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Karta Kaske
Ethiopian Biodiversity Institute
Kebede Woldetsadik
Haramaya University
Kedir Oshone
kedirosh@gmail.com
Ethiopian Institute of Agricultural Research based at Melkessa Agricultural Research Center
Zelalem Bekeko
Haramaya University

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Onion (*Allium cepa* L.) Seed Production and Supply Systems among Smallholder Farmers in the Central Rift Valley, Ethiopia

Karta Kaske Kalsa[1], Kebede Woldetsadik Wakjira[2], Kedir Oshone Hussen[1*], Zelalem Bekeko Erena[3].

[1*]Source Technology Multiplication and Seed Research, Ethiopian Institute of Agricultural Research based at Melkassa Agricultural Research Center, P.O.Box:436, Adama, Ethiopia.
[1] Ethiopian Biodiversity Institute, P.O.Box: 30726, Addis Ababa, Ethiopia.
[1]E-mail: kartakaske@gmail.com,
[2,3]Department of Plant Sciences, Haramaya University, P.O.Box:138, Dire Dawa, Ethiopia.
[2]E-mail: kwolde58@gmail.com
[3]E-mail: zelalembekeko@yahoo.com

Corresponding Author: Kedir Oshone Hussen
[1*]E-mail: kedirosh@gmail.com, ORCID: https://orcid.org/0009-0008-6021-5974

ABSTRACT

Onion (*Allium cepa* L.) is an important high-value crop grown extensively in Ethiopia, particularly in the Central Rift Valley (CRV), where the conditions are ideal for both bulb and seed production. However, the region faces challenges such as low productivity, unauthentic and counterfeit seeds, poor production practices, and inefficient seed supply systems. This study assessed the current onion seed sources and production practices, post-harvest handlings, seed supply systems, and associated challenges and opportunities among smallholder farmers. A cross-sectional research design was employed using multistage sampling techniques. Data were analyzed using IBS SPSS software and Microsoft Excel. The results showed that majority of farmers obtained seeds from informal sources such as local markets (18.80%), shops (21.37%), and other farmers (17.10%). Open-pollinated varieties were the most commonly used (70.20%), with hybrid varieties being less popular (8.28%). Traditional seed production practices were predominant, with high seed rates, local varieties, and intensive field managements. Post-harvest losses were around 10-20% in quantity and quality. Seed sources were significantly associated with access to extension services ($P \leq 0.05$). Seed losses were found to be positively and significantly correlated with poor storage practices ($r=0.42$, $P \leq 0.01$). Unauthenticated seed sources, weak institutional linkages, limited extension services, inadequate seed processing facilities, and fragmented seed distribution systems were major challenges. In conclusion, strengthen formal and intermediate seed systems through establishing public-private partnership (PPP) networks and enforcement of national seed policy, proclamation, regulation, and standard for produced and imported seeds. Enhancing access to certified seeds and establishing formal distribution networks are crucial measures to decrease the prevalence of poor quality seeds and boost productivity for sustainable development. This contributes to some of the Sustainable Development Goals like Zero Hunger, No Poverty, Decent Work and Economic Growth,

Responsible Consumption and Production, and Climate Action. These findings provide valuable insights for policymakers, seed producers and other stakeholders looking to improve onion seed systems in Ethiopia and similar agro-ecological situations.

Keywords: *Allium cepa*, Onion Seed systems, Seed sources, Post-harvest practices, Seed handlings, Smallholder farmers, Central rift valley.

1. INTRODUCTION

Onion (*Allium cepa.* **L**.) is one of the most important vegetable crops grown in Ethiopia. It is a valuable vegetable crop worldwide [1]. As a bulb crop, it is extremely important in the daily diet and income generation for producers and traders. It is also widely grown for local consumption, nutritional values and medicinal properties [2]. Moreover, it is mainly produced by smallholder farmers as a source of cash income and for flavoring the local stew '*wot'* [3, 4]. Worldwide, annual onion bulb production is 108,260,011.29 tons [5] with area coverage of 5,719,714 hectares. In Ethiopia, the estimated area coverage of onion is 3,041 hectares with an annual production of 38,163.52 tons of bulbs. Its productivity in the country, including the Central Rift Valley area is low with a national average yield of 12.55 tons per hectare compared to the world's average yield of 18.93 tons per hectare [5]. However, global countries should contribute in the 2030 Agenda of Sustainable Development Goals (SDGs) like Zero Hunger, No Poverty, Decent Work and Economic Growth, Responsible Consumption and Production, and Climate Action [6], through increasing seeds production and productivity.

The potential benefits from increasing the use of quality seeds of a diverse range of crop varieties by farmers are widely acknowledged as it increases food security through improved crop productivity [7]. Increasing the quality of seeds can increase the yield potential of the crop significantly and is one of the most economical and efficient inputs to agricultural development [8]. The availability of viable and vigorous seed at planting time is important for achieving the targets of agricultural production, while good quality seed acts as a catalyst for realizing the potential of other inputs [9]. Seed production is a vital part of onion growing and is a highly specialized business [10]. Onions are considered as biennial crops in true seed production. They complete the vegetative phase from raising seedlings to mother bulb production in the first season. The mother bulbs are used as planting material for true seed production in the second season. The demand for quality true seeds is increasing with prices from season to season [11]. The production of high-quality onion true seeds requires technical skill and knowledge.

Crop productivity is increased by the use of quality seeds of high-yielding varieties and judicious use of fertilizers and water. It is estimated that, all other factors remaining the same, the use of quality seed of high-yielding varieties increases crop yield by 15-20% [12]. The productivity of open-pollinated onion true seed in Ethiopia varies from 1 ton to 1.3 tons per hectare [3]. This productivity is low compared to some other countries in the world [13], which is 2 tons per

hectare. The low productivity of onion true seeds in the country is due to availability of poor quality seeds among other factors. However, the reasons for the delivering of poor quality seeds of onions from farmers are not clearly identified so far. Most farmers rely on informal seed systems, characterized by poor-quality recycled seeds that are often susceptible to diseases and exhibit low germination rates [14]. The current seed production system in Ethiopia is characterized by a mix of formal, intermediate, and informal sectors with smallholder farmers relying heavily on saved seeds and local markets [15]. While the formal and intermediate seed sectors provide certified seeds, their reach is limited, leading to dependency on informal seed sources that may lack genetic purity and physiological quality [16].

The seeds available in the local markets or shops either imported from abroad or produced in the country are poor in quality [3]. Climate change impacts seeds production by altering crop phenology, such as germination, flowering, pollination, seed filling, and harvesting. These changes impact seed size, dormancy, yield, and quality [17]. Previous studies reported research gaps on agronomic practices of onion crop in Ethiopia in general and the Central Rift Valley region in particular [18,2,19] reported that the production of vegetables, including onion bulbs was affected by biotic and abiotic factors. However, no studies have been carried out so far on the status of open-pollinated onion seed production, sources of seeds, perception of seed quality, adulteration of seeds, pre-harvest production practices, and post-harvest handling practices in Ethiopia, particularly in the Central Rift Valley. Moreover, onion seed supply systems, challenges, and opportunities were rarely investigated and documented across locations for policy-makers, onion seed producers, and agro-dealers. Therefore, the objectives of this study were to: (1) investigate the onion seed sources and current seed production practices, (2) examine farmers' perception of seed quality and preferences for onion varieties, (3) assess the onion seed replacement and planting rates, (4) identify and document challenges and opportunities associated with quality seed production, and (5) Provide possible recommendations that contribute for the global sustainable development goals.

2. METHODOLOGY

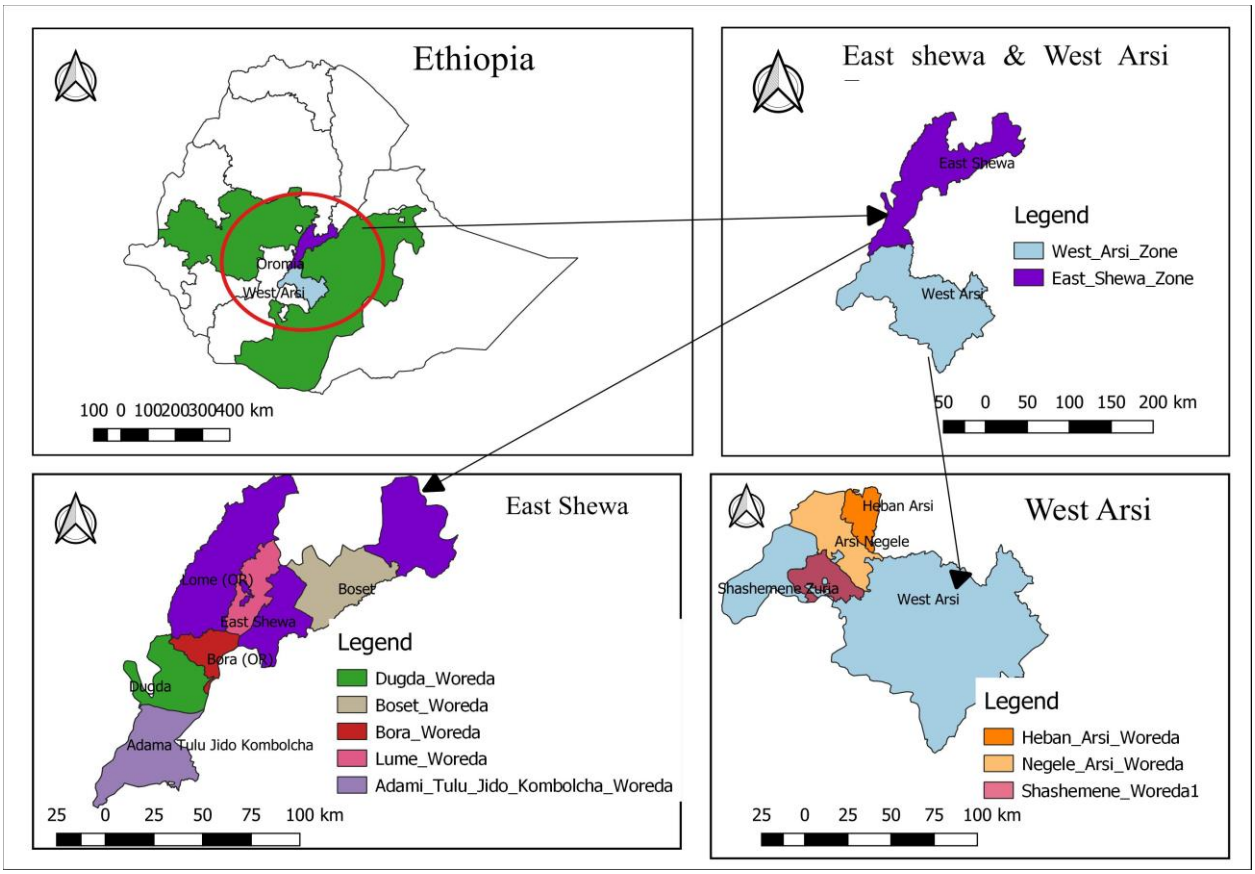
2.1 Selection of the Study Area

The study areas were purposively selected for their significance in onion production in Ethiopia. The field survey was conducted in two major onion-producing zones in the Central Rift Valley: East Shewa and West Arsi in the Oromia National Regional State (Fig. 1). A total of 8 *Woredas* and 13 markets were visited across these regions. One *Kebele* per *Woreda* was included in the study (Table 1). The selection of study sites was based on factors such as production potential, cultural and agro-ecological differences, and the importance of onion seed production systems in the regions.

2.2 Description of the Study Sites

East Shewa zone is situated between 38 º 03′ to 40 º 05′ E longitude and 7 º 04' to 9 º 10′ N latitude, covering an area of approximately 13,766.50 km^2. This zone comprises five *Woredas* (Boset, Lume, Bora, Dugda and ATJK) (Figure 1). The altitude in the zone varies from 538 to 3100 meters above sea level (m.a.s.l.). The average annual rainfall ranges from 458 to 518 mm, with about 67% of the total rainfall occurring mainly from June to September, peaking in July and August [20]. The annual average minimum and maximum temperatures in the CRV ranged from 13.4 to 14.2 ºC and from 27.5 to 28.7 ºC, respectively [21]. The climate in the area is classified as semi-arid and sub-humid based on the moisture index. The dominant soil types in the East Shewa zone are Andosols, Vertisols, Rendzinas, Phaeozems, and Fluvisols [22]. The zone has a total of 965,093 household heads [23]. The total number of population in the zone is 2,185,839, with 1,111,129 males and 1,074,710 females [24].

West Arsi zone is spans from 38 º 00′ to 40 º 00′ E longitude and from 6 º 00′ to 7 º 35′ N latitude, covering an area of approximately 12938 km^2. This zone comprises three *Woredas* (Shashamanne, Nagelle Arsi and Heban Arsi) (Fig. 1). The altitude in the zone ranges from 500 to 3200 meter above sea level (m.a.s.l). Annual rainfall in the area ranges from 600 mm to 1400 mm during the main rainy seasons. The average monthly temperature varies between 15 and 20 °C. The dominant soils in the zone are Orthicluvisol, Eutric Combilsols, and Vertisols. The total number of household heads in the West Arsi zone is 1,647,746 [23]. The total number of population in the zone is 2,998,140 with 1,480,435 males and 1,517,705 females [24].



Source: Ethiopian Mapping Agency of administrative boundary shape files (2025)

Fig. 1 Representative Map of the selected zones and specific *Woredas* in Ethiopia



Source: Own field survey data (2024 to 2025)

Fig. 2 Farmer's (a) and research's (b) EGS multiplication fields visited during survey work.

2.2 Research Design and Pretest Questionnaires

A cross-sectional research design was employed to collect data at a single point in time. The survey included both qualitative and quantitative data. The study aimed to examine onion seed sources, some pre-harvest seed production practices, post-harvest seed production and handling practices, and storage conditions among farmers across locations at the time of investigation. Zones, *Woredas* and *Kebeles* with high onion production were purposefully selected. A checklist of draft questionnaires was prepared and a pretest survey was conducted with key informant interviews from Adami Tullu Jido Kombolcha (ATJK) and Dugda *Woredas,* one *Kebele* from each. Key informants were purposively selected from each *Kebele* to pretest prepared questionnaires. All key informants were asked the same set of questions, designed to be easily understood. The pretest of questionnaires was made to ensure the inclusion of all necessary parameters in the final questionnaires. Nine household heads were purposively selected and interviewed to test the data collection instruments, assess questionnaires clarity for respondents, estimate interview time, and revise the questionnaires. Finally, interviews were made with randomly selected from list of onion producers and suppliers.

2.3 Sample size determination

Multistage sampling procedures were utilized in this study and a total of 302 household heads were selected from eight *Kebeles* using simple random sampling with probability proportional to sample size (PPS) starting from May 2024 (Table 1). The sample size for this study was calculated using the formula provided [25]. The formula for calculating the sample size (N) is given by;

$$n = \frac{n_0}{1+\frac{n_0-1}{N}} \quad \text{.. (1)}$$

n_0: Cochran’s sample size computed using the formula for ideal sample size;
N: the size of the population;

For this study, the number of smallholder farmers engaged in onion cultivation was known to be 1387 household heads. Thus, the result of this computation indicates that the number of sample is 302.

$$n = \frac{385}{1+\frac{385-1}{1387}} = 301.76 \approx 302$$

Table 1 Sample sizes of smallholder farmers interviewed and FGDs in different sites of the eight *Kebeles* in the study

Selected	Selected	Selected	Total No.	No. of	No. of	Proportion	Number of

*zones	**Woredas*	**Kebeles*	of HHHs part. in vegetable production	HHHs prod. onion in each *Kebele*	Sample size per zone	of sampled No. of HHHs	FGDs Participants
East Shewa	Boset	Doni kombe	897	184	225	40	24
	Lume	Koka Nagawo	1040	107		23	14
	Bora	Mallima bari	761	178		39	21
	Dugda	Bakale girrisa	807	274		60	24
	ATJK	Edo gojola	862	288		63	24
West Arsi	Shashamanne	Karara fillicha	572	91	77	20	14
	Nagelle Arsi	Kararu	504	80		17	15
	Heban Arsi	Boku wolda	512	185		40	24
Total	8	8	5955	1387	302	302	160

Note: **Kebele* is the lowest administrative unit. **Woreda* is administrative unit higher than *Kebele*, and *zone is large administrative structure positioned below the region that contains several *Woredas* in Ethiopia, HHHs=Household heads, **Sources:** *Woredas* Agricultural Offices (WAO) (2024 to 2025)

2.4 Sampling procedures

A multi-stage sampling approach was used to select study areas and representative samples of household heads, with a focus on onion seeds/bulbs producers. The selection of zones in the first stage was made on onion production potential, while *Woredas* and *Kebeles* were chosen in the second stage through participatory discussions with vegetable experts and development agents (DAs). Onion producers were randomly selected from the list of onions producers in the selected *Kebeles*, and onion seed producers were purposively chosen. Interviews were conducted with selected onion producing respondents and seed producers. The sample size in each *Kebele* was determined using probability proportional to sample size (PPS) based on a sample frame from *Woreda* Agricultural Offices and *Kebeles* development agents. A total numbers of 302 household heads were selected and interviewed. Sixteen focus group discussions (FGD), two from each *Kebele* were held with onion producers to approve or disprove the data collected from individual farmers.

2.5 Data collection approaches and sources

A field survey involving a combination of qualitative and quantitative data collection methods was undertaken from May 2024 to September 2025 to collect data from representatives of various onion producers' and suppliers with value chain actors, and services providers. Survey questionnaires, containing both open and close-ended questions aligned with the study

objectives were prepared for interviews. The questionnaires were tailored to local conditions, and ten well-trained enumerators with experience in household surveys and knowledge of the local culture and languages (Afan Oromo and Amharic) were employed to collect the data for this study.

Primary data were collected through key informants/ experts interviews, household heads or farmers' interviews and farmers' focus group discussions (2 FGDs per *Woreda* or *Kebele*). Horticultural experts from zonal, *Woredas* and *Kebeles* level (DAs) were interviewed as key informants on onion seeds production, handling and supply or marketing. In total, 15 horticulture experts (20% female) and 13 Agricultural Development Agents (23% female) were interviewed using a checklist developed for the purpose of gathering data. Additionally, interviews were conducted with two seed field inspectors (50% female) and two lab technicians (50% female) from the Oromia Region Agricultural Produce and Inputs Control Authority in Asella and Shashamanne cities. Interviews were made with randomly selected household heads from list of *Kebeles*' onion producers. In total 302 household heads (~30% female) were interviewed using semi-structured questionnaires to gather information on demographics, socio-economic factors, seed production practices, seed sources, seeds storage conditions, seed delivery systems, seed or variety preferences, replacement rates, seed processing and handling, challenges, and opportunities in the onion seeds production.

Focus group discussions (FGDs): In each of the study sites, data collection started by introducing the study to the *Kebele* DA and lead farmer, who were generally grassroots development workers and administrators of the *Kebeles*, respectively. Subsequent focus group discussions (FGDs) with a mix of male, female, and youth farmers helped to explore the local context of onion bulb and seed production, identify important actors, and understand sources and markets of onion seeds. These discussions also explored the society's awareness of the onion supply chain. Additionally, discussions continued on farming practices and onion seed systems with onion farmers. The FGDs lasted for 1.3 to 2 hours. Two FGDs per *Woredas or Kebeles* was conducted. In each *Kebele* of the selected *Woredas*, mixed of women, men and youth group participated in one FGD sessions. The size of each FGD ranged from six to twelve (6-12) participants to ensure everyone had enough time to share ideas. In total one hundred and sixty (16% female, 52% male and 32% youth) persons provided the necessary qualitative data for this study. In each *Kebele* participant of FGD was not the part of the individuals participated in the formal interviews. All discussions were guided by checklists prepared for the purpose of the study.

Secondary data were collected from various reports that were available from zonals, *Woredas* and *Kebeles* level agriculture offices of the study areas. In addition, desk reviews were made using relevant published materials and websites of national and international organizations like Ministry of Agriculture (MOA), Central Statistical Agency (CSA), EHDA, Ethiopian Institute of

Agricultural Research and Ethiopian Revenue and Customs Agency, and FAOSTAT. Data obtained from various sources were triangulated and checked for consistency before analyses.

