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Evaluating Seed Security and Varietal Erosion of Finger Millet (Eleusine coracana) in Northern Ethiopia

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***Abstract*—Finger millet (Eleusine coracana) serves as a vital climate-resilient crop for food security in Ethiopia, but smallholder seed systems face severe structural constraints. This study investigated seed management, diversity, and security across three agro-ecologically distinct districts in the Amhara region: Dera, Sekota, and Mecha, using data extracted from 264 randomly sampled households. The empirical findings indicate that finger millet production remains highly labor-intensive, relying entirely on manual operations and traditional knowledge. While post-harvest sorting and cleaning are universally practiced, household labor dynamics exhibit highly significant regional variations. Dera relies heavily on female-driven labor (79.1%), whereas Mecha and Sekota utilize collaborative, family-wide labor models. Although 83% of smallholders actively execute field-level seed selection based on yield and disease resistance, the genetic erosion of local landraces has accelerated significantly over a 15-year period (2009–2023) due to land scarcity, low agricultural productivity, and poor organoleptic traits. Systemic seed insecurity is critically compromised across all study areas, affecting 56.4% to 69.8% of surveyed households. The underlying drivers are highly region-specific: recurrent droughts account for 40.7% of germplasm losses in arid Sekota, while emergency consumption of preserved seed stocks during seasonal food scarcities accounts for 34.9% of losses in Mecha. Crucially, all smallholders lacked physical or chemical post-harvest pest protection measures during storage. To enhance smallholder sustainability, interventions must prioritize deploying ecologically targeted, drought-tolerant, and lodging-resistant varieties; establishing localized, community-based seed banks; and introducing cost-effective hermetic storage options.**

Keywords*—finger millet, Seed security, Varietal loss, Seed selection, Smallholder farmers, Ethiopia

I. Introduction

The finger millet (Eleusine coracana) crop is a natural tetraploid plant that is still central to food security and essential in combating nutritional insecurity in the drought-prone tropics of Ethiopia. The Amhara Region is home to the majority of the country's production, with the three zones of West Gojam, Awi, and Central Gondar accounting for close to 40% of the national yield [5]. Apart from its resistance to climatic variations, finger millet is valued for its superior nutritional composition, which features more calcium and iron content than that of maize. Finger millet is also versatile in making traditional foods like injera, genfo, and tella. Although finger millet grain has high biological value and medicinal properties useful in treating anemia and diabetes, it still falls into the category of an underutilized species (NUS).

The productivity of finger millet in Ethiopia is still critically low, as reflected by the yield range in Amhara Province (531 to 2688 kg/ha), which is much lower than the worldwide potential yield of 5000 kg/ha. This productivity challenge results from the interaction of biotic stresses, particularly blast disease caused by *Magnaporthe grisea*, with fundamental socioeconomic factors. A recent study shows that the limited availability of good seed is among the major challenges. Most farmers depend on landrace seeds that show poor germination, vigor, and disease resistance [7, 18]. In addition, the prevalence of a non-formal seed system involving saving, managing, and exchanging seed through manual practices without any quality checks may lead to genetic deterioration and excessive moisture content during storage, beyond the ideal levels of 8-10%.

Despite extensive literature on the seed systems of other staple crops in Ethiopia, such as teff, sorghum, and maize, finger millet is at a disadvantage due to an identified lack of adequate information concerning the particularities of seed provision processes [12]. Currently, there is a clear disconnect between research-led breeding initiatives and traditional manual methods practiced by farmers. To overcome these inherent weaknesses, it is important to examine the changing dynamics of the formal and informal seed sources in relation to the qualities valued by local populations [3]. This paper seeks to understand the dynamics of finger millet in an effort to create a sustainable, community-based seed system for the crop.

II. Materials And Methods

A. Description of the study District

This research was carried out in three sampled woredas in the Amhara National Regional State, Ethiopia: Dera, located in the South Gondar Zone; Mecha, in the West Gojjam Zone; and

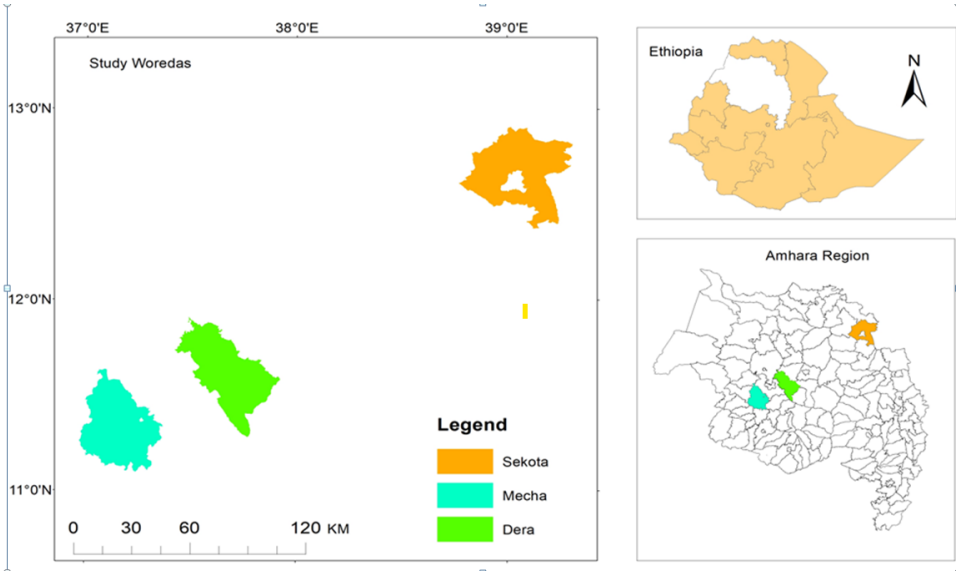


Fig. 1. A location map of the study districts in the Amhara Regional State, Ethiopia

Sekota, in the Waghimra Zone (Fig. I). These woredas were selected purposefully, as they represent major production zones for finger millet in the region.

