCLUSIONS

Crop research, seed production and quality assurance, financing availability, promotion, and capacity building are all heavily reliant on the public sector. For the national seed system to evolve in a balanced manner, this is essential. The formal seed system is a purposefully designed framework that entails a series of steps culminating in genetically enhanced goods, specifically certified seeds from validated cultivars. Plant breeding or a range of development programs that incorporate a structured release and maintenance system are the first steps in the chain.

The national goal of food self-sufficiency and food security in the nation, national governments have made significant expenditures in crop improvement and seed source. Nevertheless, little is known about how the formal and unofficial barley industries in each nation operate. To assess the state and effectiveness of the formal seed system, focus groups, key informant interviews, secondary data, and seed samples for quality standards are utilized. The acceptance of enhanced malt barley varieties by farmers and their sources was also evaluated in the study. It evaluated seed management techniques, information sources on agricultural technologies, and farmers' selection criteria for varieties.

The adoption of improved malt barley types has been aided by the manufacturing of seeds and raising public awareness. Access to and availability of malted barley varieties are facilitated by farmer-based seed multiplication and marketing. Farmers' seed samples were gathered, and their physical, physiological, and moisture content were examined and contrasted. The individual varieties differed significantly from one another. The formal and informal sectors' malt barley seed samples fulfilled the minimal national seed requirement in terms of physical quality.

This study provides valuable insights into the impact of the seed system on malt barley production, quality, and nitrogen content in the Amhara region of Ethiopia. It highlights the importance of accessing high-quality seeds through formal channels to enhance crop productivity and brewing quality. Further research in this area can contribute to the development of strategies to improve the formal seed system and promote sustainable malt barley production in the region.

Recommendations

Overall, the survey results a well-functioning formal seed system for malt barley is essential for ensuring a consistent supply of high-

quality seeds to farmers. By optimizing seed quality, access, and support, the seed system can contribute to improved yields, quality, profitability, and sustainability in the malt barley industry.

CRediT authorship contribution statement

Berhan Getie: Writing - Original Draft, Writing - Review & Editing, Supervision **Tilahun Tadesse:** Formal analysis, Investigation, **Kindie Tesfaye:** Data Curation, Visualization **Enyew Adgo:** Resources, Methodology **Teferi Alem:** Conceptualization, Validation

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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