2.6 Conceptual framework

Onion is a vital vegetable crop globally, with significant contributions to economy, nutrition, medicinal properties, and flavors. In Ethiopia, it is grown extensively under rain fed in the "Meher" season and under irrigation in the off season for local consumption, local markets, exports, and planting for true seed production that playing a crucial role in the rural economy and job creation. Despite its potential for economic and health benefits, production and productivity have not reached the required levels, leading to inconsistent trends and limited benefits for farmers [26, 27]. Several factors contribute to the low levels of onion production. According to [28] onion production is significantly influenced by gender, age, educational level, production experience, land covered by onion, and household size has a significant influence on onion production; and challenged by timely and adequate supplies, inadequate irrigation and unfair, high cost of major production inputs. Besides, the low productivity could be attributed to the low fertility of soil, inappropriate use of fertilizer, limited availability of quality seeds and minimal applications of modern inputs with appropriate agronomic practices used [29]. Conceptual framework of this study was developed based on review of relevant literatures and empirical evidences of dependent and explanatory variables demonstrated in Fig. 3. The variables considered in this framework encompass socio-demographic variables, actors involved in EGS production. Seed production practices, Institutional factors, market related variables, and seed governing rules were considered. Socio-demographic variables include sex, age, educational level, marital status, livelihood style and household size. Seed production practices taken into account are farmland allocated for bulb and seed production, mother bulb and true seed production experience, seed sources and acquisition techniques, criteria for selecting quality seeds, replacement periods, reasons for replacement, seed quality perception, types of onion seeds used, and variety preferences. Also seed handling practices that influence onion seed production are harvesting time, harvesting rounds, drying, threshing and cleaning. In the onion production practices seed supply chain is the most important which include exchange between farmers, shops to farmers, market to farmers, and their combinations. Market factors (like market access, price stability, brokers' involvement, and etc.) influenced on onion seeds' market participation.

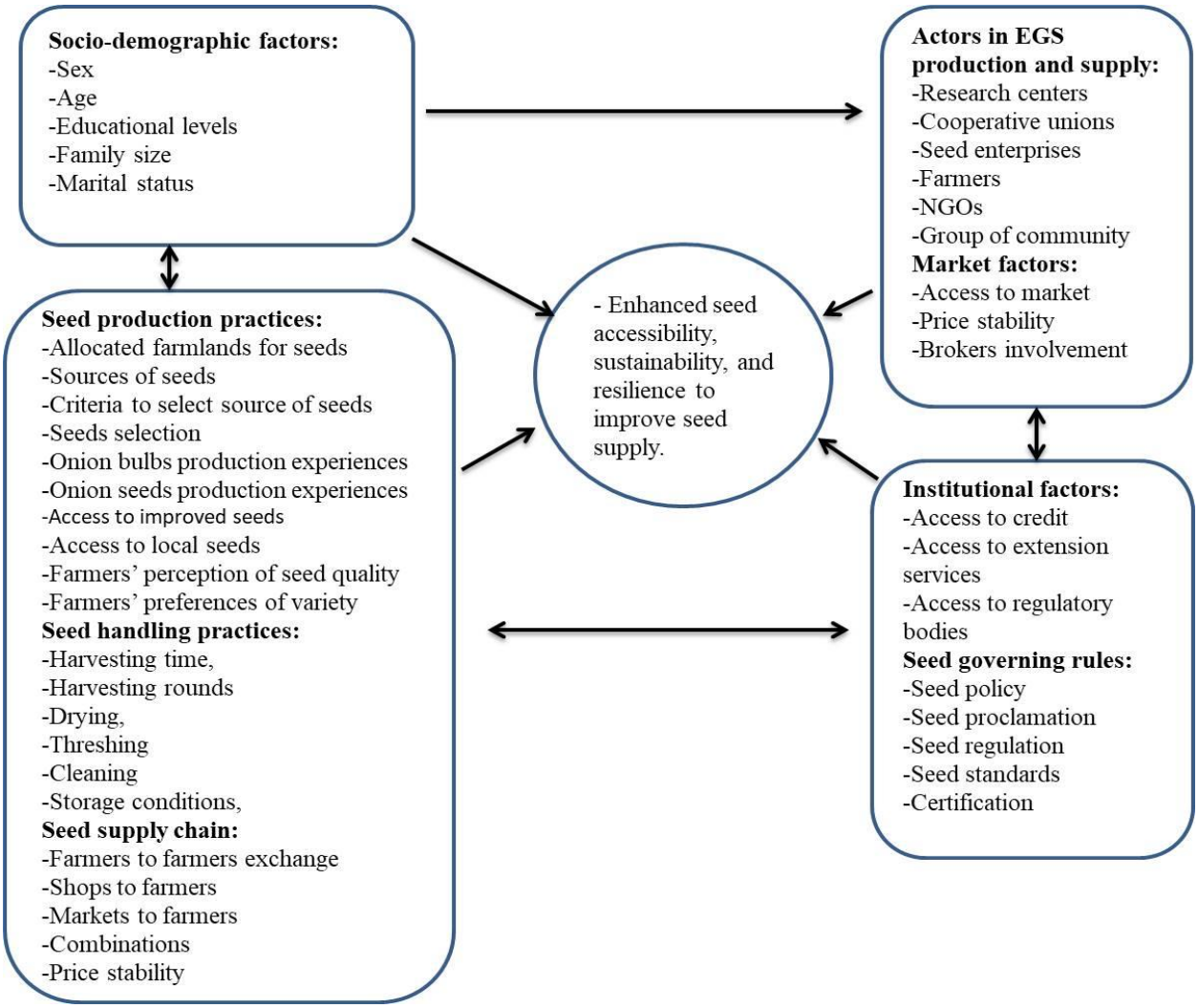


Fig. 3 Conceptual framework of the onion seed production and supply chain, **Sources:** Own conceptualization (2025) and literatures [30].

2.7 Model fitness for this study

Previous studies have highlighted the most commonly used approach to empirically analyze productivity is to employ a production function as a starting point [31]. A production function, in its broadest sense, establishes a connection between output (Y) and various inputs (X), with both variables potentially being vectors. A specific functional form of the production function needs to be selected in empirical analyses. In line with [32], it is assumed that a firm's value added is determined by various functional forms, including linear, quadratic, square root, trans-log, and Cobb-Douglas. We have opted to employ the linear production function estimated using the ordinary least squares (OLS) model. This choice was made due to its exceptional flexibility and suitability in analyzing farm-level data when compared to other functional forms. Moreover, it is value noting that the aforementioned models assume that all explanatory variables must be continuous. However, in the context of onion production, there exist both continuous and

categorical variables that influence the outcome. Consequently, the chosen linear production function model holds great potential, as it allows for the incorporation of explanatory variables in various forms, thereby enabling the generation of efficient estimates [33]. Accordingly, the estimation of the production function focuses on the linear production function model. The mathematical multiple linear regression formula is:

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \beta_k X_{ki} + \epsilon_i \quad \text{(2)}$$

Equation (4) represents the multiple linear regression model that we need to estimate, where Y_i is vector of onion production (outcome); β_0 = Intercept (expected value of Y when all X=0); $\beta_1,\beta_2,\ldots,\beta_k$ = Regression coefficients (slopes) representing the change in Y for a one-unit change in X_j, holding other predictors constant; $X_{1i},X_{2i},\ldots,X_{ki}$ = a set of independent (explanatory or predictor) variables which affects onion production including socio-economic, demographic, production, institutional and farm related factors; and ε_i is a vector error of term (residuals, representing unexplained variation).

2.8 Data analysis

The data were analyzed using the IBM SPSS version 23 software and Microsoft Excel based on the objective of the study. Descriptive and inferential statistics, along with relevant statistical tests were employed to analyze the quantitative data. Chi-square test was used to analyses the relationship between socio-demographic and onion production factors across farmers and agro-ecological locations. Qualitative data were analyzed using a five-point Likert scale ranking, narration, and interpretation to provide meaningful insights. Linear regression analysis was used to analyze dependent and independent variables that predict the major factors affecting onion seed productivity such as production practices, handlings and supply chain systems. Multiple Linear Regression (MLR) Model was used for both descriptive and inferential statistics**,** based on the objective of the study. It is considered as descriptive to summarize relationships between variables where regression coefficients (β\betaβ) act to measure association [34]. Again it considered as inferential to generalize the findings from a sample to a population and test hypothesis (t-tests, F-tests, p-values) and confidence intervals for coefficients [35, 36]. Test whether one variable is statistically significant effect over the other variables.

3. RESULTS

This section provides a socio-demographic characteristic of the respondents. The first section includes thirteen sub-sections based on the interviews with onion farmers and FGDs, the second section includes three sub-sections based on the interviews with onion farmers, and the third section includes seven sub-sections of the interviews with onion farmers, while the last section includes three sub-sections of FGDs and interviews with onion producers. The 1st section covers

key aspects of onion production practices, including land allocation, mother bulb and true seed production, seed sources and acquisition techniques, criteria for selecting quality seeds, replacement periods, reasons for replacement, seed quality perception, types of onion seeds used, and variety preferences. The 2nd section includes factors influencing onion seed production such as true seed rate, production method, bulb rate and size, true-to-type varieties, and planting timing. The 3rd section include the process of producing onion seeds involving selecting seed umbels, harvesting rounds, post-harvest processing, seed productivity, packaging materials, and storage. The last section includes seed supply chain, challenges, and opportunities associated with onion seed production practices were also discussed.

3.1 Socio-demographic Characteristics

Male-headed households dominate both onion bulbs (70.53%) and seed (74.36%) production activities as shown in Table 2. In terms of education, the study found that 45.4% of onion bulb producers and 41.03% of seed producers had only completed primary education (grades 1-4). Among seed producers, 29.06% had completed grades 5-8. Overall, seed producers had higher levels of education compared to bulb producers. Regarding livelihoods, most onion bulb producers (82.45%) and seed producers (76.07%) are engaged in mixed farming. A smaller percentage of bulb producers (17.55%) and seed producers (23.93%) depend only on crop production.

Table 2 Socio-demographic characteristics among bulb and seed producers

Socio-demographic factors	Status	Bulbs producers N=302		Seeds producers N=117		Mean ±SD
		Freq.	%	Freq.	%	
Sex	Male	213	70.53	87	74.36	1.29 ±0.46
	Female	89	29.47	30	25.64	
Age of respondents	< 20	0	0	0	0	46 ±10.98
	20-30	39	12.91	14	11.97	
	31-40	48	15.89	19	16.24	
	41-50	107	35.43	43	36.75	
	51-60	102	33.77	39	33.33	
	>61	6	1.99	2	1.71	
Educational level	Illiterate	14	4.64	5	4.27	3.32 ±1.12
	Adult education	39	12.91	16	13.68	
	1-4	137	45.36	48	41.03	
	5-8	80	26.49	34	29.06	
	9-12	16	5.30	5	4.27	
	College level	12	3.97	6	5.13	
	Higher education	4	1.32	3	2.56	
Marital status	Married	270	89.40	105	89.74	1.14 ±0.44
	Single	21	6.95	8	6.84	
	Widowed	0	0	0	0	
	Divorced	11	3.64	4	3.42	

Livelihood styles of respondents	Crop production only	53	17.55	28	23.93	2.65 ±0.76
	Rearing animals only	0	0	0	0	
	Both crop production and animal rearing practices	249	82.45	89	76.07	

Note: % = Percentage, Freq = Frequency, N= Number of households, SD=Standard deviation, **Source:** Own field survey data (2024 to 2025).

The study found that seed producers are more likely to specialize in crop production compared to bulb producers. The average age of household heads engaged in onion bulb production was 46 years, while for seed production, it was 46.16 years. These ages fall within the productive working age range in Ethiopia. The average household family sizes were 5.56 for bulb producers and 5.41 for seed producers, with household labor participation ranging from 1 to 9 members (Table 3).

Table 3 Mean and standard deviation of age and family sizes of household heads among bulb and seed producers

Demographic characteristics	Onion bulb producers N=302	Onion seed producers N=117
	Mean ±SD	Mean ±SD
Age of the household heads (years)	46 ±10.98	46.16 ±10.57
Total household family sizes (numbers)	5.56 ±2.05	5.41 ±2.00

Note: N=Numbers of households, SD=Standard deviation. **Sources:** Own field survey data (2024 to 2025).

3.2. Associations Between Socio-demographic and Mother Bulb Production

Chi-square test results analyzed the relationship between socio-demographic characteristics and mother bulb and seed production factors across farmers and *Woredas* (Table 4). Sex did not show a significant difference (P=0.473) among individual farmers, but there were highly significant variations (P≤0.001) across *Woredas*. Age distribution among farmers was not significant (P=0.462), but there were highly significant variations (P≤0.001) across *Woredas*. Educational levels did not differ significantly among farmers, while there were significant disparities (P≤0.001) among *Woredas*. There were no significant differences observed among farmers (P=0.469) and across *Woredas* (P=0.907) in marital status. There were highly significant differences (P≤0.001) observed in household family size across *Woredas*, with no significant differences (P=0.450) among farmers.

Production factors such as bulb production experiences, land allocation and bulb storage duration were influencing onion mother bulb production (shown in Table 4). The results revealed that no significant differences were observed among farmers (P=0.466) and across *Woredas* (P=0.538) in bulb production experiences. Farmland allocation did not vary significantly (P=0.456) among farmers, while highly significant differences (P≤0.001) were observed across *Woredas*. Farmers

stored bulbs for different periods to produce true seeds and respond to market price fluctuations. The duration of bulb storage for the market did not vary significantly (P=0.466) among farmers, while significant differences (P≤0.001) were observed across *Woredas*.

Table 4 Associations between socio-demographic and mother bulbs production factors among farmers and *Woredas*

Variables	Farmers			*Woredas*		
	χ2	df.	P values	χ2	df.	P values
Sex	302.00[a]	301	0.473[ns]	27.867[a]	7	0.000***
Age	1208.00[a]	1204	0.462 [ns]	444.760[a]	28	0.000***
Educational level	1812.00[a]	1806	0.456 [ns]	501.942[a]	42	0.000***
Marital status	604.00[a]	602	0.469 [ns]	7.639[a]	14	0.907[ns]
Total HH size (number)	2416.00[a]	2408	0.450 [ns]	346.634[a]	56	0.000***
Bulbs production experiences	906.000[a]	903	0.466[ns]	19.740[a]	21	0.538[ns]
Land covered by onion bulbs	1812.000[a]	1806	0.456 [ns]	177.383[a]	42	0.000***
Bulbs storage duration	906.000[a]	903	0.466 [ns]	407.502[a]	21	0.000***

Note: NS=Non significant, *, **and*** significance at 5%, 1% and 0.1% probability levels, ha = Hectare, **Sources:** Own field survey data (2024 to 2025), df=Degree of freedom, P=probability

3.3. Associations Between Socio-demographic and Onion Seed production

Socio-demographic and seed production factors exhibited highly significant associations across *Woredas* (P≤0.001), while no significant differences were observed among individual farmers (Table 5). Most socio-demographic and seed production variables did not show significant associations at the farmer level. Preferences for open-pollinated onion varieties also varied significantly across *Woredas* (P≤0.001), underscoring the importance of location in variety selection and supply. Certain factors including sex, marital status, seed replacement rate, seed production experience, and land covered by onion seeds did not show significant variation among farmers and across *Woredas* (Table 5). However, seed replacement rates stood out as an exception among production variables, suggesting potential challenges related to access to improved seeds. Seed production experience appeared uniform across farmers, indicating a shared knowledge base.

Table 5 Associations Between Socio-demographic and onion seed production factors among farmers and *Woredas*

Variables	Farmers			*Woredas*		
	χ2	df.	P values	χ2	df.	P values
Sex	117.000[a]	116	0.457 [ns]	8.648[a]	7	0.279[ns]
Age	3159.000[a]	3132	0.364 [ns]	296.814[a]	189	0.000***
Educational level	702.000[a]	696	0.429 [ns]	198.941[a]	42	0.000***
Marital status	234.000[a]	232	0.451 [ns]	12.242[a]	14	0.587[ns]
Total HH size	936.000[a]	928	0.420 [ns]	178.271[a]	56	0.000***

Seed sources for seeds producers	1404.000[a]	1392	0.405 [ns]	228.265[a]	84	0.000***
Seed sources for bulbs producers	3624.000[a]	3612	0.441 [ns]	503.419[a]	84	0.000***
Seed replacement rates	117.000[a]	116	0.457 [ns]	3.673[a]	7	0.817 [ns]
Seeds production experience	302.000[a]	301	0.473 [ns]	10.903[a]	7	0.143 [ns]
Land covered by onion seeds	468.000[a]	464	0.439 [ns]	31.642[a]	28	0.289 [ns]
Seeds storage duration	468.000[a]	464	0.439 [ns]	168.550[a]	28	0.000***
Bulbs storage duration for seeds	351.000[a]	348	0.445 [ns]	85.641[a]	21	0.000***
Seeds harvesting frequency	468.000[a]	464	0.439 [ns]	124.957[a]	28	0.000***
Criteria to estimate seed quality	2718.000[a]	2709	0.448[ns]	433.224[a]	63	0.000***
Farmers' perception on seed quality	2416.000[a]	2408	0.450[ns]	431.617[a]	56	0.000***
Seed harvest frequency	468.000[a]	464	0.439[ns]	124.957[a]	28	0.000***
Bulbs selection criteria for seeds	936.000[a]	928	0.420[ns]	118.786[a]	56	0.000***
Bulb sizes selection criteria	234.000[a]	232	0.451[ns]	83.271[a]	14	0.000***
Preferences of open pollinated varieties	3601.000[a]	3588	0.436[ns]	89.084[a]	13	0.000***
Land cultivating frequency	906.000[a]	903	0.466[ns]	229.993[a]	21	0.000***
Harvesting indicators of true seeds	702.000[a]	696	0.429[ns]	109.184[a]	42	0.000***

Sources: Own field survey data (2024 to 2025)

3.4. Determinants of onion seed production factors

The study used multiple linear regression analysis to investigate the impact of socio-demographic, institutional, and production variables on onion seed production practices. The OLS estimates in Table 8 provide insights into the factors influencing onion seed production and quality in the study area. Prior to interpreting the model, the assumptions were checked, and diagnostic tests were conducted to ensure the data's reliability and the model's fit. Multi-collinearity diagnostics showed acceptable variance inflation factor (VIF) values below 10. Various tests were performed to confirm the assumptions of multiple linear regressions, such as linearity, homoscedasticity, normality of residuals, and multi-collinearity. Scatter plots of standardized residuals against predicted values were used to assess linearity and homoscedasticity, while histograms of residuals and Normal P-P plots were used to check the normality of residuals.

The test results confirmed that the regression model had a good fit with an R^2 of 0.646 and an Adjusted R^2 of 0.585, indicating that the explanatory variables explained approximately 59.5% of the variation in the dependent variable. The model accounted for 64.6% of the variation in the dependent variable, with the remaining 35.4% attributed to other factors not included in the model. The model also explained 58.5% of the variation in onion seed productivities (Adjusted $R^2 = 0.585$) (Table 6). The regression model was statistically significant ($F = 10.528$, $P = 0.000$), showing that the independent variables collectively influenced onion seed production performance and quality (Table 7). Multi-collinearity was within acceptable limits, and no serious issues (VIF < 10). The Durbin-Watson statistic was close to 2, indicated independence of residuals (Table 8). Various factors influenced the dependent variable, including constants (B =

703.367, P = 0.018), age of respondents (B = 4.215, P = 0.027), harvesting rounds of onion seed umbels (B = 47.421, P = 0.000), storage structure of onion seeds (B = 74.416, P = 0.000), and perception of onion seed quality (B = -86.394, P = 0.000). Gender, educational level, marital status, and other production factors did not have a significant impact on the dependent variable (Table 8). The gender of the household head did not significantly impact onion seed production among farm households. However, a 1% increase in male-headed onion producers led to a 48.09% increase in production, holding all other factors constant.