Dera woreda: This woreda lies within the South Gondar Administrative Zone and is about 35 km west of Bahir Dar. The woreda is well-positioned between the zonal capital, Debre Tabor, and the capital of the Amhara National Region, Bahir Dar (79 km away). The boundaries of this woreda include Lake Tana to the west, Fogera to the north, and the Abbay River to the south, which marks the boundary between Dera and the West Gojjam Zone. Dera woreda experiences a bimodal precipitation pattern; while the first (short) rains occur from March to April, the second (longer) rains fall from June to September. Dera falls under the mid-altitude (Woina Dega) agro-ecological zone, in which maize, teff, and wheat form the major cropping systems along with finger millet [6].

Mecha District: One of the well-known districts of the West Gojjam Zone is the Mecha District, whose headquarters is found 35 km away from Bahir Dar and 530 km from Addis Ababa. The physical attributes of the district are mainly made up of highlands, where 97.1% of the district is categorized as semi-highlands. Among the total areas of the district, a substantial amount of land (107,210 ha) is arable and good for farming activities. It is important to note that the district has the Koga large-scale irrigation dam, which allows irrigation in an area of 7,000 hectares [11]. The crop season in the district starts at the beginning of June and ends in September.

Sekota District: The Sekota district is located within the zone of Waghimra, approximately 120 km from Lalibela and 500 km from Bahir Dar. As opposed to the other study sites, the Sekota district constitutes the dryland area in the Amhara region with only one rainy season (Kiremt) between June and September. The district consists of an area of 53,531 hectares, 49% of which is cultivated. The main activity in this district is farming, which provides the livelihood for over 98% of the inhabitants of the district. There is also diversity in agro-ecology, whereby the district comprises 14 lowland and 11 midland kebeles [13].

B. Maintaining the Integrity of the Specifications

The research was carried out based on the collected data, using the method of multi-stage sampling. Three-stage sampling methods were applied to select study sites and samples of finger millet-growing farmers. Administrations were selected purposively, from high to low. In the first instance, three districts were selected from the Waghimera, South Gondar, and West Gojam zones using a purposive sampling method, based on their finger millet production potential. In the second stage, peasant associations were chosen purposively based on their production potential; specifically, Hamusit and Wal peasant associations were selected from the Sekota district, Wenchit and Geregera peasant associations from the Dera district, and Enamert and Enguti from the Mecha district for the individual household survey. In the last step, several finger millet-growing farmers were selected using a random sampling technique. The number of samples in each peasant association was determined according to their populations within the peasant associations. The sample size in the peasant associations was calculated using the following formula given by [17].

$$N = \frac{N}{1 + N(e)^2} \quad (1)$$

Where n is the sample size, N is the number of total households in the peasant association, and e is the level of precision considered.

The minimum level of acceptable precision is 10%. However, for this study, a 5% precision level was used. Based on official district agricultural office registries, the total finger millet-producing household populations (N) for the selected kebeles were N = 1,515 for Dera (Wenchit

TABLE I. GEOGRAPHICAL DESCRIPTION AND WEATHER DATA OF THE STUDY AREAS

Area	Altitude (masl)	Latitude	Longitude	Annual rainfall (mm)	Annual Temperature (°C)
Mecha	1960	11° 25’ 20″ N	37° 10’ 20″ E	1200–1800	17.5–20.0
Dera	1560–2600	11° 23’ 15″–11° 53’ 30″ N	37° 25’ 45″–37° 54’ 10″ E	1000–1500	13.0–30.0
Sekota	2200	12° 26’ 01″ N	38° 41’ 44.71″ E	400–900	15.0–28.0

TABLE II. NUMBER OF SAMPLED HOUSEHOLDS IN THE STUDY DISTRICT

Study District	Sample size (n)
Dera	110
Mecha	63
Sekota	91
Total	264

and Geregera), N = 1,180 for Sekota (Hamusit and Wal), and N = 785 for Mecha (Enamert and Enguti). Applying the Yamane formula to these institutional population bases yielded corresponding target sample sizes of 110, 91, and 63 households, respectively, ensuring statistical representation (Table II). Furthermore, six focus group discussions were conducted (two per district, with each group consisting of 8 to 12 systematically selected smallholder farmers), as well as individual interviews carried out with eighteen key informants whose knowledge was extensive. The areas, farms, crops, and problems facing the peasant association were discussed. To ensure comprehensive demographic representation, the FGDs were deliberately stratified to include a balanced mix of male and female farmers, spanning young adult smallholders to elderly village leaders recognized for their deep ancestral farming knowledge. Qualitative data from these sessions were transcribed, categorized, and analyzed utilizing inductive thematic analysis to triangulate and explain the quantitative survey patterns.