Table 6 Regression Analysis by Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
.804[a]	.646	.585	152.004	1.610

Note: R=Correlation, R^2=Coefficient of determination, Adjusted R^2 = corrected R^2, Std=Standard

Table 7 Regression Analysis by ANOVA[a]

Sources of variation	Sum of Squares	df	Mean Squares	F	P-value
Regression	4135399.561	17	243258.798	10.528	0.000[b]
Residual	2264320.267	98	23105.309		
Total	6399719.828	115			

Table 8 Multiple linear regression model estimates coefficients of predictors

Variables	Unstandardized Coefficients		Standardized Coefficient	t. test	P-values	Collinearity Statistics	
	B	Std. Error	Beta (β)			Tolerance	VIF
(Constant)	703.367	292.036	-	2.408	.018	-	-
Gender of respondents	48.093	34.582	.089	1.391	.167	.888	1.126
Age of respondents	4.215	1.875	.177	2.248	.027	.582	1.719
Educational level	6.369	13.882	.032	.459	.647	.720	1.388
Marital status	-30.532	40.839	-.056	-.748	.456	.636	1.573
Seed production experiences	2.879	2.981	.065	.966	.336	.788	1.269
Seed replacement periods	.580	.451	.082	1.286	.201	.888	1.126
Onion seed sources	1.287	8.235	.010	.156	.876	.810	1.234
Access to poor quality seeds	134.356	109.372	.091	1.228	.222	.661	1.513
Types of onion seeds	32.451	46.479	.046	.698	.487	.819	1.221
Farmland allocated for seed production	-76.242	93.740	-.056	-.813	.418	.769	1.301
Rate of true seeds	-5.417	4.626	-.099	-1.171	.244	.507	1.974
Harvesting rounds of umbels	47.421	6.862	.821	6.910	.000	.256	3.906

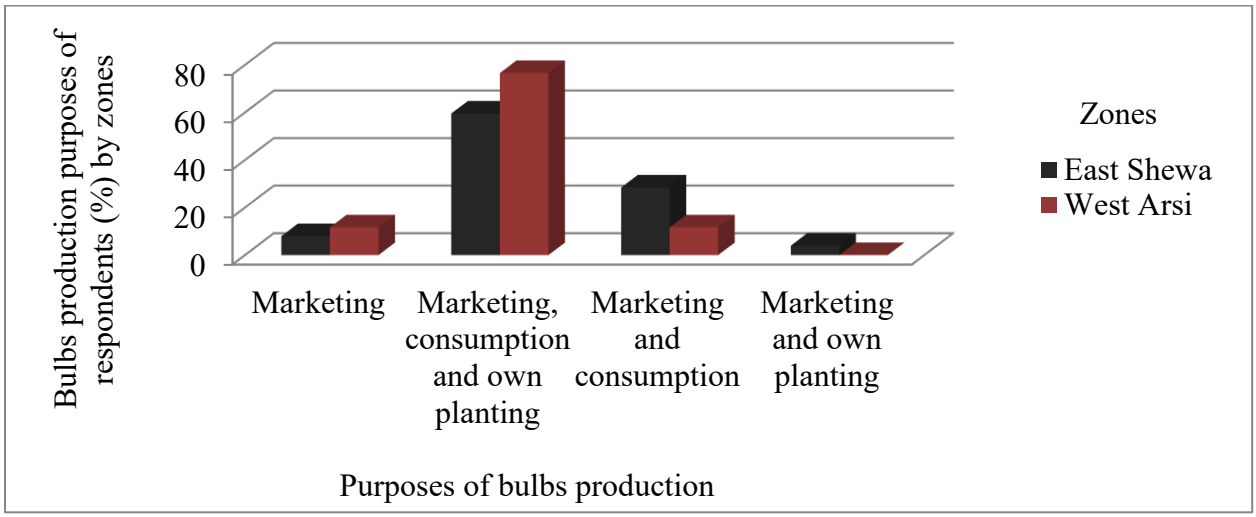
Storage structures for seeds	74.416	19.812	.441	3.756	.000	.262	3.819
Storage lengths for seeds	-.237	14.373	-.002	-.016	.987	.297	3.371
Perception of onion seed quality	-86.394	10.929	-.665	-7.905	.000	.511	1.959
Awareness on quality seeds	-22.665	43.535	-.035	-.521	.604	.802	1.247
Average prices of seeds	15.179	22.895	.095	.663	.509	.175	5.714

Note: B=Unstandardized Coefficients, β=Beta, **Sources:** Own survey data (2024 to 2025)

a. Dependent Variable: Productivity or yield of open-pollinated onion seeds

3.5. Determination of Onion Production

Onion was identified as an important food and cash crop among surveyed farmers. Farmers produced onions for single and combined multiple purposes, such as fresh market sales, household consumption, and planting materials. The majority of farmers were produce for "consumption, marketing and planting" (63.91%), followed by "marketing and consumption" (24.17%), fresh marketing only (8.94%), and "marketing and planting" (2.98%). In the West Arsi Zone, most farmers produced onions for combined purposes of marketing, consumption, and planting (Fig. 4). Focus group discussions (FGDs) confirmed that farmers usually produce onions for diverse purposes. The survey further revealed that 38.74% of farmers produced both onion bulbs and true seed, whereas 61.26% produced only bulbs in the study areas.



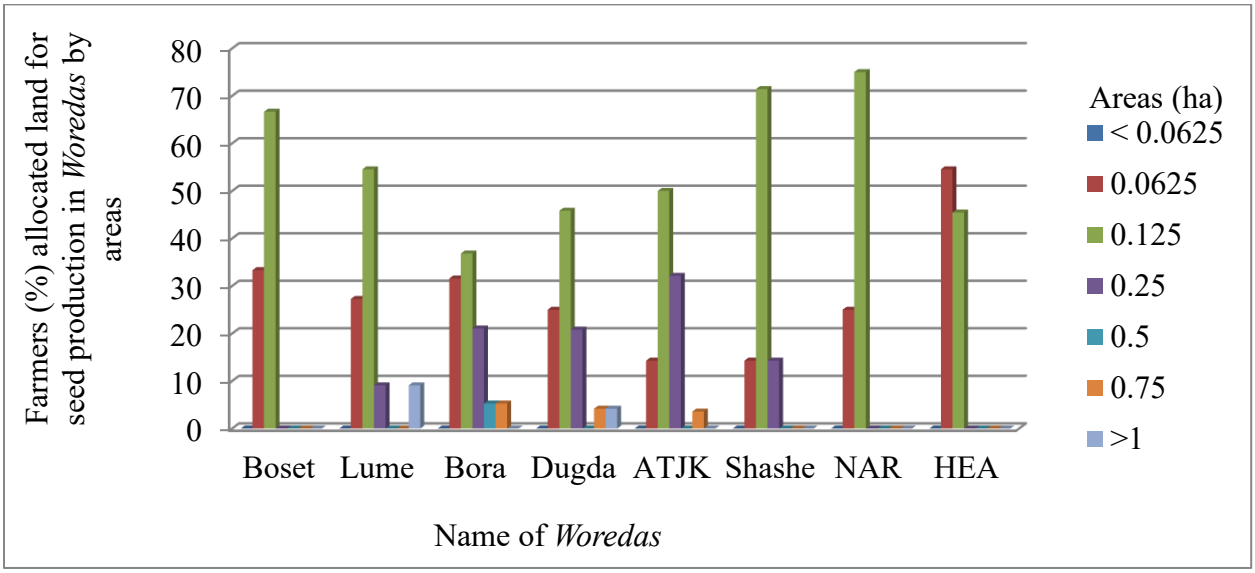
Source: Own field survey data (2024 to 2025)

Fig. 4 Purposes of bulb production (N=302) in the study areas of Ethiopia

3.5.1 Land allocation for onion seed production

There were no significant differences among *Woredas* in farmland allocation for onion seed production (Fig. 5). Most farmers allocated small plots (around 0.125 ha) for onion seed

production. Farmers identified several constraints limiting larger-scale seed production, including labor-intensive, high production costs, climate variability, pest infestations, limited financial capacity, risk aversion, and lack of crop insurance. However, a few knowledgeable and capable farmers allocated more land to onion seed production as bulb production, particularly in Heban Arsi *Woreda*, where differences in farmland allocation among farmers were observed.

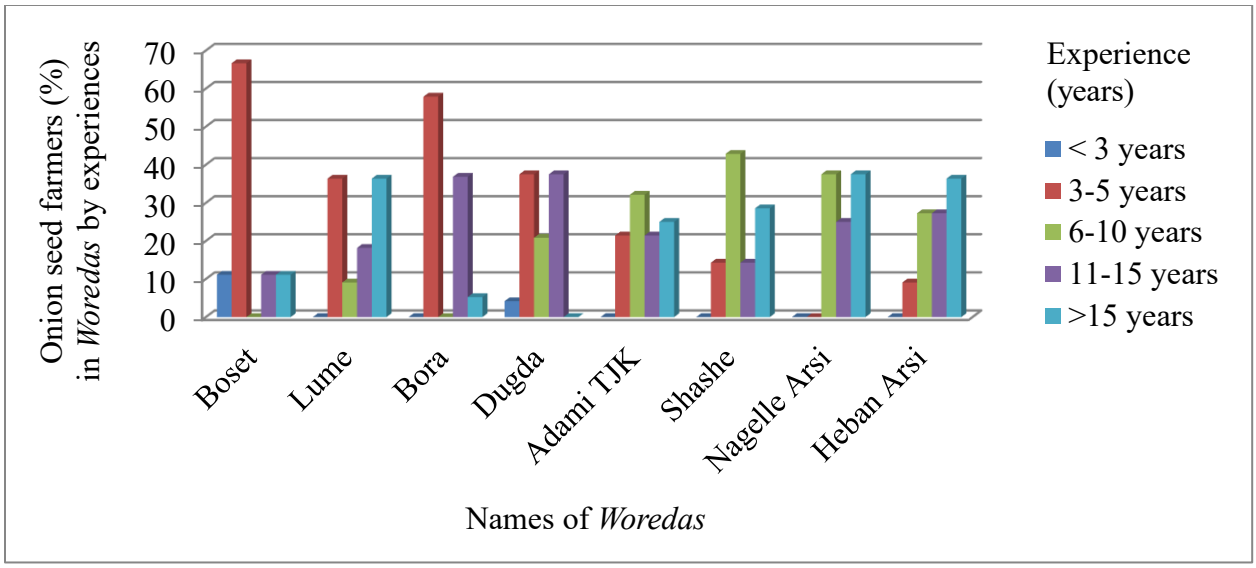


Source: Own field survey data (2024 to 2025)

Fig. 5. Distribution of respondents (%) by average areas of farmlands allocated for onion true seeds production (ha) in selected *Woredas*

3.5.2 Experiences in onion seed production

The survey found that 61.26% of onion producers in selected *Woredas* lack experience in onion seed production. Most farmers (over 70%) have less than 10 years of experience, while 26.5% have 11-15 years, and only 22% have more than 15 years of experience (Fig. 6). Local seed multiplication, especially at the farmer level, remains underdeveloped, with only a small percentage of farmers possessing long-term experience in seed production.

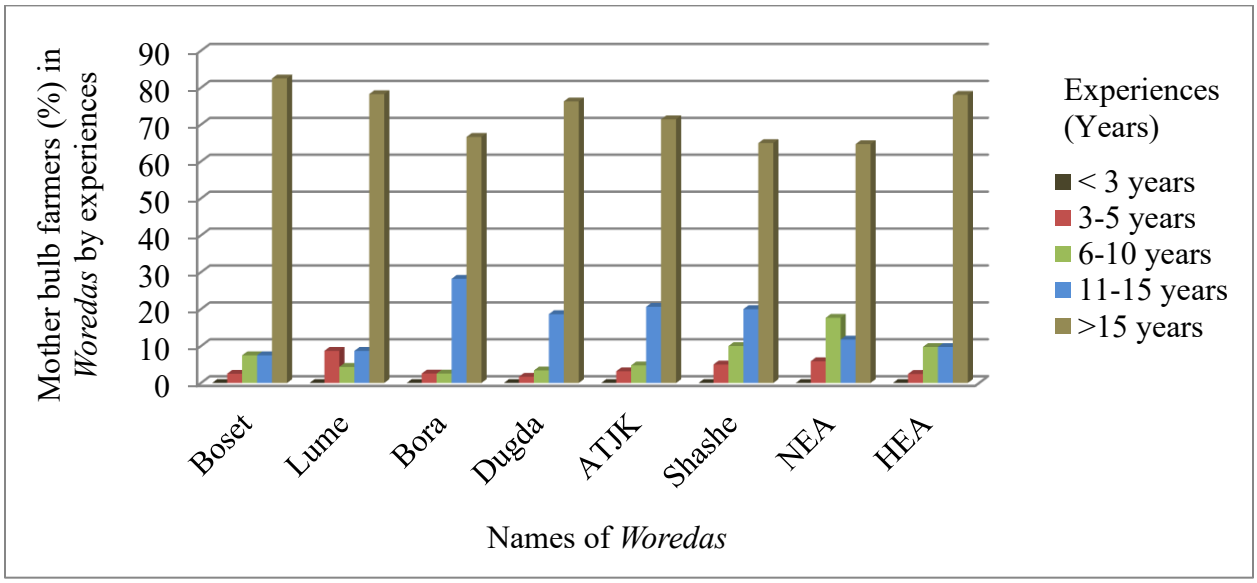


Sources: Own field survey data (2024 to 2025)

Fig. 6 Distribution of respondents (%) in onion seed production experience (years) across selected *Woredas*

3.5.3 Experiences in mother bulb production

The survey revealed that onion bulb production has a significant history in the study areas, with most of the farmers having over 15 years of experience (Fig. 7). However, onion seed production is still limited in terms of scale and knowledge.



Sources: Own field survey data (2024 to 2025)

Fig. 7 Distribution of respondents (%) in bulb production experiences (years) across selected *Woredas*

3.5.4 Sources of onion seeds

The survey findings provide a comprehensive look at how onion seeds are sourced. Most producers rely heavily on informal like farmers and local markets/shops, and semi-formal sources like cooperative unions and organized farmers' groups. Formal sources such as research centers, seed enterprises, seed importer companies, and NGOs were not widely utilized. Informal sources like shops (36.42%), local markets (16.89%), and other farmers (15.23%) were the primary sources for onion production (Table 9). In Boset *Woreda*, neighbors (55.56%) were the significant dominant seed sources. In Lume *Woreda*, other farmers (27.30%) and a combination of other farmers with local markets (27.30%) were significant. In Bora *Woreda*, local markets (52.63%) were the primary sources. In Dugda *Woreda*, shops (45.83%) were the most prominent. In Adami TJK *Woreda*, a combination of other farmers with local markets and NGOs (21.43%) were the largest category, though research centers (14.29%) and cooperatives (17.86%) played roles. In Shashamanne (57.14%) and Nagelle Arsi (62.5%), the primary sources were other farmers. In Heban Arsi, shops (36.36%) and own saved seeds (18.18%) were important (Table 10). Only 3.42% of seed producers across all *Woredas* were accessing improved seeds from research centers.

Table 9 Sources of onion seeds for bulb producers (N=302) in this cropping season

Sources of onion seeds	Name of *Woredas*																Total	
	Boset		Lume		Bora		Dugda		Adami TJK		Shasha Manne		Nagelle Arsi		Heban Arsi			
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Own saved	0	0	0	0.00	0	0.00	7	11.86	1	1.59	0	0	0	0.00	3	7.32	11	3.64
Relatives	0	0	3	13.04	1	2.56	0	0.00	0	0.00	0	0	0	0.00	0	0.00	4	1.32
Neighbors	17	42.5	0	0.00	2	5.13	4	6.78	0	0.00	0	0	0	0.00	0	0.00	23	7.62
Other farmers	0	0	11	47.83	7	17.95	2	3.39	7	11.11	10	50	9	52.94	0	0.00	46	15.23
Local market	0	0	0	0.00	15	38.46	14	23.73	2	3.17	5	25	4	23.53	11	26.83	51	16.89
Shops	22	55	3	13.04	13	33.33	31	52.54	17	26.98	0	0	0	0.00	24	58.54	110	36.42
Research centers	0	0	0	0.00	0	0.00	0	0.00	7	11.11	0	0	0	0.00	0	0.00	7	2.32
Cooperative Union	0	0	0	0.00	1	2.56	1	1.69	3	4.76	0	0	0	0.00	1	2.44	6	1.99
NGOs	0	0	0	0.00	0	0.00	0	0.00	9	14.29	0	0	0	0.00	2	4.88	11	3.64
Other farmers and local markets	1	2.5	6	26.09	0	0.00	0	0.00	0	0.00	0	0	0	0.00	0	0.00	7	2.32
Other farmers, local markets and NGOs'	0	0	0	0.00	0	0.00	0	0.00	9	14.29	0	0	0	0.00	0	0.00	9	2.98
Relatives and neighbors	0	0	0	0.00	0	0.00	0	0.00	8	12.70	0	0	0	0.00	0	0.00	8	2.65
Other farmers, local markets and shops	0	0	0	0.00	0	0.00	0	0.00	0	0.00	5	25	4	23.53	0	0.00	9	2.98
Total	40	100	23	100	39	100	59	100	63	100	20	100	17	100	41	100	302	100

Sources: Own field survey data (2024 to 2025)

Table 10 Sources of onion seeds for seed producers (N=117) in this cropping season

Sources of onion seeds	Name of *Woredas*																Total	
	Boset		Lume		Bora		Dugda		Adami TJK		Shasha Manne		Nagelle Arsi		Heban Arsi			
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Own saved	0	0.00	0	0.00	0	0.00	2	8.33	0	0.00	0	0.00	0	0	2	18.18	4	3.42

Relatives	0	0.00	2	18.18	0	0.00	0	0.00	0	0.00	0	0.00	0	0	0	0.00	2	1.71
Neighbors	5	55.56	0	0.00	1	5.26	2	8.33	0	0.00	0	0.00	0	0	0	0.00	8	6.84
Other farmers	0	0.00	3	27.30	3	15.79	1	4.17	4	14.29	4	57.14	5	62.5	0	0.00	20	17.10
Local markets	0	0.00	0	0.00	10	52.63	4	16.67	1	3.57	1	14.29	2	25	4	36.36	22	18.80
Shops	3	33.33	2	18.18	3	15.79	11	45.83	2	7.14	0	0.00	0	0	4	36.36	25	21.37
Research centers	0	0.00	1	9.10	0	0.00	0	0.00	4	14.29	0	0.00	0	0	0	0.00	5	4.30
Cooperative Union	0	0.00	0	0.00	2	10.53	4	16.67	5	17.86	0	0.00	0	0	0	0.00	11	9.40
NGOs	0	0.00	0	0.00	0	0.00	0	0.00	3	10.71	0	0.00	0	0	1	9.09	4	3.42
Other farmers and local markets	1	11.11	3	27.30	0	0.00	0	0.00	0	0.00	0	0.00	0	0	0	0.00	4	3.40
Other farmers, local markets and NGOs’	0	0.00	0	0.00	0	0.00	0	0.00	6	21.43	0	0.00	0	0	0	0.00	6	5.13
Relatives and neighbors	0	0.00	0	0.00	0	0.00	0	0.00	3	10.71	0	0.00	0	0	0	0.00	3	2.56
Other farmers, local markets and shops	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	28.57	1	12.5	0	0.00	3	2.56
Total	9	100	11	100	19	100	24	100	28	100	7	100	8	100	11	100	117	100

Sources: Own field survey data (2024 to 2025)

3.5.5 Acquisition of onion seeds

Farmers and other onion producers mainly bought onion seeds through buying from informal sources like other farmers, relatives, neighbors, local markets, and shops, while others from research centers, cooperative unions, and NGOs. In Lume, Shashamanne, and Nagelle Arsi *Woredas*, other farmers were the primary seed suppliers. The study found that only 9.4% of seed producers obtained their seeds from cooperative unions, and 4.3% from research centers (Table 9 and 10).

3.5.6 Seed sources selection criteria

The primary factor influencing seed source choice was seed availability, cited by 44.70% of farmers (46.22% in East Shewa and 40.26% in West Arsi) zone (Table 11). Seed price was the second most important factor (30.46%). Agronomic traits such as disease resistance (15.23%), drought tolerance (3.31%), and yield potential (2.32%) were less commonly considered, while shelf life was not selected at all.

Table 11 Sources of onion seeds selection criteria

Seeds source selection criteria	Name of zones				Total	
	East Shewa		West Arsi			
	N	%	N	%	N	%
Availability of seeds	104	46.22	31	40.26	135	44.70
Prices of seeds	68	30.22	24	31.17	92	30.46
Yield potential	6	2.67	1	1.30	7	2.32
Seeds quality	4	1.78	1	1.30	5	1.66
Resistance to diseases	33	14.67	13	16.88	46	15.23
Tolerance to drought	6	2.67	4	5.19	10	3.31
Adaptability	4	1.78	3	3.90	7	2.32
Total	225	100	77	100	302	100

Sources: Own field survey data (2024 to 2025)

3.5.7 Quality seed selection criteria

The primary factor for farmers in selecting quality seeds (24.17%) was trust in the seed sellers, especially in Bora (46.15%) and Lume (30.43%) *Woredas* (Table 12). The second most significant criterion was a combination of seed plumpness and color (22.85%). In Boset, 62.5% of farmers emphasized plumpness and color. In ATJK, Shashamanne, and Nagelle Arsi *Woredas*, farmers considered a holistic approach, taking into account combining plumpness, size, color, and trust.

Table 12 Criteria to estimate high quality seeds of onion from different sources (true seeds)

Seed selection criteria	Name of *Woredas*																**Total**	
	Boset		Lume		Bora		Dugda		Adami TJK		Shasha manne		Nagelle Arsi		Heban Arsi			
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Seed plumpness	2	5	4	17.39	0	0.00	3	5.08	4	6.35	0	0	2	11.76	8	19.51	23	7.62
Seed size	0	0	4	17.39	5	12.82	1	1.69	9	14.29	5	25	5	29.41	5	12.20	34	11.26
Seed color	0	0	2	8.70	11	28.21	16	27.12	1	1.59	1	5	1	5.88	1	2.44	33	10.93
Trust on organizational or personnel	13	32.5	7	30.43	18	46.15	21	35.59	4	6.35	4	20	0	0.00	6	14.63	73	24.17
Seed plumpness, trust of organizational or personnel	0	0	6	26.09	0	0.00	0	0.00	0	0.00	0	0	0	0.00	0	0.00	6	1.99
Seed plumpness, seed size, seed color and trust of organizational or personnel	0	0	0	0.00	0	0.00	0	0.00	18	28.57	10	50	9	52.94	0	0.00	37	12.25
Seed plumpness, seed size, seed color	0	0	0	0.00	0	0.00	0	0.00	9	14.29	0	0	0	0.00	0	0.00	9	2.98
Seed size and trust of organizational or personnel	0	0	0	0.00	0	0.00	0	0.00	9	14.29	0	0	0	0.00	0	0.00	9	2.98
Seed plumpness and seed size	0	0	0	0.00	0	0.00	0	0.00	9	14.29	0	0	0	0.00	0	0.00	9	2.98
Seed plumpness and seed color	25	62.5	0	0.00	5	12.82	18	30.51	0	0.00	0	0	0	0.00	21	51.22	69	22.85
Total	40	100	23	100	39	100	59	100	63	100	20	100	17	100	41	100	302	100

Sources: Own field survey data (2024 to 2025)

3.5.8 Seed or variety replacement periods

The survey revealed that 88.89% of farmers replaced their onion seeds within three years, while 92.31% in West Arsi and 87.91% in East Shewa zones (Table 13). The most common replacement frequency was every 4 to 5 years (36.75%), followed by 6 to 7 years (22.22%), and 2 to 3 years (17.09%) (Fig. 8). Longer replacement periods (6-7 years) were more frequent in West Arsi (34.62%) zone. Approximately 11% of farmers do not replace their seeds at all.