C. Data Types and Sources

Primarily, the data for this study were collected from primary sources using multiple data-gathering instruments, such as semi-structured household-level surveys and questionnaires. The six focus group discussions and individual interviews were conducted with key informants who had in-depth knowledge about the areas, the farms, crops, local conditions, and problems in the peasant association. Additional information was collected from relevant governmental organizations to back up information captured through individual interviews and group discussions. Enumerators who spoke the local language were recruited and trained. The questionnaire was pre-tested on a few selected samples, and then, based on the results, it was refined. Secondary data was also collected from published and unpublished sources.

D. Data Collection Method

Primary data were collected through focus group discussions and individual interviews on household characteristics (household type, distribution of households by educational status, age, and family size), household resource base characteristics, farmers’ adoption and seed sources, farmers’ agronomic practices and perceptions, contractual seed production practices, partners’ involvement, and coordination.

E. Methods of Data Analysis

Statistical analyses for social data were performed using the SPSS (2012) (Version 21) computer package [8]; relationships were explored through frequencies and descriptive statistics. The Statistical Package for the Social Sciences (SPSS) version 21 was used to code, tabulate, and analyze the data gathered from the field survey. To summarize the socioeconomic traits of the respondents, simple descriptive statistics were utilized to differentiate the mean, percentage, and standard deviation. To determine the significance of variations across the three agro-ecological districts, inferential statistical tools were deployed. Pearson’s chi-square (X^2) tests of independence were performed on categorical variables, including landrace distribution patterns, storage modalities, and seasonal seed security statuses. For continuous variables, such as household labor dynamics, livestock holding sizes (TLU), seeding rates, and crop yields, mean values across the districts were statistically evaluated using a one-way analysis of variance (ANOVA). Statistical significance for all inferential assertions was evaluated at a confidence threshold of $p < 0.05$.

III. RESULTS AND DISCUSSION

A. Socioeconomic and Demographic Attributes of Sampled Households

The socioeconomic and demographic characteristics of the 264 selected smallholder households across the three surveyed districts (Dera, Sekota, and Mecha) fundamentally shape regional finger millet seed management practices and technology adoption frameworks (Table III).

A highly pronounced gender disparity in farm leadership exists across the study areas. Male-Headed Households (MHHs) strongly dominate the sample, representing 84.5% of households in Dera, 94.5% in Sekota, and 100.0% in Mecha. Conversely, Female-Headed Households (FHHs) comprise a minor portion of the sample, restricted to 15.5% in Dera and 5.5% in Sekota, with a complete absence in the Mecha cohort. Pearson’s chi-square test of independence reveals that this unequal cross-district distribution of household headship is statistically significant ($X^2 = 18.34$, $p < 0.01$). This institutional gender imbalance suggests that agricultural decision-making and seed resource channels are predominantly structured around male farmers, signaling potential cultural and systemic constraints regarding the economic empowerment and independent resource access of female farmers in districts like Sekota and Mecha.

The average age of the sampled household heads is approximately 47 years. This demographic placement indicates that the majority of farm managers belong to the economically active population and possess the essential physical capacity required to fulfill the intensive, manpower-driven operations of traditional finger millet production. Family size and

TABLE III. DEMOGRAPHIC CHARACTERISTICS OF THE SAMPLE HOUSEHOLDS (N=264)

Variables	Dera (n=110) % / Mean	Sekota (n=91) % / Mean	Mecha (n=63) % / Mean	Pearson Chi-Square (χ^2, p-value)
Gender Balance				
Male-Headed Households (MHH)	84.5	94.5	100.0	$\chi^2 = 18.34$, $p < 0.01$**
Female-Headed Households (FHH)	15.5	5.5	0.0	(Combined Headship Analysis)
Education Level (%)				
Illiterate	43.60	57.30	0.00	$\chi^2 = 94.18$, $p < 0.001$***
Read and Write	32.70	30.80	65.10	
Formal Primary (Comp/Non-comp)	14.50	3.30	27.00	
Adult Education	8.20	8.80	3.20	

Source: Survey Data, 2023/24. Pearson's chi-square test reveals that the variation in household literacy and formal educational primary completion rates between the three districts is statistically highly significant ($X^2 = 94.18$, df = 6, $p < 0.001$).

composition directly dictate the internal labor supply available for these strenuous manual tasks. Across the study sites, the active agricultural labor pool (household members older than 15 years) varies by district. The average presence of adult female laborers ranges from 1.25 in Sekota to 1.97 in Mecha, while the average number of adult male laborers is tightly distributed between 1.78 and 1.89 per household. In line with traditional labor divisions, elderly family members primarily support field crop operations, while younger children manage livestock herds. Although larger households gain a clear production advantage via expanded labor availability, overall household productivity remains heavily dependent on land-holding sizes and available technology.

Household literacy and formal schooling levels serve as vital catalysts for processing technical information, adopting improved seed varieties, and market integration. The baseline educational status of household heads varies dramatically across the three districts. Mecha displays an exceptionally high literacy profile, with 0.0% illiteracy; instead, 65.10% of its household heads possess basic reading and writing skills, and 27.00% have completed or partially completed formal primary education. In stark contrast, serious structural educational deficits emerge in the remaining regions: the illiteracy rate reaches 43.60% in Dera and peaks at 57.30% in Sekota. Formal primary completion rates fall to just 14.50% in Dera and a critically low 3.30% in Sekota, while participation in adult literacy programs remains limited across all sites (ranging from 3.20% to 8.80%).

Pearson's chi-square test confirms that the observed cross-district variations in illiteracy, basic literacy, and formal primary educational attainment are statistically highly significant ($X^2 = 94.18$, df = 6, $p < 0.001$). Given that higher formal education and literacy correlate positively with the successful adoption of formal seed technologies and commercial market engagement, the severe educational deficits observed in Sekota and Dera present major bottlenecks that may hinder institutional technology transfer and formal agricultural extension efforts in those communities.

B. Abbreviations and Acronyms

The economic resilience and production capacity of smallholder finger millet farmers across the study areas are intrinsically linked to their available resource endowments, land allocation strategies, and accumulated agricultural experience (Table IV). A comprehensive review of household capital bases, crop distribution setups, and agronomic management methods highlights clear regional variations among the Dera, Sekota, and Mecha districts.

During the 2022/2023 cropping season, the sampled smallholders managed a mean cultivated landholding of approximately 1.52 hectares. Land tenure analysis indicates a highly decentralized ownership profile: approximately 74% of the cultivated land is self-owned under state-backed security arrangements, while the remaining 26% is accessed through informal land leasing and sharecropping markets. In the structurally constrained agroecology of the Sekota district, where formal tenant-landlord legal frameworks are largely absent, share farming functions as a critical informal institution. Here, landowners and tenant farmers manage distinct agricultural operations on the same plot without establishing an official business partnership, effectively distributing both the production risks and the final crop returns.

Livestock assets represent a vital pillar of smallholder livelihood security, serving as a primary source of organic manure fertilizer, traction draft power, and household capital diversification. Across the entire sample, average livestock ownership stands at 3.96 Tropical Livestock Units (TLU) per household. However, this endowment varies dramatically by geographic region. Smallholders in the Mecha district maintain the largest herds (6.40 ± 1.99 TLU), outstripping capital levels observed in Dera (3.14 ± 0.80 TLU) and Sekota (2.37 ± 0.74 TLU). A one-way analysis of variance (ANOVA) confirms that these regional differences in livestock holdings are statistically highly significant ($F = 214.36$, $p < 0.001$). The elevated mean and larger standard deviation recorded in Mecha reveal that while smallholders in this zone possess a substantially stronger asset base, wealth distribution within the community is highly stratified.

Human capital, measured via specialized farming experience, shows a similarly robust yet varied distribution. The sampled managers exhibit a deep baseline of indigenous technical knowledge, averaging 26 years of active engagement in finger millet cultivation. This experience peaks in the Mecha district at an average of 30.25 ± 9.88 years, followed by Dera (25.52 ± 11.18 years) and Sekota (23.63 ± 7.98 years); these cross-regional variations are highly significant ($F = 12.82$, $p < 0.001$). This prolonged operational experience directly enhances smallholders' local seed selection capacity and adaptive field management skills, serving as an informal mechanism to stabilize yields during unfavorable seasons.

Land allocation priorities for finger millet reveal distinct regional specialization trends. Smallholders in Dera dedicate the greatest land area specifically to finger millet production (0.67 ha). Conversely, although households in Mecha manage a larger overall land portfolio (allocating up to 1.96 ha to general farming), they prioritize high-input cereals like maize and wheat, relegating finger millet to a secondary crop. In Sekota, agricultural land use is heavily geared toward drought-resilient sorghum and teff setups, which are grown in parallel with finger millet to mitigate the threat of total crop failure.

A critical finding of this study is the statistically significant variation in agronomic seeding rates and corresponding grain productivities across the districts. Smallholders in Dera apply an exceptionally high seeding rate (48.29 ± 15.30 kg/ha), achieving an average grain yield of 1.169 ± 0.458 tons/ha. Farmers in Mecha use a similarly dense seeding rate (40.32 ± 8.12 kg/ha) but generate lower mean productivity of 0.603 ± 0.226 tons/ha. In contrast, Sekota smallholders utilize a conservative seeding rate (18.49 ± 4.79 kg/ha), which yields a data-supported output of 0.689 ± 0.090 tons/ha. One-way ANOVA calculations verify that these geographic variations are highly significant for both seed application rates ($F = 314.15$, $p < 0.001$) and final grain yields ($F = 84.62$, $p < 0.001$). The elevated sowing densities documented in Dera and Mecha represent a deliberate risk-avoidance strategy linked to traditional manual broadcasting methods. This interpretation was explicitly verified during focus group discussions (FGDs), where smallholders explained that high sowing densities function as a practical buffer against poor seed germination and seedling mortality caused by variable seed quality or hard soil crusting. However, descriptive and inferential parameters indicate that this approach triggers severe intraspecific plant competition for soil nutrients and light, which ultimately reduces input efficiency and limits potential yields. Conversely, the resilient performance of the low seeding rate in Sekota highlights how local dryland farming methods have evolved. This approach optimizes the overall plant population relative to low moisture availability. Focus group participants in Sekota confirmed that their low-density broadcasting methods are deliberately adjusted to maximize scarce soil moisture and prevent catastrophic vegetative wilt during early to mid-season dry spells. Ultimately, the highly significant statistical differences observed across these three districts demonstrate that distinct socio-ecological environments are governed by unique local constraints, requiring highly targeted, region-specific agricultural extension interventions rather than uniform policy recommendations.