Table 13 Check whether farmers replace their onion seeds or not in the last three years

Asked whether they replace their onion seed or variety in the last three years	Name of zones				Total	
	East shewa		West Arsi			
	N	%	N	%	N	%
Yes	80	87.91	24	92.31	104	88.89
No	11	12.09	2	7.69	13	11.11
Total	91	100	26	100	117	100

Sources: Own field survey data (2024 to 2025)

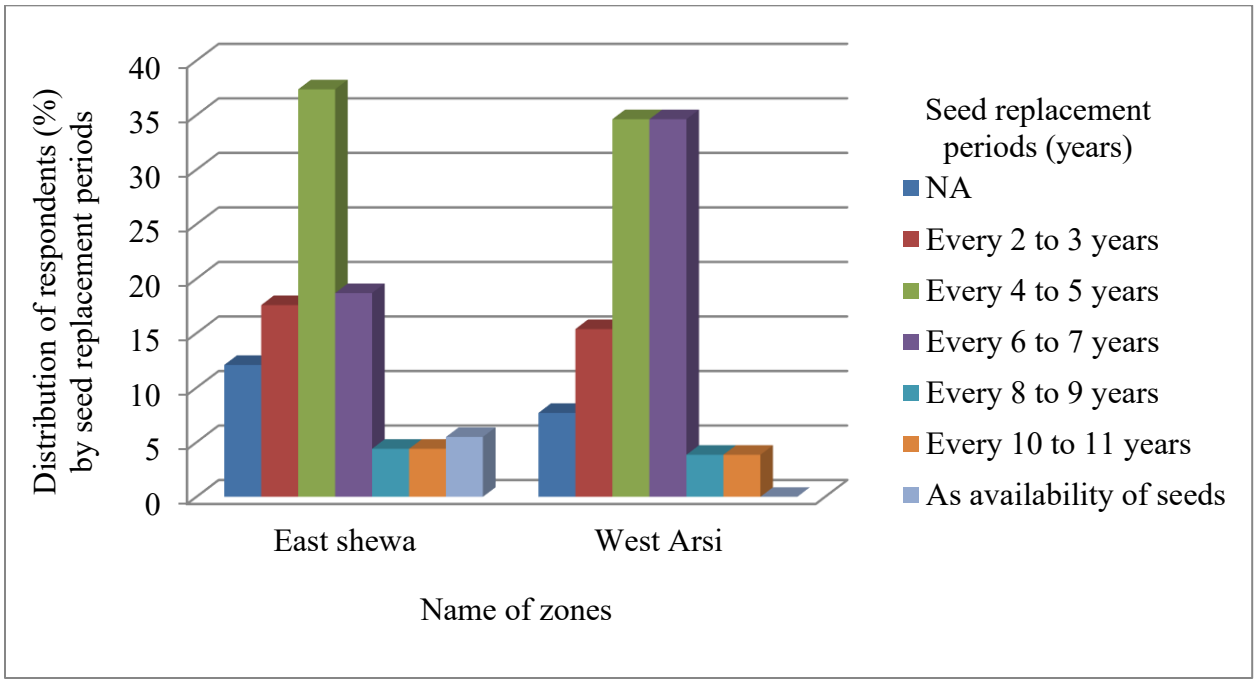


Fig. 8 Onion seed or variety replacement periods among zones

3.5.9 Reasons for onion seed or variety replacement

The survey found that 7.79% of farmers in West Arsi and 3.11% in East Shewa zones replaced seeds primarily to introduce new varieties (Table 14). Farmers considered multiple traits simultaneously, such as pest resistance, drought tolerance, and yield. In East Shewa, 7.56% of farmers specifically chose seeds for a combination of age, yield, and resistance. The most

significant factor for replacement in both East Shewa (54.67%) and West Arsi (50.65%) zones' farmers' was the lack of saved seeds and timely availability.

Table 14 Seeds or variety replacement reasons of farmers among the zones

Farmers selected several seed sources to obtain onion seeds for planting purposes, why?	Name of zones				Total	
	East Shewa		West Arsi			
	N	%	N	%	N	%
To replace old seeds or variety	7	3.11	6	7.79	13	4.30
Search for better seed quality	3	1.33	0	0.00	3	0.99
Search for better seed or bulbs yields	4	1.78	1	1.30	5	1.66
Search for better resistant to diseases and insect pests	5	2.22	0	0.00	5	1.66
Search for better tolerance to heat and drought	4	1.78	1	1.30	5	1.66
Since no own seed or variety	3	1.33	1	1.30	4	1.32
Since timely available in the area	4	1.78	1	1.30	5	1.66
To replace old variety, to replace old seed, better seed qualities, better seeds/bulbs yields, better resistance to diseases and insects pests, better tolerance to heat and drought, since no own seeds/ variety and since timely available in the areas.	12	5.33	11	14.29	23	7.62
To replace old variety, to replace old seed, better seed qualities, better seeds/bulbs yields, better resistance to diseases and insects pests.	17	7.56	8	10.39	25	8.28
To replace old variety, to replace old seed, better seed qualities, better tolerant to heat and drought and since no own seeds/ variety.	7	3.11	0	0.00	7	2.32
To replace old variety, to replace old seed, better seed qualities, better resistance to diseases and insects pests and since no own seeds/ variety.	9	4.00	0	0.00	9	2.98
To search for better seed qualities, better resistance to diseases and insects pests and since no own seeds/ variety.	9	4.00	0	0.00	9	2.98
To search for better seed qualities, better resistance to diseases and insects pests and since timely available in the areas.	9	4.00	0	0.00	9	2.98
To replace old variety, to replace old seed, better seed qualities, better seeds/bulbs yields, better resistance to diseases and insects pests, and since timely available in the areas.	9	4.00	0	0.00	9	2.98
To search for better seed qualities, better resistance to diseases and insects pests, and better tolerant to heat and drought.	0	0.00	9	11.69	9	2.98
Since no own seeds/ variety and since timely available in the areas.	123	54.67	39	50.65	162	53.64
Total	225	100	77	100	302	100

Sources: Own field survey data (2024 to 2025)

3.5.10 Farmers' perception on onion seed quality

The survey found that majority of respondents (29.47%) perceived quality seeds as those free from rot, diseases, weeds, and mixtures, possessing "true to type" physical characteristics (Table 15). In West Arsi, 31.17% prioritized seeds free from deterioration with good color and size, while 28.89% in East Shewa had similar views. West Arsi farmers showed a significantly higher preference for medium-to-large seed sizes (29.87%) compared to East Shewa (7.56%). East Shewa farmers focused more on single traits (physical purity), whereas West Arsi farmers preferred multi-trait combinations.

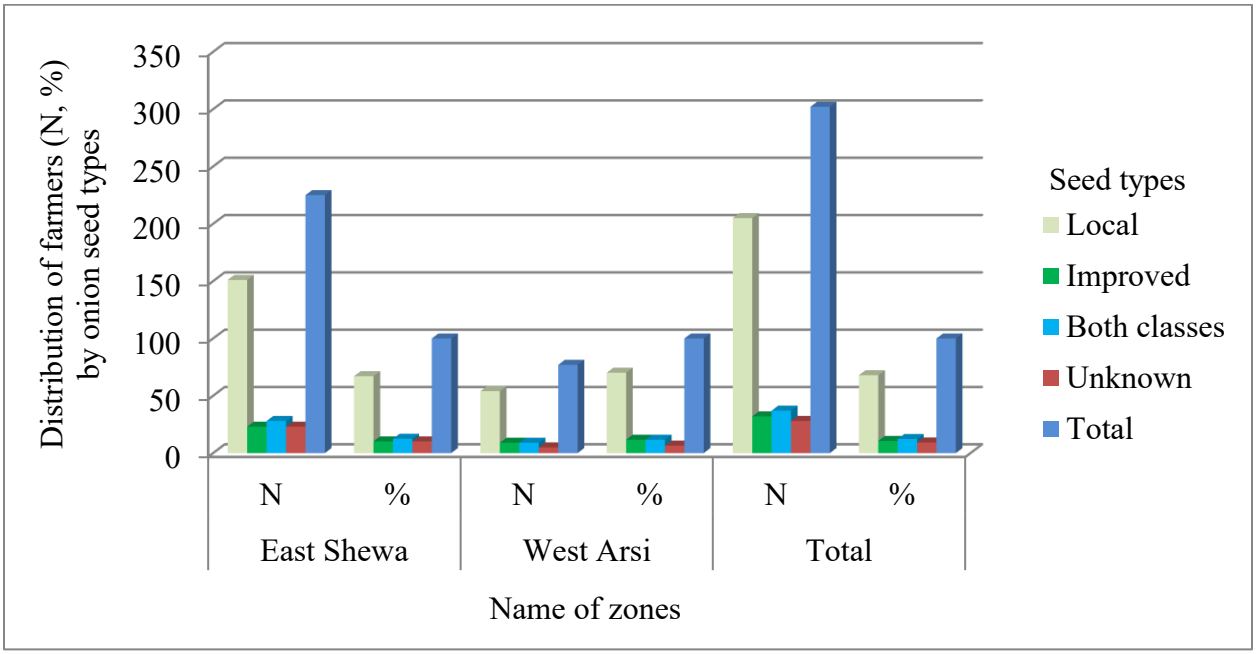
Table 15 Perception of farmers' on onion seed quality

Farmers' perception on onion seed quality	Name of zones				Total	
	East Shewa		West Arsi			
	N	%	N	%	N	%
Seeds color/ plumpness	21	9.33	1	1.30	22	7.28
Free from deterioration or rots	29	12.89	5	6.49	34	11.26
Medium seed size	15	6.67	9	11.69	24	7.95
Free from mixtures of other varieties	32	14.22	2	2.60	34	11.26
Free from mixtures of other crop	12	5.33	2	2.60	14	4.64
Seeds color/ plumpness, free from deterioration or rots, small and large seed size, free from diseases, free from mixtures of other varieties and free from mixtures of other seed crops.	65	28.89	24	31.17	89	29.47
Seeds color/ plumpness, free from deterioration or rots, small seed size, medium seed size, large seed size, free from diseases, free from mixtures of other varieties and free from mixtures of other crops.	5	2.22	7	9.09	12	3.97
Seeds color/ plumpness, free from deterioration or rots, free from diseases, free from mixtures of other varieties and free from mixtures of other crops.	6	2.67	4	5.19	10	3.31
Seeds color/ plumpness, free from deterioration or rots, medium seed size, large seed size, free from diseases, and free from mixtures of other crops.	5	2.22	0	0	5	1.66
Seeds color/ plumpness, medium and large seed sizes, and free from deterioration or rots, diseases, mixtures of other varieties and other seed crops.	17	7.56	23	29.87	40	13.25
Seeds color/ plumpness, free from deterioration or rots, and medium seed size	18	8	0	0	18	5.96
Total	225	100	77	100	302	100

Sources: Own field survey data (2024 to 2025)

3.5.11 Classes of onion seeds used by farmers

The majority of farmers (67.88%) preferred local varieties where 67.11% in East Shewa and 70.13% in West Arsi zones. Only 10.6% of farmers used improved varieties exclusively, while 12.25% used a combination of both local and improved varieties (Fig. 9).



Sources: Own field survey data (2024 to 2025)

Fig. 9 Classes of onion seeds using by farmers

3.5.12 Onion varieties used by farmers

Bombey Red is the dominant variety (48.01% overall), particularly in East Shewa (51.21%) zone. Naffis adoption was higher in West Arsi (37.14%) than in East Shewa (23.67%) zone. Adama Red was marginal at 2.17%. Regarding hybrids, Red Passion-F1 led with 48% adoption (57.14% in West Arsi), followed by Caramelo-F1 (28%). Jamber-F1 was found exclusively in East Shewa (Table 16) zone.

Table 16 Open-pollinated and hybrid onion varieties currently using by farmers

Open-pollinated onion varieties	Name of zones				Total	
	East Shewa		West Arsi			
	N	%	N	%	N	%
Bombey red	106	51.21	27	38.57	133	48.01
Adama red	4	1.93	2	2.86	6	2.17
Naffis	49	23.67	26	37.14	75	27.08
Bombey red and Robaf	48	23.19	15	21.43	63	22.74
Total	207	100	70	100	277	100
Hybrid onion varieties						
Red passionF1	8	44.44	4	57.14	12	48

JamberF1	5	27.78	0	0.00	5	20
CarameloF1	5	27.78	2	28.57	7	28
RussetF1	0	0	1	14.29	1	4
Total	18	100	7	100	25	100

Sources: Own field survey data (2024 to 2025)

3.5.13 Preferences for onion varieties

High bulb yield was the top priority for 52% of hybrid growers and 38.3% of Open-pollinated variety growers (Table 17). In West Arsi zone, 42.86% of hybrid growers prioritized multi-trait combinations (pest resistance and drought tolerance), whereas in East Shewa zone, only 5.56% respondents looked for multi-trait combinations, with most focusing on yield plus one extra trait.

Table 17 Preferences for open-pollinated and hybrid onion varieties

Preferences for open pollinated onion varieties	Name of zones				Total	
	East Shewa		West Arsi			
	N	%	N	%	N	%
Highest bulbs yields	85	41.06	21	30.00	106	38.27
Diseases and Insects resistant	7	3.38	0	0.00	7	2.53
Early mature	0	0.00	1	1.43	1	0.36
High market demand and price	0	0.00	2	2.86	2	0.72
Low price of seeds	1	0.48	1	1.43	2	0.72
High quality seeds.	2	0.97	1	1.43	3	1.08
High market demand and price, diseases and insects resistant, drought and heat tolerance, early maturity, low perishability, easily seeds availability, low price of seeds and high quality of seeds.	1	0.48	1	1.43	2	0.72
Highest bulb yields and early maturity.	0	0.00	1	1.43	1	0.36
Not applicable (NA).	0	0.00	4	5.71	4	1.44
Highest bulb yields, diseases and insects resistant, and high market demand and price, and highest bulb yields and early maturity.	18	8.70	7	10.00	25	9.03
Highest bulb yields, and high market demand and prices.	4	1.93	0	0.00	4	1.44
Highest bulb yields, diseases and insects resistant, early maturity, and high seed quality.	44	21.26	6	8.57	50	18.05
Highest bulb yields, diseases and insects resistant, high market demand and price, easily seeds availability and high quality of seeds.	39	18.84	2	2.86	41	14.80
Diseases and insects resistant, early maturity, drought and heat tolerance, low perishability, high market demand and prices, easily seeds availability and low prices of seeds.	6	2.90	23	32.86	29	10.47

Total	207	100	70	100	277	100
Preferences for hybrid onion varieties						
Highest bulb yields,	10	55.56	3	42.86	13	52
Highest bulb yields, diseases and insects resistant, drought and heat tolerances.	1	5.56	3	42.86	4	16
Highest bulb yields and high quality seeds.	3	16.67	1	14.29	4	16
Highest bulb yields, diseases and insects resistant, drought and heat tolerances, high market demand and prices, and high seeds quality.	4	22.22	0	0	4	16
Total	18	100	7	100	25	100

Sources: Own field survey data (2024 to 2025)

3.6. Major onion seed production practices

3.6.1 Practices for mother bulb and seed production

Onion True Seed and Mother Bulb Rates: The survey revealed that farmers in the study areas used significantly higher true seed rates for onion bulb production than standard recommendations. The majority of farmers in East Shewa (78.02%) and West Arsi (76.92%) zones applied a seed rate of 16 to 20 kg/ha (Fig. 10). Most farmers (61.54%) used a mother bulb rate of 4 to 5 tons/ha for true seed production. However, in the East Shewa zone, some farmers planted mother bulbs up to 12 tons/ha (Fig. 11).

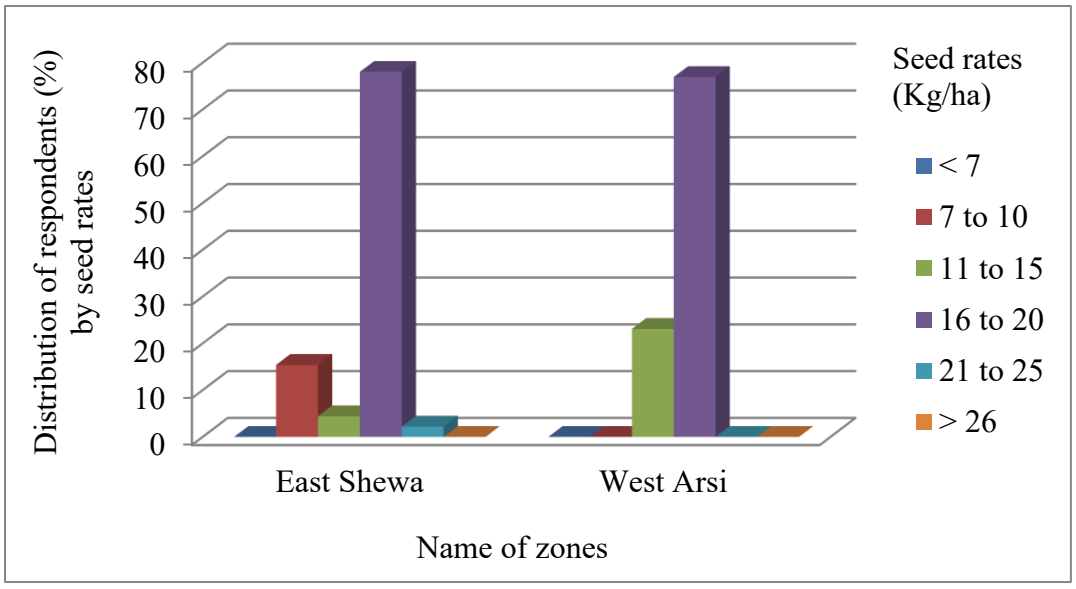


Fig. 10 Onion true seeds rate (Kg/ha) for mother bulb production

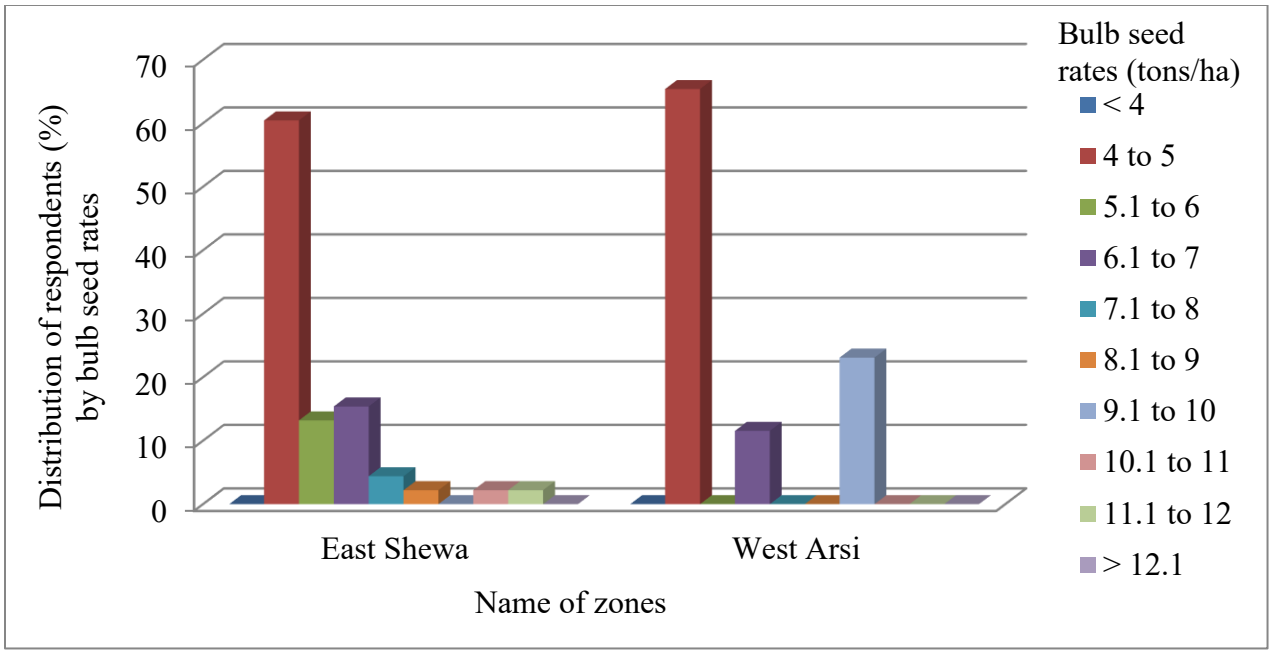


Fig. 11 Mother bulbs planting rates for true seed production (tons/ha)

Mother Bulbs Planting Times: Among the surveyed farmers majority of them (79.49%) were planted mother bulbs between October and November. This trend was more pronounced in the East Shewa zone (85.71%). Farmers in the West Arsi zone showed higher variability, with 30.77% planting between September and October and 11.54% between November and December to synchronize with low temperatures to induce flowering.