1) Finger Millet Production and Functional Importance: This is shown in Table V, which presents details of the types of major crops cultivated and the uses of finger millets within the study districts. From the analysis of the growing patterns during the 2022/2023 growing season, it becomes evident that there is variability in agricultural practices within different regions, as well as usage patterns. The Mecha district showed an equal prevalence of finger millets and maize, both making up 27.8% of the total area under cultivation. Here, farmers consider finger millets to have multifunctional value, where both food and income account for 40.3% and 40.9% respectively, and only 18.8% is used for local beverages. On the other hand, drought-resistant crops predominate in the Sekota district. Finger millet and sorghum are the most common, at 27.7% and 26.7%, respectively. Here, finger millet is used solely for food purposes, with 71.7% reporting the need to consume it, while 28.3% report local beverage preparation, and no finger millet is reported as an income source. The Dera district, on the other hand, recorded the highest diversity in terms of cultivation, where finger millet and maize made up 32.1% of the area under cultivation, while teff accounted for 29.2%. It is worth noting that Dera was the only district in which respondents mentioned finger millet straw for livestock feed (2.5%). Overall, the results have clearly indicated that finger millet's importance changes from its subsistence nature, in the form of a food security crop for dry regions such as Sekota, to its commercial nature for higher-potential regions such as Mecha.

1) Finger Millet Farmers' Preferences and Seed Marketing: The economic importance of finger millet can be further elaborated using its market participation and the subjective ranking of crops from the farmers' perspective in all three survey districts (Table VI). The data on market participation, recorded using the mean sale in tons, shows that finger millet acts as a constant source of liquidity for these farmers, although its prominence varies compared to other cereals such as maize and rice. The most active market participation for finger millet is found in the district of Dera, where farmers sold an average of 2.97 tons. Although the highest-earning crop in the district of Dera is maize (6.59 tons), finger millet is one of the key commodities. Likewise, farmers sold an average of 2.28 tons of finger millet in the district of Mecha. However, finger millet had the lowest rate of market participation in the district of Sekota, where farmers sold 0.18 tons on average. Preference rankings of farmers, which take into account the value, significance, and marketability of the crops, also show the importance of finger millet among farmers as a key crop. For instance, farmers in the Dera district all agreed on finger millet being the priority, with 70% of the farmers rating it as such. The dominance of finger millet in this district can be attributed to the fact that it is the most common and widely sold cereal in Dera. Despite the small quantities of finger millet being sold in the Sekota district, 63.7% of the farmers still considered finger millet their first choice. This is indicative of the fact that finger millet in Sekota may not be very marketable but is highly valued as an enduring food source in tough environmental conditions. In the Mecha district, 36.5% of farmers indicated finger millet as their first priority crop, but a bigger number (47.6%) rated maize higher for its market value and high yields. Finger millet remained important in the Mecha district because 46% of the respondents rated it second among their priorities. The disparity in the number of ranks in each of the three study districts depends on the degree of

TABLE IV. COMPARATIVE ANALYSIS OF SMALLHOLDER RESOURCE BASES, AGRONOMIC MANAGEMENT, AND YIELD DYNAMICS ACROSS STUDY DISTRICTS

Parameter / Resource Base	Dera District (Mean ± SD)	Sekota District (Mean ± SD)	Mecha District (Mean ± SD)	ANOVA Test Statistic (F, p-value)
Farming Experience (years)	25.52 ± 11.18	23.63 ± 7.98	30.25 ± 9.88	F = 12.82, p < 0.001***
Livestock Ownership (TLU)	3.14 ± 0.8	2.37 ± 0.74	6.4 ± 1.99	F = 214.36, p < 0.001***
Finger Millet Seed Rate (kg/ha)	48.29 ± 15.3	18.49 ± 4.79	40.32 ± 8.12	F = 314.15, p < 0.001***
Finger Millet Grain Yield (tons/ha)	1.169 ± 0.458	0.689 ± 0.09	0.603 ± 0.226	F = 84.62, p < 0.001***

Source: survey data, 2023/24. Share farming is where two parties (the landowner and share farmer) carry on separate farming businesses on the same area of land without forming a partnership or company. Both parties share the benefits/risks of farming; significance levels evaluated at a confidence threshold of $p < 0.05$ {*} indicate highly significant differences ($p < 0.001$) across the three socio-ecological environments.

TABLE V. FINGER MILLET'S RELEVANCE AND THE TYPE OF CROP GROWN (N = 264)

Type of Crops	Dera District	Sekota District	Mecha District
	Freq (%)	***Freq (%)***	***Freq (%)***
Maize	110 (32.1)	0 (0.0)	63 (27.8)
Finger Millet	110 (32.1)	91 (27.7)	63 (27.8)
Tef	100 (29.2)	65 (19.8)	38 (16.7)
Sorghum	0 (0.0)	88 (26.7)	0 (0.0)
Others (Wheat, Barley, etc.)	23 (6.6)	85 (25.8)	63 (27.7)
Total	343 (100)	329 (100)	227 (100)
Importance of Finger Millet			
Animal Feed	8 (2.5)	0 (0.0)	0 (0.0)
Income Source	77 (25.8)	0 (0.0)	61 (40.9)
Food Consumption	104 (34.9)	91 (71.7)	60 (40.3)
Local Beverage	109 (36.6)	36 (28.3)	28 (18.8)
Total	298 (100)	127 (100)	149 (100)

Survey data 2023/24; Note: Percentages for importance may reflect multiple responses per household; "District-level variation in the functional value of finger millet (e.g., shifts from pure subsistence food security in Sekota to commercialized income generation in Mecha) is highly significant ($X^2 = 112.45$, $df = 6$, $p < 0.001$).