Seed Production Systems: Farmers in both zones exclusively utilize a two-stage "seed-to-bulb" and "bulb-to-seed" approach. True seeds are sowed on the beds, raised seedlings transplanted for mother bulb production, and then high-quality bulbs are selected, stored, and replanted to produce the next generation of true seeds (Table 18). The "seed-to-seed" method was not observed. Due to the biennial nature of onions and a reliance on seasonal rain rather than controlled environments, farmers produce seed only once per year.

Table 18 Onion true seeds production methods and rounds per year

Techniques of onion seeds production	Name of zones				Total	
	East Shewa		West Arsi			
	N	%	N	%	N	%
Seeds to bulbs	91	100	26	100	117	100
Bulbs to seeds	91	100	26	100	117	100
Seeds to bulbs and bulbs to seeds	91	100	26	100	117	100
Seeds to seeds	0	0	0	0	0	0
Total	91	100	26	100	117	100
Onion true seeds production rounds per year						

Once	91	100	26	100	117	100
Twice	0	0	0	0	0	0
Total	91	100	26	100	117	100

Sources: Own field survey data (2024 to 2025)**, Note:** Due to multiple responses no add up.

3.7. Harvest and post-harvest processes for onion true seed production

3.7.1 Selection of seed umbels: Farmers practiced seed selection processes at a single or multiple stages approaches based on crop physiognomies and farmers knowledge. In the pre-harvest stage, 21.37% of farmers demarcated high-performing field sections (Table 19), while others selected large umbels before or after harvest to thresh separately for the next planting season. Selection varied by zone, but the emphasis remained on selecting large umbels and cleaning seeds to maintain physical and physiological seed qualities.

Table 19 Stages of seed selection for the next planting season

Stages used to select high quality true seeds	Name of zones				Total	
	East Shewa		West Arsi			
	N	%	N	%	N	%
Select large umbels in the fields	0	0	3	11.54	3	2.56
Demarcate good section of fields before harvest	16	17.58	9	34.62	25	21.37
Select after dried, threshed and cleaned	2	2.20	0	0	2	1.71
Select large umbels after harvested	7	7.69	0	0	7	5.98
Select large umbels after harvest, select after dried, threshed and cleaned	58	63.74	14	53.85	72	61.54
Select large umbels in the fields, select after dried, threshed and cleaned and select large umbels after harvested	5	5.49	0	0	5	4.27
Select large umbels in the fields, demarcate good section of fields before harvest and select large umbels after harvested	3	3.30	0	0	3	2.56
Total	91	100	26	100	117	100

Sources: Own field survey data (2024 to 2025)

3.7.2 Harvesting standards and rounds: The majority of farmers (62.64% in East Shewa and 69.23% in West Arsi) harvested seeds when the umbels or seeds were physiologically well-dried (Table 20). In East Shewa, farmers showed variability in harvesting when seed umbels exposed or opened from 10 to 40% as a cue, while West Arsi farmers were more uniform, harvesting when seed umbels opened from 30 to 40%.

3.7.3 Seed Processing and Productivity: Common practices included drying, threshing, cleaning, sorting, washing, grading, packing and sealing. In East Shewa zone, seed washing and re-drying were specifically reported. While most waited for umbels to dry, 16.24% threshed

seeds before the umbels were fully dried (Table 21). On-farm productivity of onion true seeds for 60.68% of farmers ranged between 0.5 and 0.7 tons/ha (Fig. 13).

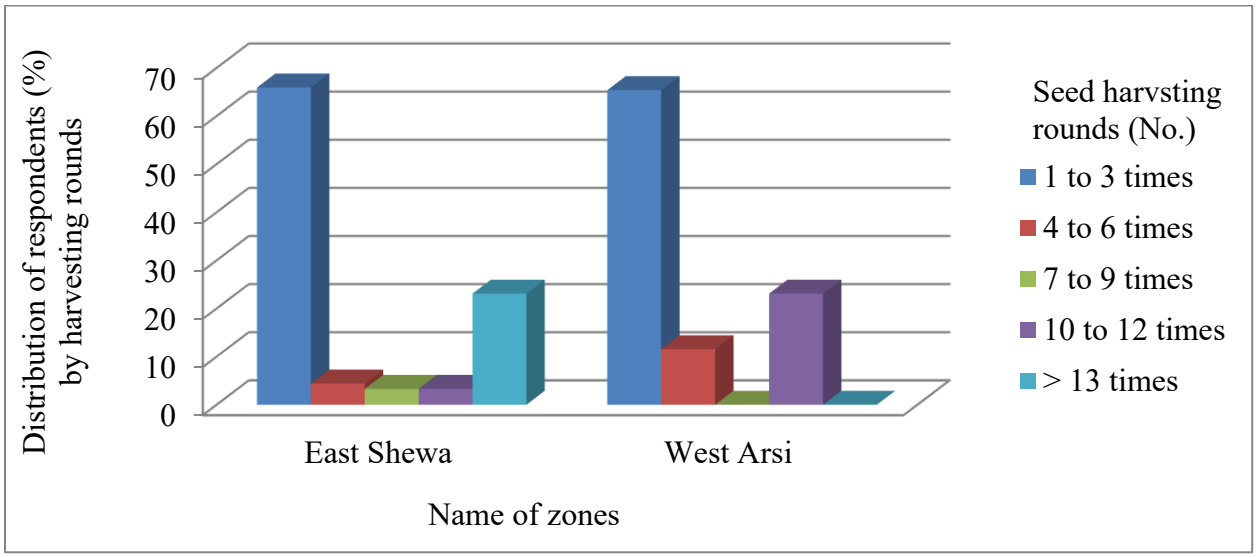
3.7.4 Seed Packaging and Storage: Polypropylene bags (non-hermetic) were the dominant packaging material (58.97%), followed by plastic sheets (30.77%). PICS bags (hermetic) were used by a very limited number of farmers (Table 22). Storage durations varied: 51.28% of farmers practiced long-term storage (over 13 months), while 24.79% stored seeds for only 3 months (Table 23). Short-term storage (3 months) was more frequent in West Arsi (37.04%) than in East Shewa zone.

Table 20 Important indicators to harvest onion seed umbels

Indicators to harvest onion seed umbels	Names of zones				Total	
	East Shewa zone		West Arsi zone			
	N	%	N	%	N	%
Harvest when 10-20% of seeds exposed	3	3.30	0	0	3	2.56
Harvest when 20-30% of seeds exposed	12	13.19	0	0	12	10.26
Harvest when 30-40% of seeds exposed	9	9.89	4	15.38	13	11.11
Harvest when well dried	57	62.64	18	69.23	75	64.10
Harvest arbitrary	4	4.40	1	3.85	5	4.27
Harvest when enough labor exist	4	4.40	2	7.69	6	5.13
Harvest when seed price high	2	2.20	1	3.85	3	2.56
Total	91	100	26	100	117	100

Sources: Own field survey data (2024 to 2025)

Most producers (65.81%) harvested seeds multiple times (1 to 3 rounds) per season. Notably, in East Shewa zone 23.08% of farmers harvested more than 13 rounds in a single harvesting season (Fig. 12).



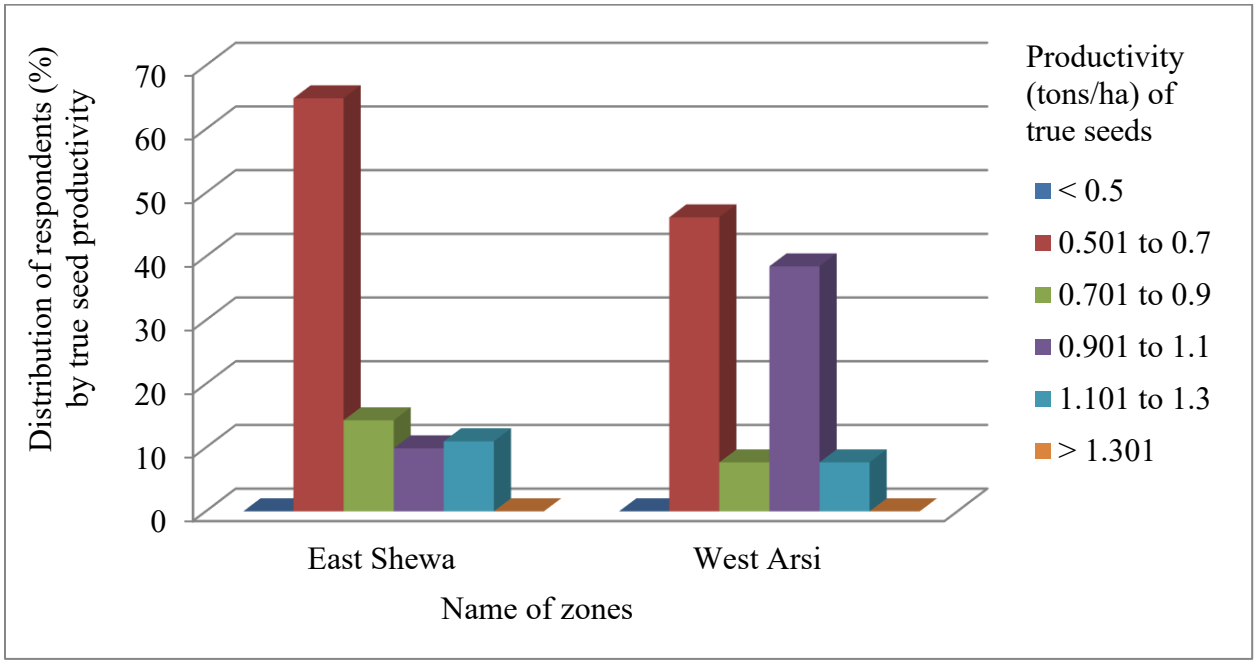
Sources: Own field survey data (2024 to 2025)

Fig. 12 Distribution of respondents (%) by onion true seed harvesting rounds (Numbers)

Table 21 Post-harvest seed management practices among the zones

Post-harvest seed management practices	Name of zones				Total	
	East Shewa		West Arsi			
	N	%	N	%	N	%
Washing seeds by clean water after threshed	4	4.40	0	0	4	3.42
Re-drying the soaked seeds	4	4.40	0	0	4	3.42
Dry umbels after harvest, threshing after dry, clean by blowing seeds in the air, sorting seeds, grading seeds, packing and sealing.	50	54.95	17	65.38	67	57.26
Dry umbels after harvest, threshing after dry, clean by blowing seeds in the air, sorting seeds, washing by water, re-drying the seeds, packing and sealing.	19	20.88	4	15.38	23	19.66
Threshing without drying, clean by blowing seeds in the air, sorting seeds, packing and sealing.	14	15.38	5	19.23	19	16.24
Total	91	100	26	100	117	100

Sources: Own field survey data (2024 to 2025)



Sources: Own field survey data (2024 to 2025)

Fig. 13 Productivity (tons/ha) of open pollinated onion true seeds across the zone

Table 22 Storage structures or containers for onions true seeds

Packaging materials for	Name of zones	Total

onions true seeds	East Shewa		West Arsi			
	N	%	N	%	N	%
Cloth bags	3	3.33	0	0	3	2.56
Plastic sheets-local	24	26.67	12	44.44	36	30.77
Polypropylene bags	54	60	15	55.56	69	58.97
PICS bags	2	2.22	0	0	2	1.71
Cloth bags and polypropylene bags	7	7.78	0	0	7	5.98
Total	90	100	27	100	117	100

Sources: Own field survey data (2024 to 2025)

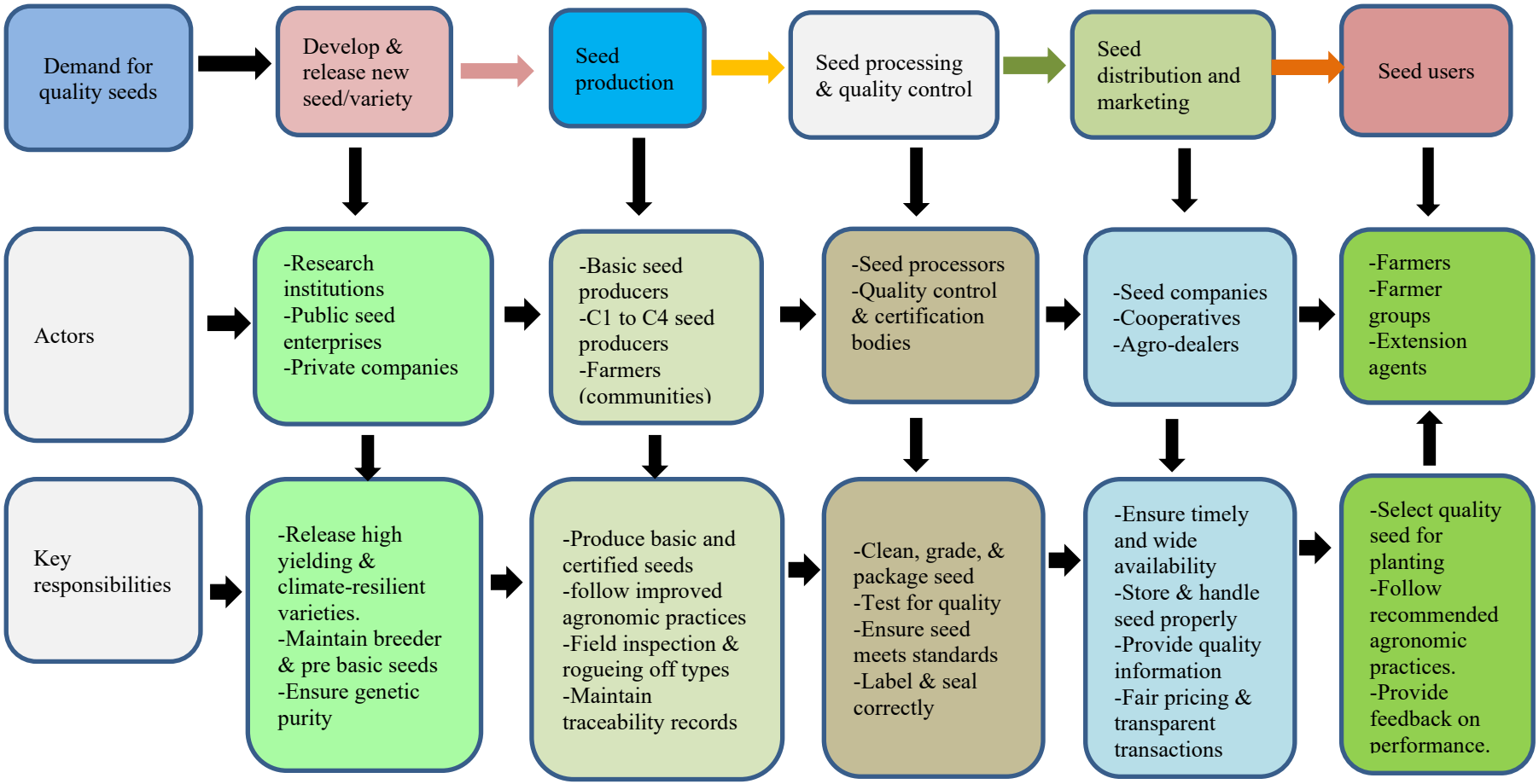
Table 23 Storage longevity for onions true seeds

Storage length of onions true seeds	Name of zones				Total	
	East Shewa		West Arsi			
	N	%	N	%	N	%
3 months	19	21.11	10	37.04	29	24.79
6 months	7	7.78	0	0	7	5.98
9 months	1	1.11	5	18.52	6	5.13
12 months	15	16.67	0	0	15	12.82
> 13 months	48	53.33	12	44.44	60	51.28
Total	90	100	27	100	117	100

Sources: Own field survey data (2024 to 2025)

3.8. Onion seed supply chain

The survey found that interviews made with farmers and key informants (experts, DAs, *Kebele* leaders, and model farmers) identified that the onion seed supply system in Ethiopia operates through three primary channels: the formal, intermediate, and informal seed systems. These systems involve a network of actors including research institutions, seed companies, enterprises, cooperative unions, traders, and farmers. The identified processes cover how seeds were produced, multiplied, distributed, and accessed by farmers ((Fig. 14). Focus Group Discussions (FGD) confirmed the results obtained through interviews made with individual farmers' and key informants.



Sources: Own field survey data (2024 to 2025)

Figure 14 Seed supply chain with actors and responsibilities in case of onion seeds

3.8.1 Constraints in onion seed supply

The major constraints in onion seed supply were summarized in Table 24. The main constraint was limited public and private sector engagement in seed multiplication and supply (65.81%). A significant number of respondents identified limited popularization of varieties (64.96%) and awareness creation (63.25%) as major bottlenecks. Furthermore, limited local production of quality seeds (60.68%) and weak seed quality control and certification (62.39%) were prominent. Agro-ecological challenges and limited identification of farmland suitability for commercial seed production were each cited by more than 60% of respondents. Significant variations of constraints were observed across locations and individual farmers. Farmers in the East Shewa zone reported higher percentages of constraints compared to West Arsi zone. The East Shewa zone also had a larger number of seed-producing farmers.

Table 24 Major constraints in onion seed supply

Constraints in onion seed supply	Name of zones				Total	
	East Shewa		West Arsi			
	Freq.	%	Freq.	%	Freq.	%
Limited public and private sectors engagement	65	71.43	12	46.15	77	65.81
Limited popularization of varieties	64	70.33	12	46.15	76	64.96
Limited awareness creation	60	65.93	14	53.85	74	63.25
Agro-ecological challenges	58	63.74	16	61.54	74	63.25
Limited identification of suitable farm lands	61	67.03	12	46.15	73	62.39
Weak seed quality control and certification	60	65.93	13	50	73	62.39
Limited quality seed supply (EGS)	58	63.74	13	50	71	60.68
Limited local production of quality seeds	60	65.93	11	42.31	71	60.68
Shortage of new crop varieties	55	60.44	13	50	68	58.12
Total	91	100	26	100	117	100

Sources: Own field survey data (2024 to 2025)**, Note:** No add up to 100% since respondents mentioned multiple responses

3.9. Challenges in onion seed production

The majority of farmers (90.7%) identified infested storage rooms as the most significant factor for poor quality, ranking it as extremely important (Table 25) with a low standard deviation (0.516). Infected seeds and harvesting conditions were ranked second (75.5% extremely important), while unfavorable storage conditions were ranked third (72.2%). Infected storage bags were ranked fourth (38.7% extremely important). Conversely, 88.1% of farmers considered insect damage the least important factor in seed storage. Under field condition majority of farmers (79.5%) rated diseases and insect pests as a serious constraints (Table 26). Majority of farmers (76.8%) influenced by high input prices, and substantial percentage of farmers (69.9%) reported low productivity as a challenge. Lack of true-to-type varieties (61.3%) and untimely availability of inputs (66.2%) were also significant problems. Shortage of farmland (64.2%),

limited irrigation facilities, and shortage of pollinators were rated as minor or least severe problems.