TABLE VI. MEAN SALES (TONS) AND CROP PREFERENCE RANKING BY DISTRICT

Crop Type	Dera District (Mean ± SD)		Sekota District (Mean ± SD)		Mecha District (Mean ± SD)
Maize	6.597 ± 0.511		0.00 ± 0.00		11.82 ± 0.247
Finger Millet	2.968 ± 0.267		0.180 ± 0.029		2.28 ± 0.153
Teff	1.098 ± 0.130		0.030 ± 0.010		0.87 ± 0.099
Rice	1.568 ± 0.426		0.00 ± 0.00		0.00 ± 0.00
Wheat	0.009 ± 0.009		0.070 ± 0.017		3.41 ± 0.275
Crop Preference	***District***	***1st Rank (%)***		***2nd Rank (%)***	***3rd Rank (%)***
Finger Millet	Dera	70.0		21.8	7.3
	Sekota	63.7		20.9	15.4
	Mecha	36.5		46.0	17.5

Source: survey data, 2023/24. The number of ranks varied across the district due to the different respondents growing different numbers of crops and ranking them differently.

diversity in agricultural products, in addition to agro-climatic conditions. It can thus be concluded that the sales and preferences data reveal that finger millet constitutes the most valuable agricultural commodity in Dera and Sekota, while maize holds the top position as a primary economic resource in the Mecha district. Finger millet, therefore, plays a pivotal role in the livelihoods of rural communities, varying from being commercially valuable to vital for survival, depending on the region.

C. *Farmers' Knowledge and Selection Criteria for Finger Millet Varieties*

The finger millet landraces found in Northwestern Ethiopia are maintained through the continued use of traditional finger millet landraces, which are differentiated into varieties based on the color of the seeds they bear: Tikur (black), Kiy (red), and Nechi (white). Results from the survey show that there is very high usage of the local varieties in finger millet cultivation, but the adoption of improved cultivars is quite new and limited to a few areas (Table VII). In the Dera district, the most common variety is Tikur, accounting for 79.1% of households, followed by Kiy (7.3%) and a combination of the two (12.7%). Dera is the most developed district with respect to the adoption of technology; 15.5% of the respondents used the improved Necho variety in the previous growing season, starting in 2012. The Sekota district is the only district depending on informal seed sources; no improved variety usage has been recorded in this district. In the Sekota district, the popular varieties are Tikur (65.9%), Kiy (23.1%), and Nechi (11%).

The farmers' choice of cultivars is affected by numerous environmental, marketing, and consumption considerations.

TABLE VII. DISTRIBUTION OF LOCAL AND IMPROVED FINGER MILLET VARIETIES

Variety Category	Dera (n=110) %	Sekota (n=91) %	Mecha (n=63) %
Local Landraces			
Black (*Tikur*)	79.1	65.9	28.6
Red (*Kiy*)	7.3	23.1	61.9
White (*Nechi*)	0.9	11.0	9.5
Improved Varieties			
Mecha / Necho / Both	12.7	0.0	4.8
Total	100	100	100

TABLE VIII. KEY FARMER SELECTION CRITERIA BY DISTRICT (TOP PRIORITIES)

Rank	Dera	Sekota	Mecha
1	Market Preference (76.4%)	Food Quality (62.3%)	Seed Size (100%)
2	Pest Tolerance (64.5%)	Marketability (62.7%)	Lodging Tolerance (65.0%)
3	*Injera* Quality (49.1%)	Brewing Purpose (63.2%)	Pest Tolerance (46.9%)
4	Yield (61.6%)	Yield (52.5%)	Low Fertility Tolerance (46.2%)

Analysis of the data shows that although all the cultivars are selected based on their productivity, the preferred traits of cultivars differ depending on agro-ecological zones. The Dera district's farmers are mostly concerned about productivity, where Tikur (61.6%) emerges as the favorite variety because of its high productivity potential. Marketability (76.4%), pest resistance (64.5%), and injera quality (49.1%) emerge as key selection criteria in the area (Table VIII). In the Sekota district, characterized by arid land, resilience and home use are major considerations in selecting a suitable cultivar. In Sekota, farmers highly value marketable crops (62.7%), brewing quality (63.2%), and good food crops (62.3%). Tikur emerges as the most preferred variety in the district, with 52.5% preference attributed to its ability to withstand environmental stress. The farmers in the Mecha district are mainly interested in agricultural stability and ease of handling. Lodging tolerance (65.0%) and seed size (100%) emerged as the main selection criteria for selecting the Nechi variety. On the other hand, farmers select Kiy mainly due to high germination (45.4%), uniform maturity (47.8%), and soil fertility tolerance (46.2%).

Adaptability and biological resistance also become very important in varietal selection. The ability to tolerate drought becomes an issue in all research sites, especially Sekota (48.5%) and Mecha (48.1%), due to irregular rainfalls and the risk of manual plant establishment. Likewise, biological resistance also becomes an issue, as pest and disease resistances vary from one region to another; for example, disease resistance is more important in Dera (18.1%) and Sekota (39.7%) compared to Mecha. All these factors prove that developing a general strategy for improving seeds is insufficient. Indigenous farmers' knowledge, which they exhibit by prioritizing certain attributes such as uniform maturation to facilitate the harvesting process and better brewing capacity to meet the demand of the local markets, should be incorporated into official breeding practices.

D. Seed Sources and Access Mechanisms

The ability to produce finger millet sustainably in northwestern Ethiopia is highly influenced by the availability of sources for seeds. The seed procurement process among the farmers is quite sophisticated, involving several means of sourcing the seeds, which include local markets, neighbors, relatives, and government institutions (Table IX). The processes involved include buying, bartering grains for seeds, borrowing, rotating funds, and gifting. Proximity to the sources of the seeds still remains one of the most important factors in determining the varieties adopted. In the case of Dera, the majority (95.5%) of the farmers can source their seeds within a walking distance of two hours from their local Kebele centers, whereas 79% of the farmers from Sekota use their local Kebele centers to source their seeds, with the remaining 20.9% sourcing from other places. Their seeds come from neighboring administrative units. The Mecha district presents a scenario where 27% of the farmers are able to source their seeds within a two-hour distance, in contrast to Dera (93.7%) and Sekota (84.6%).

The mode of seed procurement differs according to the district, depending on the level of integration of the agricultural market and social network. In the case of the Dera district, the social network is very significant. In the case of the Mecha district, survey data revealed a distinct, dual-natured procurement behavior: while 100% of the farmers utilize local markets to buy seed stocks at the start of a planting year (as shown in Table 10), their choice of market varieties is driven heavily by informal farmer-to-farmer commercial networks operating inside those market structures. Specifically, 55.6% of these purchases are sourced from recognized local seed-producing farmers trading within the market, followed by purchases from generic grain traders (39.7%) and direct village neighborhood sharing (20.6%). This finding is consistent with that of [20], who indicated that there exists a complicated seed procurement channel among finger millet growers in Ethiopia.

This preference for informal sources can be attributed to certain advantages that the farmers see in them. For instance, 43.4% of Dera farmers prefer informal sources because it enables them to choose the best possible seeds. In addition, the respondents reported a high degree of institutional trust and a relatively low cost of procurement, at 37.6% and 19%, respectively. These findings corroborate those in [19]; such local seed systems are more sustainable, economical, and geographically closer than other options. During the 2023 cropping season, the significance of farm-saved seeds was apparent, as 75.5% of Dera farmers and 52.7% of Sekota farmers depended on them. As noted [14], the exact seed source has a considerable influence on its physiological quality and, ultimately, the general productivity and vigor of the germinated crops.

E. Seed Systems and Purchasing Dynamics of Finger Millet

Informal mechanisms are prevalent in the study area's finger millet seed industry, where farmers adopt informal mechanisms due to their traditional practices based on gifts, barter systems, and purchases at the village level (Table IX). Informal systems, such as gifts, trade, and purchases from village markets, serve as the main source of agricultural

TABLE IX. DYNAMICS OF SEED ACQUISITION AND PURCHASING BEHAVIORS AMONG FINGER MILLET FARMERS

Variable	Dera (n=110) %	Sekota (n=91) %	Mecha (n=63) %
Initial Source: Families/Relatives	75.5	27.5	30.1
Initial System: Gift/Exchange	89.1	24.2	60.4
2023 Source: Own Saved Seed	75.5	52.7	9.5
Purchasing Status: Yes	39.1	50.5	100.0
Purchase Frequency: Every Year	8.2	60.4	38.1
Main Reason: Replace Old Varieties	3.6	37.4	60.3
Main Reason: No Own Seed	0.9	4.4	100.0
Distance to Seed: < 2 Hours	93.7	84.6	27.0

continuity because they are both affordable and available. Historical trends in access to finger millet seeds show a considerable level of influence from social capital and family ties; for example, in the Dera district, 75.5% of the farmers acquired their initial finger millet seeds either from families or relatives via gift or exchange (89.1%). On the other hand, the Sekota district showed a preference for purchasing, while the Mecha district demonstrated a higher tendency for exchange as a means of acquiring the first seeds, at 60.4%. This pattern is consistent with the results reported by [14] and [15], who note that when formal industries do not satisfy local demands, farmers have to step forward in producing and selling seeds.

In the 2023 season, farm-saved seeds became an important element of the system since 75.5% of Dera farmers and 52.7% of Sekota farmers used their harvested seeds. On the other hand, a remarkable change was observed in Mecha, where 54% of the farmers purchased seeds from the market to meet their demands during the 2023 season. It is important to mention here that access to seeds was limited by locality in two out of three districts; 93.7% and 84.6% of farmers from Dera and Sekota, respectively, traveled up to two hours, while 52.4% from Mecha traveled between three and five hours.

The purchasing patterns and motivations regarding seeds differ significantly among the three regions, indicating their differing degrees of seed security. Farmers in the Mecha region are 100% dependent on the market for seeds due to their total absence of seed saving and their need to replace their existing seeds (60.3%). Farmers in the Sekota region have to replace their seeds regularly, as they buy new seeds every year with the objective of acquiring better cultivars. On the other hand, the Dera region's farmers are the most independent regarding their seeds, as 60.9% of the farmers there do not buy any seeds, and when they do, they do so only very infrequently (once every 3 or more years). When buying seeds, their main objective is replacing their existing seeds (23.6%) to ensure physiological viability and yield consistency.