Table 25 Causes of onion poor seed quality

Causes of onion poor seed quality	Five point Likert Scales										Mean	SD	Ranks
	Extremely important (1)		Very important (2)		Moderately Important (3)		Slightly important (4)		Not at all important (5)				
	N	%	N	%	N	%	N	%	N	%			
Infected seeds/harvesting conditions	228	75.5	47	15.6	25	8.3	1	0.3	1	0.3	1.34	0.673	2
Insect damages	1	0.3	3	1.0	8	2.6	24	7.9	266	88.1	4.82	0.546	5
un conducive storage conditions	218	72.2	52	17.2	20	6.6	7	2.3	5	1.7	1.44	0.848	3
Infected storage bags	117	38.7	119	39.4	59	19.5	4	1.3	3	1.0	1.86	0.842	4
Infested storage rooms	274	90.7	20	6.6	4	1.3	2	0.7	2	0.7	1.14	0.516	1

Sources: Own field survey data (2024 to 2025)**, Note:** No add up due to multiple responses, 1=Extremely important, 2=Very important, 3=Moderately Important, 4=Slightly important and 5=Not at all important

Table 26 Onion true seeds production constraints

Are the following factors your major constraints facing you in the onion seeds and bulbs production?	Five point Likert Scales										Mean	SD
	Not at all a problem (1)		Minor problem (2)		Moderate problem (3)		Major problem (4)		Serious problem (5)			
	N	%	N	%	N	%	N	%	N	%		
Shortage of farm lands	18	6.0	194	64.2	53	17.5	9	3.0	19	6.3	2.41	0.917
Lack of irrigation facilities	52	17.2	176	58.3	59	19.5	15	5.0	0	0	2.12	0.744
Less emphasis given by government in the last three years	52	17.2	9	3.0	25	8.3	216	71.5	0	0	3.34	1.150
Lack of credit	39	12.9	18	6.0	200	66.2	36	11.9	9	3.0	2.86	0.893
High input price	0	0	9	3.0	28	9.3	232	76.8	33	10.9	3.96	0.566
Timely un availability of inputs	34	11.3	9	3.0	41	13.6	200	66.2	18	6.0	3.63	0.878
Lack of true to type varieties	9	3.0	33	10.9	0	0	75	24.8	185	61.3	4.41	0.906
Poor seeds or input quality	15	5.0	18	6.0	7	2.3	237	78.5	25	8.3	3.86	0.713
Limited knowledge and skills	27	8.9	34	11.3	198	65.6	34	11.3	9	3.0	3.26	0.784
Occurrences of diseases and insect pests	37	12.3	0	0	0	0	25	8.3	240	79.5	4.44	0.890

Weeds prevalence	43	14.2	33	10.9	202	66.9	6	2.0	18	6.0	2.75	0.935
Flower aborting	58	19.2	9	3.0	59	19.5	176	58.3	0	0	3.17	1.165
Low productivity	0	0	1	.3	67	22.2	211	69.9	23	7.6	3.85	0.538
Labor constraints	70	23.2	22	7.3	201	66.6	9	3.0	0	0	2.49	0.881
Limited of budget	35	11.6	33	10.9	207	68.5	18	6.0	9	3.0	2.78	0.840
Shortage of waters due overloads	49	16.2	42	13.9	192	63.6	19	6.3	0	0	2.60	0.832
Birds damage on fields	26	22.22	38	32.48	48	41.03	4	3.42	1	0.86	2.28	0.879
Shortage of pollinators (honey bee)	60	51.28	40	34.19	16	13.68	1	0.86	0	0	1.64	0.748

Sources: Own field survey data (2024 to 2025), **Note:** No add up due to multiple responses, 1= Not at all a problem, 2=Minor problem, 3= Moderate problem, 4= Major problem and 5=Serious problem

3.9.1 Correlation between onion seed production constraints

A strong negative correlation (-0.717) was found between the shortage of farmlands (SFL) and the lack of emphasis given by the government (LEG). Positive correlations were found between timely unavailability of inputs (TUI) and high input prices (0.583), as well as lack of true-to-type varieties (0.430). The absence of true-to-type varieties also correlated strongly with government negligence (r = 0.578) (Table 27). Weed prevalence (WP) was linked with labor constraints (0.613) and low productivity (0.510). A negative correlation existed between farmer knowledge and pest occurrence (r = -0.138*). A strong negative correlation (-0.717) was found between the shortage of farmlands (SFL) and the lack of emphasis given by the government (LEG). Positive correlations were found between timely unavailability of inputs (TUI) and high input prices (0.583), as well as lack of true-to-type varieties (0.430). The absence of true-to-type varieties also correlated strongly with government negligence (r = 0.578). Weed prevalence (WP) was linked with labor constraints (0.613) and low productivity (0.510). A negative correlation existed between farmer knowledge and pest occurrence (r = -0.138*).

Table 27 Correlation between onion seed and bulb production constraints

Onion seeds and bulbs production constraints	SFL	LIF	LEG	LC	HIP	TUI	LTTV	PSIQ
Shortage of farm lands (SFL)	1							
Lack of irrigation facilities (LIF)	.364**	1						
Less emphasis given by government (LEG)	-.717**	-.574**	1					
Lack of credit (LC)	-.286**	-.089	.092	1				
High input price (HIP)	.054	-.445**	.293**	-.018	1			
Timely un availability of inputs (TUI)	-.219**	-.429**	.371**	.210**	.583**	1		
Lack of true to type varieties (LTTV)	-.279**	-.090	.578**	-.003	.326**	.430**	1	
Poor seeds or input quality (PSIQ)	-.077	.133*	.035	-.214**	-.378**	.070	.086	1
Onion seeds and bulbs production constraints	LKS	ODIP	WP	FA	LP	LCs	LB	SWDO
Limited knowledge and skills (LKS)	1							
Occurrences of diseases and insect pests (ODIP)	-.138*	1						
Weeds prevalence (WP)	.238**	-.189**	1					

Flower aborting (FA)	-.009	.239**	.418**	1				
Low productivity (LP)	-.006	.042	.510**	.720**	1			
Labour constraints (LCs)	.108	-.030	.613**	.712**	.707**	1		
Limited of budget (LB)	-.213**	.286**	.067	.283**	.124*	.243**	1	
Shortage of waters due overloads (SWDO)	-.132*	.013	.346**	.711**	.591**	.465**	.148**	1

Sources: Own field survey data (2024 to 2025)**, Note:** * Correlation is significant at the 0.05 level (2-tailed), ** Correlation is significant at the 0.01 level (2-tailed)

3.10. Opportunities for onion seed production

The survey found that there were several opportunities to produce onions, such as high market demand, export potential, and agro-ecological suitability in the East Shewa and West Arsi zones. Demand for hybrids and disease-free seeds are increasing, as many farmers currently use local seed varieties. Ethiopia currently imports a significant volume of hybrid seeds. EIAR and regional centers are actively participating in releasing open-pollinated improved onion varieties.

4. DISCUSSIONS

4.1. Socio-demographic Characteristics

The observed dominance of male-headed households in onion bulb and seed production aligns with previous studies in Ethiopia [30], which emphasized gender disparities in high-value crop production. This dominance of male-headed households (87%) reported in onion production, indicated a consistent trend at the national level. This gender imbalance is often attributed to factors like access to resources, extension services, and market linkages that favor male farmers. Furthermore, Samuel [37] and [38] noted that female farmers in Ethiopia face challenges in engaging in high-value crops production like onions due to time constraints, market uncertainties, and lack of capital. The current study suggested that female participation is further limited in seed production, which requires more technical knowledge, inputs, and risk-taking compared to bulb production.

The education levels found in this study where a large portion of producers only completed primary education that reflect limited rural access to formal schooling, as supported by [39]. Similarly, a study by [40] found that a high proportion of smallholder farmers in Ethiopia operate with low levels of formal education, particularly in onion-producing regions like East Shewa and West Arsi zones. However, this study found that seed producers had slightly higher levels of education, which differs from previous research [41, 42] that reported seed production was predominantly done by older, less-educated farmers using informal systems. This shift may suggest a growing commercialization and professionalization of onion seed systems, attracting better-educated individuals seeking market-oriented opportunities [43]. It may also reveal targeted efforts by NGOs and development programs to involve youth in higher-value agricultural ventures [44].

The strong reliance on mixed farming observed in this study reflects how rural households integrate crop production with livestock to ensure food security and income stability [45]. The [43] highlights the importance of such integrated farming systems in increasing resilience to climate and market shocks. The trend toward crop specialization among seed producers aligns with emerging seed systems, where factors such as access to knowledge, extension services, and market incentives can influence farmers to focus on the production of high-value crops [41].

The average age of the household heads falls within the productive working age range in Ethiopia, suggested that onion seed and bulb production are dominated by adults who likely have both experience and decision-making capacity for labor-intensive agriculture. This aligns with previous studies by [46] and [47], indicating that middle-aged individuals are most active in onion farming. Furthermore, the findings on household family size align with a [48] report and research by [49] in the East Shewa zone. This data highlights the importance of family labor in onion production systems; larger household sizes provide more labor availability to support various stages of production, post-harvest handling, and cost-saving measures, particularly in smallholder frameworks where access to hired labor may be limited.

4.2. Associations Between Socio-demographic and Mother Bulb Production

The significant variations in sex and age across *Woredas* suggest localized demographic trends. The gender disparities observed at the *Woreda* level align with previous studies by [50] and [51], which found location-dependent gender roles in agriculture. Also [41] noted gender disparities in seed systems, indicating that these patterns may vary across crops and socio-economic factors. The highly significant variations in age distribution across *Woredas* highlight the need for targeted policy interventions based on local age trends.

Similarly, the disparities in educational levels among *Woredas* align with [52], who emphasized the importance of considering localized demographic trends in policy planning, as well as [41] and [53], who noted the need to address educational disparities locally in agricultural interventions. Conversely, marital status showed no significant differences, which align with [54], who found that marital status has limited influence on crop production practices compared to educational levels and size of farmland allocation. The findings revealed that larger household family sizes clustered in certain *Woredas* suggests impacts on labor availability in more agrarian or resource-dependent areas. This is consistent with [55], who noted that regional variations in household size affect agricultural labors.

The consistent of production factors like bulb production experiences among farmers' reflects findings by [56], who reported that onion production experience among smallholders is generally long-standing across regions. However, farmland allocation for bulb production varied significantly across *Woredas*. This suggests that while allocation strategies are consistent among

individual farmers, they are seriously influenced by geographic locations, a finding supported by [57], who found that local landholding patterns determine land allocation. Finally, the significant differences across locations in bulb storage duration highlight how post-harvest practices are influenced by local infrastructure, climate conditions, and market dynamics. This supports previous studies [58] that demonstrated regional disparities in storage infrastructure that can result in diverse and localized seed conservation approaches.

4.3. Associations Between Socio-demographic and Onion Seed production

The lack of significant associations at the farmer levels suggests that individual traits like sex, marital status, seed replacement rate, seed production experience, and land covered by onion seeds have limited influence on seed production activities. This aligns with previous studies by [53] and [56], which highlight the greater impact of external factors. The uniformity in seed production experience suggests the presence of community learning and informal seed exchange networks, in line with [58] research. The significant differences in varietal preferences among Woredas stress the importance of local adaptation, climate, and farming practices in seed selection. This is consistent with the findings of [59] and [60], who emphasize the location-specific nature of varietal preferences in informal seed systems. The consistent seed replacement rates emphasize on the challenges of limited availability and high costs of quality seeds, as noted by [43] and [53]. This indicates that local institutional capacity, market access, and agro-climatic conditions play a more significant role in seed production and varietal adoption than socio-demographic factors. These findings emphasize the importance of tailored policy interventions and extension services to enhance seed access and adoption in local contexts.

4.4. Determinants of onion seed production factors

The data was analyzed using a Multiple Linear Regression model due to the quantitative nature of the dependent variable and the presence of multiple explanatory variables. The study identified significant factors influencing onion seed production practices, including seed sources, production experience, farmland allocations, replacement periods, perception of seed quality, types of onion, harvesting rounds, and socio-demographic factors such as sex, age, educational levels, and marital status. The normality of residuals was assessed using histograms and normal P-P plots to ensure the validity of subsequent t-tests for individual coefficient significance and F-tests for overall model fit. Linearity and homoscedasticity were evaluated through scatter plots of standardized residuals against predicted values. In onion and vegetable production regression models, homoscedasticity assumptions are often challenged by variables like farm size or unequal inputs resource access [30].

In studies on onion production, factors such as farming experience, age of the household head, and land size allocated to onion production often show significant overlap [46, 61]. Research on onion production constraints and input efficiencies in smallholder landscapes consistently

highlights these factors, as various environmental and structural constraints can impact production outcomes. The size of the onion farm also plays a crucial role, with a one-unit increase in farm size leading to a 9.3% rise in production, assuming other variables remain constant [30]. Household experiences in onion production contribute to improved production outcomes, as farmers gain familiarity with the production environment and enhance their expertise in onion cultivation. Experienced farmers also demonstrate better administrative skills that benefit their production and handling practices [29].

The use of standard residual scatter plots ensures that the error term (ϵ) maintains a constant variance across all levels of the predictors, validating the use of ordinary least squares (OLS) for estimating the relationship between dependent and independent variables. An R2 value of 0.646 indicates that 64.6% of the total variance in onion seed production practices is collectively explained by the specified predictors in the linear regression model. However, the Adjusted R2 decreases to 0.585 (58.5%). Unlike R2, which increases with the addition of new variables, the Adjusted R2 penalizes the model for including predictors that do not significantly enhance explanatory power [62]. The difference between R2 and Adjusted R2 suggests that some variables in the model may have limited or insignificant predictive value, reducing the overall effectiveness of the model. The remaining 35.5% of the variation is influenced by unaccounted factors outside the model, such as climate, biotic stresses, agronomic practices, and institutional factors in onion cultivation. Multi-collinearity diagnostics revealed that the Variance Inflation Factor (VIF) and tolerance values for all independent variables were within acceptable limits, as noted by [30]. This confirms that collinearity between variables is manageable, allowing for the isolation of each predictor's unique impact on onion production. The Durbin-Watson statistic value was close to 2, indicating the absence of first-order autocorrelation in the residuals [63].

4.5. Determination of Onion Production

The dominance of combined production objectives indicates that onion production serves both subsistence and commercial functions for smallholder farmers. The greater emphasis on bulb production compared with seed production suggests that farmers prioritize immediate market returns and household consumption over the technically demanding seed initiative. Similar observations were reported by [64], who noted that farmers commonly dedicate specific portions of land to bulb and seed production according to market demand and production capacity. Focus group discussions (FGDs) confirmed that farmers usually produce onions for diverse purposes. The findings also indicate that onion seed production remains a specialized activity practiced by a limited proportion of farmers, likely due to its higher technical and financial requirements.

4.5.1 Land allocation for onion seed production

The predominance of small farmland allocation for onion seed production suggests that the farmers are still considered risky and resource demanding practices. Similar findings were

reported by [53] and [56], who associated limited farmland allocation with high input costs, technical complexity, and insufficient extension support. The larger farmland allocation observed among a few experienced farmers indicates differences in technical knowledge, resource access, and production capacity. Previous studies [41] showed that farmers with better training and access to agricultural inputs are more likely to engage in seed production activities. Similarly, Food and Agriculture Organization [43] emphasized the role of extension services and technical support in expanding seed production capacity. The observed differences in Heban Arsi Woreda may therefore be linked to better irrigation access, extension services, and local seed demand, consistent with the findings of [65].

4.5.2 Experiences in onion seed production

Lack of seed production experience highlights a gap in practical knowledge and seed production expertise, leading to a reliance on external seed sources. This dependency can result in increased costs and unpredictability, especially for smallholder farmers [66]. The study highlights the importance of pluralistic seed system development to achieve seed security, supporting similar recommendations [41]. Despite awareness, the majority of farmers continue to depend on external suppliers, indicating slow progress in decentralizing seed production. Limited extension services and logistical difficulties in rural Ethiopia contribute to the gap in agricultural extension efforts [67]. This suggested that onion seed production may have higher technical barriers, limiting local farmer engagement.

4.5.3 Experiences in Mother Bulb Production

Limited scale and knowledge in mother bulb production indicated a gap in the seed value chain. Previous studies [68, 28] have shown that expertise in bulb production does not ensure proficiency in seed production, which requires additional technical, institutional, and market skills. Also [56] noted a disparity between large-scale bulb and small-scale local seed production due to limited knowledge and inadequate infrastructure. While [58] and [69] suggested long-term crop cultivation often involves informal seed production, [43] emphasized that experience alone is not enough without effective policies and market incentives. Our survey supports this, showing that despite a long history of onion farming, seed system development remains weak in the *Woredas*.

4.5.4 Sources of Onion Seeds

The reliance of farmers on informal seed sources, highlighted the importance of informal seed systems for smallholders, as supported by [70]. The exchange of seeds among neighbors indicated strong reliance on local networks, while challenges like seed degeneration contribute to the low use of saved seeds [71]. The limited involvement of formal institutions reflects weak linkages between research centers and farmers [72]. Variations across *Woredas* suggest localized seed networks influenced by infrastructure and social trust [41]. Cooperative unions and

organized groups of seed producers serve as semi-formal sources that complement formal systems. However, the low access to improved seeds indicates a need for better linkages [72]. While policy promotes pluralistic seed systems, these results revealed a weak integration in practice, disconnecting seed system design from farmer-level realities. The use of multiple sources (shops, local markets, and farmers) indicated a strategic and adaptive approach by farmers not previously emphasized in older literatures.

4.5.5 Acquisition of Onion Seeds

The seed acquiring system through buying was a common practice among smallholders from informal sources due to limited technical and financial capacity. The overall uptake of low formal sources suggested that despite efforts by research centers to ensure quality, farmers prioritize accessibility and flexibility. However, this preference carries risks such as poor germination and susceptibility to diseases [73]. Previous studies [28] attribute the low usage of cooperative unions to weak institutional presence and distrust in seed quality.

4.5.6 Seed Sources Selection Criteria

The results suggested that farmers prioritize easy access and affordability over quality-related factors or agronomic performance. This indicated that structural and informational limitations play a significant role in decision-making, aligning with reports by [74]. The low consideration for performance traits suggested a lack of awareness or capacity to evaluate improved varieties. As noted by [75], high-quality seeds enhance productivity, but this benefit is not realized when selection becomes transactional rather than strategic due to limited knowledge as supported by [76].

4.5.7 Quality Seed Selection Criteria

The survey revealed that the majority of farmers rely on trust, emphasizing its importance in situations where formal quality assurance is lacking. The survey found that the majority of farmers rely on trust, emphasizing its importance in situations where formal quality assurance is limiting, this is supported by [41]. Visual cues like plumpness and color are used as proxies for embryo development and maturity [77]. These variations across regions suggested that local conditions and cultural norms highly influence seed choices [78]. The reliance on visual inspection and social networks further underscores the weakness of formal quality control in Ethiopia [43].

4.5.8 Seed or Variety Replacement Periods

The findings of seed replacement periods align with recommendations that seeds should be replaced every 2 to 5 years to maintain germination [79]. The longer intervals in West Arsi likely indicated challenges in seed access and financial constraints as supported by [41]. The low

percentage of farmers in East Shewa who replace seeds only when new ones are available (5.49%) suggested the inconsistencies of market supply. Furthermore, environmental factors like climate change and a lack of extension support contribute to the risk of seed degeneration for those who do not replace seeds regularly [78].

4.5.9 Reasons for Onion Seed or Variety Replacement

The findings of seed or variety replacement reasons align with [79], who noted that while replacement is ideal every season, farmers often retain old seeds longer than recommended. The shift towards multi-trait selection in East Shewa aligns with [80] findings, indicated that as farms diversify, performance becomes more important than just simple availability. The high reliance on informal markets due to weak local vegetable seed preservation systems confirms the systemic issues identified by [81]. Variations between zones were probably due to specific agro-ecological challenges and seed availability.

4.5.10 Farmers' Perception on Onion Seed Quality

The emphasis on physical purity aligns with [71] as a universal indicator of seed quality. The strategy focused on the seed health in East Shewa (11.26%) support the [43] assertion that healthy seeds are viewed as the foundation for germination and yield. The regional differences suggest that while traditional visual assessment remains common [82], local infrastructure and extension support are beginning to shift perceptions toward more holistic health and genetic purity standards.

4.5.11 Classes of Onion Seeds Used by Farmers

The high reliance of respondents on local varieties is consistent with [53] and [83], reflecting cultural familiarity and the constraints of low-input conditions. The low adoption of improved seeds is likely linked to high costs and inadequate extension services [56]. However, the 12.25% of farmers using both types demonstrate a "pluralistic" risk-management strategy, balancing the productivity of hybrids with the resilience of local seeds [41].

4.5.12 Onion Varieties Used by Farmers

The dominance of Bombey Red is attributed to its storage ability and market demand [2]. However, such high varietal uniformity increases vulnerability to biological shocks [84]. The significant shift toward hybrids, especially Red Passion-F1contrasts with previous studies by [85] and suggests that market incentives and better seed access are finally reaching smallholders. The exclusive presence of Jamber-F1 in East Shewa reflects localized market differentiation.

4.5.13 Preferences for Onion Varieties

The universal prioritization of yield confirms its role in supporting household income [39]. The shift in West Arsi zone toward resilience traits suggests that farmers in mid-to-high altitude zones face more pronounced environmental challenges [86]. The adoption of more complex selection criteria in East Shewa zone reflects Rogers' [87] Diffusion of Innovations theory, where early adopters move beyond "yield" toward market-oriented traits like seed vigour and early maturity [88].

4.6. Major Onion Seed Production Practices

4.6.1. Practices for mother bulb and seed production

Onion True Seed and Mother Bulb Rates: The high seed rate (16-20 kg/ha) utilized by farmers drastically exceeds the recommended 3.5 to 4 kg/ha suggested by [2] and [11]. This discrepancy likely due to practical constraints such as poor seed quality, lack of precision seeding tools, and the prevalence of manual seeding, which [89] suggests necessitates higher rates to compensate for losses. However, this density risks smaller bulbs and nutrient competition, which negatively affects marketability [89, 2]. Conversely, the mother bulb rate of 4 to 5 tons/ha is below the recommended 6 to 8 tons/ha [2], leading to sub-optimal plant populations and increased weed pressure. The highest rates (12 tons/ha) found in East Shewa likely represent an attempt to maximize yield through density, though [89] and [90] warn that exceeding 10 tons/ha can compromise seed quality. These varied practices reflect a "trial-and-error" approach common in smallholder systems with limited extension support [41].

Planting Times and Vernalization: The preference for October-November planting aligns with the requirement for vernalization-exposure to temperatures of 5-15 °C for 6 to 8 weeks to induce flowering [91]. This timing is consistent with findings by [92] and [93], which identified this window as optimal for the Central Rift Valley. The avoidance of late planting (December) is likely a strategic select to escape insufficient chilling and poor bolting [91]. The early planting in West Arsi (September) zone may be a market-driven strategy to capture early prices, despite the risk of premature bolting and insufficient time to break dormancy.

Seed Production Systems: The reliance on the "bulb-to-seed" method confirms that farmers prioritize genetic purity and quality, as this method allows for the selection of true-to-type bulbs [91]. The absence of the "seed-to-seed" method is logical, given its known inefficiency in smallholder contexts [89]. The limitation of one production cycle per year highlights biannual characteristics of onion crops for true seed production.

4.7. Harvest and post-harvest processing in onion seed production

4.7.1. Selection and Timing to Improve Seed Quality: The multi-stage selection approach observed were on-farm before and after harvested that indicated a sophisticated understanding of

seed quality determinants, aligning with the importance of multi-stage selection highlighted by [94] and [95]. Similarly, the prioritization of physiological dryness over early harvest to reduce post-harvest loss is consistent with [83] and established principles that moisture content dictates storability [96]. The zonal disparities in stages of seed selection signal likely reflect local climatic differences, as noted by [97].

4.7.2. Seed Productivity and Yield Gaps: The need for multiple harvesting rounds (up to 13 in East Shewa) is a result of uneven umbel maturity, a practice [89] identifies as necessary for maximum seed recovery. However, this high frequency suggests a need for breeding varieties with uniform ripening to reduce labor costs and seed quality. The observed yield (0.5-0.7 tons/ha) is consistent with other on-farm studies [98] but significantly lower than the 1.2-1.5 tons/ha achieved at research stations for Naffis or Bombey red varieties [99]. This "yield gap" is likely due to differences in genetic potential, planting density, and pest management [89].

4.7.3. Seed Processing and Storage Risks: While washing seeds (common in East Shewa) can improve cleanliness, it risks mold and reduced viability if not handled carefully [89]. Furthermore, the 16.24% of farmers threshing un-dried umbels risk physical seed damage and poor separation efficiency [100]. The highly reliance on non-hermetic polypropylene bags poses a risk in humid conditions due to moisture exchange. The limited use of hermetic PICS bags suggests a lack of awareness or market access [101]. Most concerning is the high percentage of farmers storing seeds for over 13 months. As onion seeds are short-lived and lose vigour rapidly within 6-12 months under ambient conditions [102, 103], long-term storage without controlled environments likely leads to significant deterioration of physiological seed quality.

4.8. Onion seed supply chain

The structure of seed supply chain reflects the complex "seed value chain" and management aspects required for the flow of a new variety to the end-users. The integration of various actors suggested that variety development is only the first step in a commercial seed range that must be supported by robust management [104]. This multifaceted system indicated that the efficiency of the onion seed sector in Ethiopia depends on the coordination between research institutions, seed enterprises, farmers' cooperative union and local informal channels to ensure accessibility of seeds to smallholder farmers.

4.8.1. Constraints in Onion Seed Supply

The high percentage of concern regarding public and private engagement highlights the need for stronger institutional involvement in onion seed value chains. Similar studies [43, 105] confirm that collaboration between public research and private producers is crucial for seed availability. The bottlenecks in popularization and awareness indicate a gap in extension services and demonstrations. This aligns with [106], who reported that extension services are critical for

varietal adoption. The concern over the seed quality control suggests that a lack of inspection weakens trust in seeds, as noted by [107]. Geographically, the higher constraint reporting in East Shewa could be attributed to greater exposure to seed systems and higher expectations. Finally, the agro-ecological concerns reflect that onion seed production requires specific environmental conditions for flowering, which, if mismanaged, affects both seeds yield and quality [108].

4.9. Challenges in Onion Seed Production

The strong agreement on storage sanitation emphasizes a critical need for controlled environments. This confirms earlier findings by [109] that post-harvest handling is a major hurdle. The discrepancy regarding insect damage where respondents felt it was a minor threat but [110] reported it as significant may reflect regional differences in pest pressure. The high rating of input costs and disease aligns with global literature [89, 111]. The fact that farmers rated shortage of pollinator as "least important" suggests they may underestimate its role, as literature indicates pollination is actually critical for seed set [112]. Overall, these findings underscore the need for policy-level interventions and integrated pest management (IPM). Resource poor smallholder farmers cannot produce onion seeds since it require intensive work and budget, in addition to shortage of technical expertise. This could be improved through supporting smallholder farmers in terms of resources and technical skills which increase productivity. Similarly, Some of the SDGs of the United Nations listed in the 2030 Agenda like Zero Hunger, No Poverty and etc. fulfilled by strengthening food systems, support small-scale producers, improve services, and access to malnutrition that require urgent action [6].

4.9.1. Correlation between Constraints

The negative correlation between land shortage and government support suggests that resource-scarce areas may be suffering from weak institutional support [65]. The positive correlations in the input market suggest consistent inefficiencies in accessibility and affordability [111]. Furthermore, the link between flower abortion, labor, and productivity confirms that physiological stress and labor limitations are primary drivers of yield loss [113]. The negative correlation involving farmer knowledge suggests that capacity building through extension services can directly mitigate pest impacts [114].

4.10. Opportunities for Onion Seed Production

Ethiopia’s diverse agro-climatic zones provided a natural advantage for year-round production and disease reduction [115]. The prevalence of low-quality seeds in the current market represents a "ready market" for reliable suppliers [116]. Localizing production could save foreign exchange and improve national self-sufficiency [51]. The emergence of contract farming also offers a path to better quality control by providing farmers with technical and financial support [117].

4.11. Limitations of this study

While this study offers potential significant values in contributing a novel conceptual framework on the onion seed production, handling, supply systems, and associated challenges and opportunities, several limitations must be acknowledged. Due to binding time and financial constraints, the study scope was limited to a sample of 302 household heads across eight *Woredas* in the Central Rift Valley of Ethiopia, which may restrict the generalizability of the findings to regions with different agro-ecological and socio-economic conditions. Most information was based on farmers' and a few key informants' responses, which may cause bias or incomplete reporting. The commodity focus was restricted entirely to onion seed production systems, neglecting other crops seeds such as tomatoes and peppers. The study's cross-sectional design with short time field observations prevented the capture of critical longitudinal dynamics, including seasonal variations, environmental influences, seed price fluctuations, and long-term production trends. Predominantly the analysis was focused on informal sources with minimal representation of formal and intermediate channels, meaning it may not fully reflect the systemic complexity of the broader onion seed value chain. The study limits experimental verification of seed quality parameters as well as technical evaluations of post-harvest handling technologies that directly impact seed productivity, longevity, and quality. Consequently, a wider variety of warm-season vegetable seed productions with longitudinal research design are required to validate and strengthen the findings across diverse environments.

5. SUMMARY AND CONCLUSION

The study carried out to assesses the onion seed sources, and current seed production practices, farmers' perception of onion seed quality and preferences for varieties, seed replacement and planting rates, supply chains, and associated challenges and opportunities in the Central Rift Valley (CRV) of Ethiopia. The study revealed significant variations ($p \leq 0.001$) in demographic and production factors among different locations in onion production at the *Woredas* level. However, there were no significant variations among farmers, suggesting homogeneity. Onion seed production is dominated by smallholder farmers who rely on traditional practices and informal seed sources, mainly from local markets, shops and farmers' saved seeds. These practices often lack quality assurance, resulting in inconsistent seed quality. Seed handling practices, particularly harvesting, threshing, cleaning, drying, packing, and storage were generally inadequate, leading to deterioration and degeneration of seeds over time. The seed supply system is poorly coordinated, with weak integration between farmers, formal institutions, and intermediate seed producers. Production is further constrained by pest and disease pressures, limited access to irrigation, agrochemicals, and improved technologies, as well as insufficient extension services and knowledge gaps in technical seed production practices.

In conclusion, the Central Rift Valley has great potential for onion production despite challenges. The increasing demand for onions in Ethiopia and regional markets presents opportunities for

expanding onion seed production. To take advantage of these opportunities, targeted interventions, such as improving seed quality assurance, production practices, and access to modern technologies are needed. Strengthening seed systems among key stakeholders including research institutions, seed enterprises, private sector, farmers' cooperative unions, and regulatory authorities are crucial. Capacity buildings on storage facilities and technical backstopping for seed producers. Moreover, strengthening linkages with research-extension and collaborations among onion producers and suppliers are essential. Sound policies and investments in onion production and market development are required for sustainable development of the seed sector. Implementing the milestone strategy on national seed sector, Ethiopia can enhance its onion seed sector, improve productivity, boost incomes, and enhance food security that contribute to some of the Global Sustainable Development Goals.

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Authors' contributions

Kedir Oshone contributed to all major aspects of the research and manuscript preparation. He contributed to conceptualization, data curation, formal analysis, aid acquisition, investigation, methodology, project administration, resources, software, validation, visualization, writing of the original draft and writing-review and editing. **Karta Kaske (PhD)** was involved in conceptualization, data curation, investigation, methodology, project administration, resources, software, supervision, validation, visualization, and writing-review and editing. **Kebede Woldetsadik (Prof.)** contributed to conceptualization, investigation, methodology, supervision, validation, visualization, and writing- review and editing. **Zelalem Bekako (PhD)** was involved in conceptualization, investigation, methodology, supervision, visualization, and writing- review and editing.

Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

The study was carried out in compliance with the principles of the Declaration of Helsinki and national guidelines. We hereby declare that this is our original work and has not been published or submitted to any other journal for publication. We also confirm that the study, including its data sources and the publication of this research, was approved by the board of examiner of Melkassa Agricultural Research Center (MARC) including warm season vegetable crops research program coordinator (Chairperson), rapporteur (Researcher), facilitator (Researcher), MARC center director, and invited resource-person (Source Technology Multiplication and Seed Research Director). Board of examiner evaluated research based on guidelines 'research project proposals development and review' focused on the ethical, relevance, and other prioritized criterion, under reference number 23.1/3931/2018 by the Ethiopian Institute of Agricultural Research (EIAR). Furthermore, we ensured that informed oral consent was obtained from all respondents during the data collection processes.

Informed consent to publish

Not applicable.

Competing interest policy

The authors declare that there is no any competing interests (financial and non-financial) regarding this research work.

6. REFERENCES

1. Zhang, S., P. Deng, Y.-c. Xu, S.-w. L¨u, and Wang, J., J., 2016. Quantification and analysis of anthocyanin and flavonoids compositions, and antioxidant activities in onions with three different colors. *Journal of Integrative Agriculture, 15* (9), pp. 2175-2181. https://doi.org/10.1016/S2095-3119(16)61385-0
2. Lemma, D. and Shimelis, A., 2003. Research experiences in onion production: Research results and experiences in dry bulb and seed production in Ethiopia. Research Report No. 55. *Ethiopian Agricultural Research Organization (EARO)*, Addis Ababa, Ethiopia.
3. Lemma Dessagn, Shimeles Aklilu, Selamawit Ketema and Chimdo Anchala, 2006. The Vegetable Seed Sector in Ethiopia: Current Status and Future Prospects. ECSS, Proceedings of the Inaugural and Third National Horticultural Workshop, 26-28 April 2004, Addis Ababa, Ethiopia, *1*, pp. 191-201.
4. Fekadu M, and Dandena G., 2006. Review of the status of vegetable crops production and marketing in Ethiopia. *Uganda Journal of Agricultural Science, 12*(2), pp. 26-30. https://www.scribd.com/doc/17445082/Status-of-Vegetable-Peroduction-in-Ethiopia

5. Food and Agricultural Organization (FAO), 2025. Agricultural production statistics from 2010 to 2024. FAOSTAT Analytical Briefs, No. 121. *FAO.* [Accessed April 2026]. https://doi.org/10.4060/cd8035en
6. United Nations Department of Economic and Social Affairs (UN DESA), 2025. The Sustainable Development Goals Progress Report 2025. New York. (Revision August 2025). https://unstats.un.org/sdgs/report/2025/
7. Food and Agricultural Organization (FAO), 2009. Seed security for food security in the light of climate change and soaring food prices: challenges and opportunities. COAG/2009/Inf.7. https://www.ipcc.ch/apps/njlite/srex/njlite_download.php?id=5515
8. Food and Agricultural Organization (FAO), 2006. Quality Declared Seed System. FAO Plant Production and Protection Paper No.185, *FAO*, p.243. Rome, Italy. Quality Declared Seed System - Google Books
9. Panghal, V.P.S., Bhuker, A., Duhan, D.S. and Kumar, A., 2023. Maintaining Onion Seed Quality during Storage Through Seed Priming. *Agricultural Reviews*, *44*(2), pp. 269-272. https://doi.org/10.18805/ag.R-2458.
10. Food and Agricultural Organization (FAO), 2013. FAO Statistical Year book 2013; World Food and Agriculture. *Food and Agriculture Organization*, p.356. Rome, Italy, ISBN-13; 978-92-5-1073964. FAO Statistical Yearbook 2013
11. Nikus, O. and Mulugeta, F., 2010. Onion seed production techniques. A manual for extension agents and seed producers, Ethiopia. *FAO*., pp.1-31. https://gh-f.org/wp-content/uploads/2021/07/onion-seed-production-techniques-olani-nikus-m.-sc.-and-fikre-mulugeta-m.-sc..pdf
12. Agrawal, P.K., 2011. Climate change and its impact on agriculture. In: Souvenir-Indian Seed Congress, Feb. 22nd-23rd, Hyderabad. pp. 67-76. https://doi.org/10.18848/1835-7156/CGP/v02i03/37060
13. Chadha M.L., Altoveros E.C., Womdim R.N. and Mndiga H., 1997. Variety evaluation and seed production of vegetable crops. AVRDC Africa Regional Program, Arusha, and Tanzania, *65*(5), pp. 56-110. https://worldveg.tind.io/record/34264?v=pdf
14. Getahun, M., Tadesse, M. and Desta, A., 2018. Onion seed quality and its impact on bulb yield in Ethiopia. *African Journal of Agricultural Research*, *13*(45), pp.2532-2540.
15. Alemu, D., Muthoni, J. and Mwang'ombe, A., 2019. Seed system in Ethiopia and its contribution to agricultural productivity. *African Journal of Agricultural Research*, *14*(15), pp.723-731. https://doi.org/10.5897/AJAR2018.13841
16. Ministry of Agriculture and Natural Resources (MoANR), 2018. National seed sector development strategy (2018/19-2023). Ministry of Agriculture and Natural Resources, Addis Ababa, Ethiopia. https://www.agriculture.go.ug/wp-content/uploads/2023/01/National-Seed-Strategy.pdf
17. Rishi P. Singh, P. V. Vara Prasad, Raja Reddy K., 2013. Impacts of Changing Climate and Climate Variability on Seed Production and Seed Industry. *Advances in Agronomy*, *118*, pp. 49-110. http://dx.doi.org/10.1016/B978-0-12-405942-9.00002-5
18. Beshir W. and Peter K. 2025. Assessment of vegetable production systems in Ethiopia for the identification and promotion of sustainable agricultural practices. ESP working paper

Report No. 0001, Stichting Wageningen Research Ethiopia, Addis Ababa, p.23. SWRE-ESP-24-001. https://doi.org/10.18174/696307

19. Emana, B.; Afari-Sefa, V.; Dinssa, F.; Ayana, A.; Balemi, T.; and Temesgen, M., 2015. Characterization and Assessment of Vegetable Production and Marketing Systems in the Humid Tropics of Ethiopia. *Quarterly Journal of International Agriculture, 54* (2), pp. 163 - 187. DLG-Verlag Frankfurt/M. https://doi.org/10.22004/AG.ECON.210313
20. Gobena, D., Woldemichael A., and Hordofa T., 2017. Effect of deficit irrigation at different growth stages on onion (Allium cepa L.) production and water productivity at Melkassa, Central Rift Valley of Ethiopia. *Academic Research Journal of Agricultural Science Research*, *5* (5), pp. 358-365. https://doi.org/10.14662/ARJASR2017.042
21. Dejene, A., Kibebew K., Sheleme B., and Fassil K., 2018. Nitrate leaching under farmers' fertilizer and irrigation water use in the Central Rift Valley of Ethiopia. *International Journal of Plant & Soil Science, 21* (6), pp. 1-17. https://doi.org/10.9734/IJPSS/2018/39076.
22. Gizachew, W., and Suryabhagavan K. V., 2014. Soil-landscape modelling and mapping of soil organic carbon stocks in the East Shewa Zone, Ethiopia. *Carbon Balance and Management*, *9*(1), pp. 1-12. https://doi.org/10.1186/s13021-014-0008-x
23. Central Statistics Agency (CSA), 2022. Annual agricultural sample survey report for 2021/22: Volume II: Report on area, production and productivity of major crops (private peasant holdings, Meher season). Addis Ababa, Ethiopia: *CSA*. https://ess.gov.et/annually-price-index/. Accessed September 2023.
24. CSS (Central Statistical Services), 2023. Population Projections for Ethiopia for 30 years (2007-2037). Addis Ababa, Ethiopia. *CSS*. https://ess.gov.et/annually-price-index/. Accessed October 2025.
25. Cochran, W.G., 1977. Sampling techniques. 3rd ed. New York: John Wiley and Sons. https://www.scribd.com/document/368291518/Cochran-1977-Sampling-Techniques?utm_source=chatgpt.com
26. Yousuf M., *et al*., 2013. Compositional nutrient diagnosis (CND) of onion (Allium cepa L.). *Bangladesh Journal of Agricultural Research*, *38*(2), pp. 271-287. https://doi.org/10.3329/bjar.v38i2.15890
27. Limeneh D.F., 2021. Review on production status of onion seed yield, nutrient uptake and use efficiency of nitrogen and phosphorus fertilizations in Ethiopia. *International Journal of Agriculture Innovations and Research*, *9* (5), pp. 2319-1473. https://www.ijair.org/administrator/components/com_jresearch/files/publications/IJAIR_3319_FINAL.pdf
28. Yeshiwas, Y., Alemayehu, M. and Adgo, E., 2023. The rise and fall of onion production: Its multiple constraints on pre-harvest and post-harvest management issues along the supply chain in Northwest Ethiopia. *Heliyon*, *9*(5), pp. 1-26. https://doi.org/10.1016/j.heliyon.2023.e15905.

29. Aragie E., Alemayehu M., and Abate A., 2023. Influences of Seedling Age and Variety on the Growth and Bulb Yield of Onion in Northwest Ethiopia. *International Journal of Agronomy*, *2023* (1), p. 9132446. https://doi.org/10.1155/2023/9132446
30. Zegeye, M.B., Alemu, T.A., Sisay, M.A., Mulaw, S.G. and Abate, T.W.**,** 2024. Factors affecting onion production: An empirical study in the Raya Kobo district, Amhara Regional State, Ethiopia. *PLOS ONE*, *19*(6), e0305134. https://doi.org/10.1371/journal.pone.0305134.
31. Rogers, M. and Tseng, Y.-P., 2000. Analyzing firm-level labor productivity using survey data. Melbourne Institute Working Paper No. 20/00. Melbourne: *University of Melbourne*. https://ideas.repec.org/p/iae/iaewps/wp2000n10.html
32. Griffin, R.C., Montgomery, J.M. and Rister, M.E., 1987. Selecting functional form in production function analysis. *Western Journal of Agricultural Economics*, *12*(2), pp.216-227.
33. Abrahim, A., Alamerie, K. and Ademe, A., 2021. Determinants of onion marketed among smallholder producers in Gemechis District, West Hararghe Zone, Oromia National Regional State of Ethiopia. *International Journal of Agricultural Economics*, *6*(6), p.305. https://doi.org/10.11648/j.ijae.20210606.18
34. Gujarati, D. N., and Porter, D. C., 2009. Basic Econometrics (5th ed.). McGraw-Hill/Irwin.
35. Wooldridge, J. M., 2016. *Introductory Econometrics*: A Modern Approach (6th ed.). Cengage Learning. https://www.kufunda.net/publicdocs/Wooldridge-Introductory-Econometrics_-A-Modern-Approach-6th-Edition-c2016.pdf
36. Field, A., 2018. Discovering Statistics Using IBM SPSS Statistics (5th ed.). Sage Publications. Fungicide Resistance Action Committee (FRAC), 2020. FRAC Code List 2020: Fungicides sorted by mode of action. https://www.frac.info/
37. Samuel, G., 2013. Helping small farmers to commercialize: Evidence from growing onion and tomatoes for sale in central Ethiopia. *Future Agricultures Consortium Research Update.* https://www.future-agricultures.org. Accessed December 2024.
38. Regasa M., G., Negash, R., Bekele, A. E., and Nemera, D. B., 2020. Smallholder market participation and its associated factors: Evidence from Ethiopian vegetable producers. *Cogent Food & Agriculture*, *6*(1), pp. 1-15. https://doi.org/10.1080/23311932.2020.1783173
39. Aliyi, K., Tadesse, F. and Mohammed, W., 2016. Participatory evaluation and selection of onion (Allium cepa L.) varieties in the Central Rift Valley of Ethiopia. *African Journal of Agricultural Research*, *11*(14), pp.1245-1250. https://doi.org/10.5897/AJAR2015.10663.
40. MoANR (Ministry of Agriculture and Natural Resources), 2017. Horticulture development strategy for Ethiopia: 2016-2025. Ministry of Agriculture and Natural Resources, Addis Ababa, Ethiopia. https://www.scribd.com/document/698636962/National-Horticulture-Development-and-Marketing-Strategy-FINAL-English-VERSION-1-Com.

41. Mulesa, T. H., Dalle, S. P., Makate, C., Haug, R., and Westengen, O. T., 2021. Pluralistic seed system development: a path to seed security? Agronomy, *11*, p.372. http://doi.org/10.3390/agronomy11020372
42. Westengen, O. T., Haug, R., Guthiga, P., and Macharia, E., 2019. Governing seeds in East Africa in the face of climate change: assessing political and social outcomes. Front. Sustain. *Food Syst., 3*, p. 53. https://doi.org/10.3389/fsufs.2019.00053
43. Food and Agricultural Organization (FAO), 2020. Ethiopia seed sector assessment: Status, challenges and opportunities. Rome: Food and Agriculture Organization of the United Nations. https://www.fao.org/documents/card/en/c/CA7006EN.
44. ADRA; MCs; CRS, 2025. Seed System Security Assessment in Southeast Kasaï and Kasaï-Central Provinces, Democratic Republic of the Congo; Tudienzele, Tudituale, and GAINS Resilience Food Security Activities. Adventist Development and Relief Agency (ADRA), Mercy Corps (MCs), Catholic Relief Services (CRS), Tudienzele, Tudituale, and GAINS Resilience Food Security Activities, p.106. https://fscluster.org/sites/default/files/documents/SSSA%20Kasai%20FINAL%20REPORT%20-%20English_0.pdf (accessed on 18 February 2025).
45. Central Statistical Agency (CSA), 2021. Annual agricultural sample survey for 2020/2021 cropping season: Volume I. Report on area and production of major crops (private peasant holdings, Meher season). Addis Ababa. *CSA*. https://ess.gov.et/agriculture/. Accessed June 2024.
46. Mossie, H., Berhanie, Z. and Alemayehu, G**.,** 2020. Econometric analysis of onion marketed supply in Northwest Ethiopia. *Cogent Food & Agriculture*, *6*(1), pp.1-13. https://doi.org/10.1080/23311932.2020.1733329
47. Teklebrhan, A., Emana, B. and Gebre, G.G., 2020. Factors affecting onion market supply in Medebay Zana district, Tigray Regional State, Northern Ethiopia. *Cogent Food & Agriculture*. https://doi.org/10.1080/23311932.2020.1761025
48. Central Statistical Authority of Ethiopia (CSA), 2011. Agricultural Sample Survey for the cropping season of 2010/2011. Report on Area and Production of Major Crops, vol. I. Private Peasant Holdings, Meher Season. Addis Ababa, Ethiopia. http://www.csa.gov.et/
49. Abera, G., Ibrahim, A.M., Forsido, S.F. and Kuyu, C.G., 2020. Assessment on post-harvest losses of tomato (*Lycopersicon esculentem* Mill.) in selected districts of East Shewa Zone of Ethiopia using a commodity system analysis methodology. *Heliyon*, *6*(4), p.e03749. https://doi.org/10.1016/j.heliyon.2020.e03749
50. Gebremedhin Welu. 2015. Challenges and Opportunities of Seed Multiplication in Eastern Tigray Ethiopia. *Journal of Biology, Agriculture and Healthcare*, *5*(3), p. 42.
51. FAO, 2019. Report on the implementation of farmers' rights. Item 12 of the Provisional Agenda of the 8th session of the Governing Body of ITPGRFA. Retrieved from http://www.fao.org/3/na792en/na792en.pdf
52. Nigussie, Z., Alemayehu, G., Adgo, E., Tewodros, Y. and Freyer, B., 2016. Reasons for acceptance of improved potato varieties by smallholder producers. *International Journal of Vegetable Science*, 22(4), pp.346-352.

53. Abayneh, E., Dechassa, N. and Woldetsadik, K., 2018. Assessment of onion production practices and constraints in the Central Rift Valley of Ethiopia. *Journal of Horticulture*, *5*(2), pp.215-222.
54. Bezu, S. and Holden, S., 2014. Are rural youth in Ethiopia abandoning agriculture? *World Development*, *64*, pp.259-272. https://www.sciencedirect.com/science/article/pii/S0305750X14001727
55. Tefera, E., Young-Bohk, C. and Kwag, S.h., 2019. Role of Cooperatives and Participation of their Members in Agricultural Output Marketing: Empirical Evidence from Hetosa District, Ethiopia. *International Journal of Emerging Trends in Social Sciences*, *5*(1), pp. 1-11. https://doi.org/10.20448/2001.51.1.11
56. Tesfaye, B., and Tiruneh, R., 2020. Onion seed degeneration and yield loss in East Africa. *African Journal of Agricultural Research*, *15*(10), pp.1458-1466.
57. Bachewe, F. N., Berhane, G., Minten, B. and Taffesse, A. S., 2018. Agricultural Transformation in Africa? Assessing the Evidence in Ethiopia. World Development, *105*, pp. 286-298. https://doi.org/10.1016/j.worlddev.2017.05.041
58. McGuire, S. and Sperling, L., 2016. Seed systems smallholder farmers use. *Food Security, 8*(1), pp.179-195. https://doi.org/10.1007/s12571-015-0528-8
59. Westengen, O. T., Okongo, M. A., Onek, L., Berg, T., Upadhyaya, H., Birkeland, S., Kaur Khalsa, S. D., Ring, K. H., Stenseth, N. C. and Brysting, A. K., 2014. Ethnolinguistic structuring of sorghum genetic diversity in Africa and the role of local seed systems. Proceedings of the National Academy of Sciences, *111* (39), pp. 14100-14105. https://doi.org/10.1073/pnas.1401646111
60. Bishaw Z., Struik, P. C. and van Gastel, A. J. G., 2010. Wheat seed system in Ethiopia: farmers' varietal perception, seed sources, and seed management. *Journal of New Seeds*, *11*(4), pp. 281-327. https://doi.org/10.1080/1522886X.2010.518302
61. Wondim, M. T., and Geyo, G. B., 2024. Determinants of commercialization among onion producer households in southern Ethiopia: A double hurdle approach. *Frontiers in Environmental Economics*, *3*, p.11. https://doi.org/10.3389/frevc.2024.1443921
62. Tranmer, M., 2015. Multiple linear regressions (2nd Edition); Cathie Marsha institute Working Paper 2020-01. https://hummedia.manchester.ac.uk/institutes/cmist/archive-publications/working-papers/2020/multiple-linear-regression.pdf
63. Williams, M. N., 2013. Assumptions of multiple linear regressions: Correcting two misconceptions. *Practical Assessment, Research, and Evaluation*, *18*(11), pp. 1-14. https://www.researchgate.net/publication/256980936_Assumptions_of_Multiple_Regression_Correcting_Two_Misconceptions
64. Esmé Stuart, Asrat Asfaw, Patrick Adebola, Norbert Maroya, Alex Edemodu, Tunde Adeosun, ,Robert Asiedu and Conny Almekinders, 2021. Yam seed system characteristics in Nigeria: Local practices, preferences, and the implications for seed system interventions. *Outlook Agriculture*, *50*(4), pp. 455-467. https://doi.org/10.1177/00307270211058209

65. Spielman, D.J. and Smale, M., 2017. Policy options to accelerate variety change in developing countries. *Food Policy*, *66***,** pp.50-62. https://doi.org/10.1016/j.foodpol.2016.09.003
66. Thoreau, C., 2021. Opportunities and constraints to seed sovereignty for organic vegetable farmers in British Columbia. MSc thesis, University of British Columbia. p. 122. https://doi.org/10.14288/1.0406191.
67. Eneyew, A.J.G., 2013. United efforts: The challenges for improved research, extension and education linkages. *Journal of Agricultural Extension and Rural Development*, *1*(1), pp.001-008. https://doi.org/ 10.5897/ERR012.186.
68. Samantha, N.P.G., 2013. Issues in Big Onion Seed Production and Marketing. Hector Kobbekaduwa Agrarian Research and Training Institute (HARTI), Colombo, Sri Lanka.*5*, p. 45. http://sci-opac.lib.cmb.ac.lk/cgi-bin/koha/opac-search.pl?q=an:41126
69. Coomes, O.T., McGuire, S.J., Garine, E., Caillon, S., McKey, D., Demeulenaere, E., Jarvis, D.I., Aistara, G., Barnaud, A., Clouvel, P. and Emperaire, L., 2015. Farmer seed networks make a limited contribution to crop diversity but are key for seed security: a cross-case comparison of seed exchange systems. *Food Policy, 56*, pp.41-52. https://doi.org/10.1016/j.foodpol.2015.07.008
70. Almekinders, C. J. M., Louwaars, N. P. and De Bruijn, G. H., 1994. Local seed systems and their importance for an improved seed supply in developing countries. *Euphytica, 78* (3), pp. 207-216. https://doi.org/10.1007/BF00027519
71. Louwaars, N.P. and de Boef, W.S., 2012. Integrated seed sector development in Africa: A conceptual framework for creating coherence between practices, programs, and policies. *Journal of Crop Improvement, 26*(1), pp.39-59. https://doi.org/10.1080/15427528.2011.611277.
72. Herman de putter, Huib Hengsdijk, Samuel Tufa Roba and Dedefo Abdo Wayyu, 2012. Scoping Study of Horticulture Smallholders Production in the Central Rift Valley of Ethiopia. *Technical Report No. 495*, p. 64. https://edepot.wur.nl/249787. Accessed October 2025.
73. Christinck, A., Diarra, M. and Horneber, G., 2014. Innovations in seed systems: Lessons from the CCRP-funded project "Sustaining Farmer-Managed Seed Initiatives in Mali, Niger, and Burkina Faso". p. 75. https://www.ccrp.org/wp-content/uploads/2020/06/CCRP_SeedSystems_Nov2014.pdf. Accessed March 2026.
74. Wimalasekera, R.J.C., 2015. Role of seed quality in improving crop yields. In: P.B. Anand, ed. Crop production and global environmental issues. Cham: *Springer*, pp.153-168. https://doi.org/10.1007/978-3-319-23162-4_6.
75. McGuire, S. and Sperling, L., 2013. Making seed systems more resilient to stress. *Global Environmental Change*, *23*(3), pp.644-653. https://doi.org/10.1016/j.gloenvcha.2013.02.001.
76. Snyder, K.A., Miththapala, S., Sommer, R. and Braslow, J., 2017. The yield gap: Closing the gap by widening the approach. *Experimental Agriculture*, *53*(3), pp.445-459. https://doi.org/10.1017/S0014479716000508

77. Almekinders, C. J. M., and Louwaars, N. P., 2002. The importance of the farmers' seed systems in a functional national seed sector. *J. New Seeds, 4*, pp. 15-33. http://dx.doi.org/10.1300/J153v04n01_02
78. Sperling, L. and McGuire, S., 2013. Fatal gaps in seed security strategy. *Food Security*, *4* (4), pp. 569-579. http://dx.doi.org/10.1007%2Fs12571-012-0205-0
79. Tabor, G., and Yesuf, M., 2012. Mapping the current knowledge of carrot cultivation in Ethiopia. Technical Report submitted to Carrot Aid, Charlottenlund, Denmark. https://scispace.com/pdf/mapping-the-current-knowledge-of-carrot-cultivation-in-4dtrue13q6.pdf. Accessed February 2026.
80. Bezabih, M. and Hadera, 2007. Agro-biodiversity conservation under an imperfect seed system:the role of Community Seed Banking schemes. *Agricultural Economics, 38* (1), 77-87. https://doi.org/10.1111/j.1574-0862.2007.00283.x
81. Atilaw, A. and Korbu, L., 2011. Recent development in seed systems of Ethiopia. Improving Farmers' access to seed. Seminar paper presented at the Ethiopian Institute of Agricultural Research, Empowering Farmers' Innovation Series no. 1, *EIAR*, pp. 13-30. Addis Ababa, Ethiopia.
82. Gemechu Bekeke, 2010. Formal and informal seed systems of maize in Eastern Wollega. MSc Thesis. Ethiopia: Haramaya University. http://ir.haramaya.edu.et/hru/bitstream/handle/123456789/8192/Belay%20Kassa%20Bereded.pdf?sequence=1&isAllowed=y. Accessed March 2026.
83. Alemu, G. M., 2016. Intellectual property law and food security polices in Ethiopia. In G. Steier and K. K. Patel (Eds.). *International food law and policy*, pp. 1137-1180). Cham, Switzerland: *Springer International Publishing*.
84. Tripp, R. and Louwaars, N.P., 1997. Seed regulation: Choices on the road to reform. *Food Policy, 22*(5), pp.433-446. https://doi.org/10.1016/S0306-9192(97)00033-X
85. Asgele, Kiros, 2025. Evaluating the Adaptability of Hybrid Onions for Yield and Performance Analysis in Northwestern Tigray . *Asian Journal of Research in Agriculture and Forestry, 11*(1), pp. 179-86. https://doi.org/10.9734/ajraf/2025/v11i1374
86. Getachew, B., Azerefegne, F. and Lemma, D., 2013. Hybrid vegetable seed production in Ethiopia: Achievements, challenges, and future directions. Ethiopian Institute of Agricultural Research (EIAR), Addis Ababa, Ethiopia.
87. Rogers, E.M., 2003. Diffusion of innovations. 5th ed. New York: Free Press. https://smhp.psych.ucla.edu/pdfdocs/systemic/rogers%20diffusion.pdf. Accessed March 2026.
88. FAO, 2016. Quality declared seed system. 2nd ed. Rome: *Food and Agriculture Organization* of the United Nations.
89. Brewster, J.L., 2008. Onions and Other Vegetable Alliums 2nd edition (No. 15). CABI. http://dx.doi.org/10.1079/9781845933999.0000. Accessed April 2026.
90. Getachew Diriba, 2020. Agricultural and Rural Transformation in Ethiopia: Obstacles, Triggers and Reform Considerations policy working paper.

91. Rabinowitch H. D. and Currah L., 2002. *Allium* crop science: Recent advances. Wallingford: CABI Publishing, p.585. https://doi.org/10.1079/9780851995106.0000
92. Ashagrie Teshome, Derbew Belew, and Amsalu Nebiyu, 2021. Influence of planting date and bulb size on yield and quality of onion (*Allium cepa* L.) seed production. Cogent Food & Agriculture, 7(1), Pp. 1-14. https://doi.org/10.1080/23311932.2021.1908656
93. Gezahegn Fikre , Awoke Mensa Esrael Gisha, and Zemenu Fentahun, 2023. Determination of appropriate planting time for better seed yield of onion (Allium cepa) varieties at selected districts of Gamo Zone, Southern Ethiopia. *International Journal of Science and Research Archive, 10*(02), pp. 137-142. https://doi.org/10.30574/ijsra.2023.10.2.0901
94. Hirpa, A.; Meuwissen, M.P.M.; Tesfaye, A.; Lommen, W.J.M.; Oude Lansink, A.; Tsegaye, A.; Struik, P.C., 2010. Analysis of seed potato systems in Ethiopia. *American Journal of Potato Research, 87*, pp. 537-552. http://doi.org/10.1007/s12230-010-9164-1
95. Sharma J.P., 2011. Indian vegetable seed Industry: Potential and problems. Quality seed production of vegetable crops technological Interventions, *1*, pp. 60-78.
96. Bewley, J. D., Black, M. and Halmer, P. (eds)., 2006. The encyclopedia of seeds: science, technology and uses. Oxford, UK: Cabi International.
97. Laxman, R.H., Kumar, R., Ramesh, K.V., Saini, D.R., Sreekanth, D., Verma, R.K. and Behera, T.K., 2024. Impact of Climate Change on Vegetable Production and Management Strategies. *Vegetable Science, 51*(special issue), pp. 11-21.
98. Getachew Amare, 2014. Effect of plant spacing and NP fertilizer levels on growth, seed yield and seed quality of onion (Allium cepa Var Cepa) in MSc. Thesis Shewa robit, Northern Ethiopia, p. 66.
99. Nimona Fufa, Fekadu Gebretensay, Dasta Tsagaye, Demis Fikre, Gizaw Wegayehu, and Awoke Ali, 2021. Evaluation of Seed Production and Quality Performance of Onion (Allium Cepa L.) Varieties at Kulumsa in Arsi Zone South East Ethiopia. *Journal of Agriculture and Crops, 7* (1), pp. 33-38. https://doi.org/10.32861/jac.71.33.38
100. Sahoo ,S. K., Chakravorty S., Soren L., Mishra C. and Sahoo B. B., 2017. Effect of weed management on growth and yield of onion (Allium cepa L.). *Journal of Crop and Weed*, *13*(2), pp. 208-211. https://www.academia.edu/download/112189066/13-2-36.pdf. Accessed March 2026.
101. Bhandari G, BN Adhikari, B Bhandari, JB Adhikari, S Kaduwal and P Pokhrel, 2023. Storability of Different Hermetic Containers on Seed Quality Attributes of Maize in Khumaltar, Lalitpur. *Agronomy Journal of Nepal, 7*(1), pp. 36-42. https://doi.org/10.3126/ajn.v7i1.62065
102. Geetanjali C., I.M. Sangeeta, S.M. Prashant, Basavegowda and R.V. Beladhadi, 2019. Effect of storage conditions on seed longevity of onion (*Allium cepa* L.). *International Journal of Current Microbiology and Applied Sciences, 8*(2), pp. 1234-1242. https://doi.org/10.20546/ijcmas.2019.802.221
103. Akter, N., Haque, M., Islam, M., & Alam, K., 2025. Comparative study of onion (*Allium cepa* L.) seed quality in relation to storage containers and duration. *Bangladesh*

Journal of Nutrition and Agriculture, 39(1), pp. 1-10. https://doi.org/10.3329/bjnag.v39i1.83346

104. Thijssen, M.H., Z. Bishaw, A. Beshir and W.S. de Boef, 2008. Farmers, seeds and varieties (Eds.): supporting informal seed supply in Ethiopia. Wageningen, Wageningen International. https://edepot.wur.nl/18448. Accessed December 2025.
105. Alemu, D., Spielman, D.J. and Mekonnen, D.K., 2022. Seed System Development in Ethiopia: Achievements, Challenges, and Future Directions. Washington, D.C.: IFPRI.
106. Priya, N.K., Padhan, S.K.H., Lakra, P.K., Tripathy, P.P., Vamshi, M., Tripathi, S., Shaktawat, P. and Datta, S., 2025. Impact of extension services on knowledge enhancement and adoption of modern onion farming techniques: a review. *Journal of Science Research*, *31*(9), pp.183-201. https://doi.org/10.9734/jsrr/2025/v31i93482
107. Alemayehu, D., Tadesse, A. and Belay, S., 2020. Analysis of seed quality control and certification systems in Ethiopia: Implications for smallholder adoption. *Ethiopian Journal of Agricultural Sciences*, *30*(1), pp.45-62.
108. Ministry of Agriculture (MoA), 2023. National seed sector assessment report. Ministry of Agriculture, Addis Ababa, Ethiopia. https://www.researchgate.net/profile/Dawit-TsegayeSisay/publication/377395995_National_Seed_Sector_Coordination_in_Ethiopia_Status_Challenges_and_Way_Forward/links/65a4041cbc30165e6e380b74/National-Seed-Sector-Coordination-in-Ethiopia-Status-Challenges-and-Way-Forward.pdf
109. Bishaw, Z., Struik, P.C. and van Gastel, A.J.G., 2013. Seed systems and seed quality management in semi-arid tropics of Ethiopia. *International Journal of Plant Production*, *7*(3), pp.405-422. https://doi.org/10.22069/ijpp.2013.949
110. John L. Capinera, 2020. Handbook of vegetable pests (2nd Ed.). Academic Press. https://doi.org/10.1016/C2017-0-01577-X
111. FAO, 2021. Strengthening agricultural market systems. Rome: Food and Agriculture Organization of the United Nations.
112. Free, J.B., 1993. Insect Pollination of Crops. Academic, San Diego.
113. Kumar, R., Rathee, A.K., Dalip, D.K. and Sumit, 2017. Trends and constraints in onion production in Haryana. *Indian Journal of Economy and Development, 13*(2), pp.309-313. http://dx.doi.org/10.5958/2322-0430.2017.00086.5
114. Barrett, C.B., 2008. Smallholder market participation: Concepts and evidence from eastern and southern Africa. *Food Policy*, *33*(4), pp.299-317. https://doi.org/10.1016/j.foodpol.2007.10.005.
115. FAO, 2014. Quality declared seed system: Technical guidelines on standards and procedures. 2nd ed. Rome: Food and Agriculture Organization of the United Nations. https://www.fao.org/3/i8873en/I8873EN.pdf. Accessed November 2025.
116. Farm Africa, 2023. Strengthening agricultural marketing systems. Farm Africa Organization. https://www.farmafrica.org/wp-content/uploads/2024/07/strengthening-agricultural-market-systems.pdf. Accessed January 2026.

117. Abebe, Z., Teshome, T., Woyema, A., Tuli, M., 2020. Integrated Seed Sector Development (ISSD) program in Oromia: Performances and Achievements; Oromia National Regional State: Finfinne, Ethiopia, p. 87.