The divergence between complete market reliance (100% in Mecha) versus independent farm-saved preservation models (75.5% in Dera) demonstrates a highly significant institutional dependency split across districts ($X^2 = 138.64$, $df = 2$, $p < 0.001$)."

TABLE X. WEEDING FREQUENCY, TIMING, AND GROWTH STAGE DISTRIBUTION (N = 264)

Variable	Category	Frequency	Percent (%)
First Weeding Timing	35 Days After Sowing	70	26.5
	Mid-July	91	34.5
	Other (3-4 weeks/August)	103	39.0
Total Frequency	1 Time	43	16.3
	2 Times	215	81.4
	3 Times	6	2.3
Stage of Weeding	Knee Stage	236	48.9
	Vegetative Stage	225	46.6
	Flowering Stage	22	4.6

Source: Own survey data, 2023/24

F. Finger Millet Agronomic Packages and Management Practices

The use of modern agricultural technology and agronomy packages is necessary for ensuring high finger millet production from varying agro-ecological regions (Table X). The study, however, indicates major deficiencies in the utilization of agronomy packages such as improved seed varieties, fertilizers, and weed and pest control measures, especially within the Sekota district. The lack of knowledge of integrated agronomy practices, along with the absence of access to modern varieties of finger millet seed, has led to complete dependence on conventional varieties and traditional methods of cultivation. Most farmers view their soil fertility as either medium or low.

The preparation of the soil in the study areas involves mainly manual labor, and manual plowing is the dominant technique used. In Sekota, 72.5% of the farmers plow their farms two times prior to planting crops. This technique is thought to be the most productive in maintaining the friable state of the soil and in establishing the crop. Others perform one-time or zero plowing because of limitations in manpower and farm size. The sowing of seeds is done entirely (100%) by broadcast seeding, usually between late May and mid-June (65.9%), taking advantage of early rains. Notwithstanding the acknowledged poor soil fertility, the use of fertilizers is constrained by economic reasons, whereby 62.6% and 15.5% of the respondents considered the high cost and limited availability as major obstacles, respectively.

Weed management constitutes an essential yet labor-intensive part of the farming process, with most farmers (81.4%) practicing two weedings to minimize competition during the vulnerable growth periods. The scheduling of the first weeding generally falls within the range of 35 days post-seeding and mid-July, placing significant emphasis on the knee stage (48.9%) and vegetative stage (46.6%) of the crop. There is a noticeable discrepancy between the districts in terms of technological inputs; while 93.6% of the farmers in the Dera district rely on herbicides to aid the hand-weeding process, considerably lowering the amount of effort required, their counterparts in Sekota still rely exclusively on manual effort. Such disparities ultimately arise from a combination of factors, including soil properties, climatic conditions, and the financial capability of the family.

TABLE XI. AGRICULTURAL INFORMATION SOURCES AND SOIL FERTILITY PERCEPTIONS

Variable	Category / Source	Dera (n=110) %	Sekota (n=91) %	Mecha (n=63) %
Information Source	Bureau of Agriculture (BoA)	14.5	0.0	33.3
	Local Traders	11.8	0.0	33.3
	Neighbors / Relatives	8.2	0.0	33.3
Soil Fertility Perception	Good	20.9	0.0	14.3
	Medium	26.4	37.4	49.2
	Low	52.7	62.6	36.5
Fertilizer Usage	Applied Fertilizer	79.1	0.0	11.0
	Reason for Non-Use: High Cost	15.5	62.6	0.0

Source: Survey data, 2023/24, Information source percentages for Mecha refer to the small subset of farmers who actively sought technical packages.

1) Respondents' Information Sources and Soil Fertility Perceptions: Dissemination of agronomical information and the subjectivity of soil evaluation become crucial factors in the acceptance of agronomical packages. Farmers from both study districts have access to a limited number of sources for acquiring information: the Bureau of Agriculture (BoA), local traders, and social connections. Information availability in the Mecha district can be seen as quite balanced among a certain number of households, since all sources contribute equally to awareness concerning improved varieties, fertilizers, and general practices. The BoA is an important center of technological knowledge related to fertilizers (14.5%) and general agronomics (19.1%), whereas local traders act as the main source of knowledge about pesticides (10.9%) and herbicides (11.8%) in the Dera district (Table XI). It should be noted that farmers in both districts are not informed about crop storage at all, and only a few people in Dera receive such information from neighbors. Moreover, perceptions regarding soil fertility play an important role in farming since the majority of the respondents perceive the fertility of their soil to be "low." This is true in Sekota, where 62.6 percent of the farmers perceive their soil as "low," but no farmer considers their soil "good." Likewise, 52.7 percent of Dera and 36.5 percent of Mecha farmers consider there to be a problem with the fertility of their soils. However, there seems to be a wide disparity between soil requirements and input usage because, despite 79.1 percent of the farmers perceiving the need for soil fertility, it is hindered due to its high costs and unavailability. When nutrients are applied, they come either through cooperatives or the market, including both organic and chemical fertilizers.

G. Contractual Seed Production (CSP)

The contract and community seed production programs are also highly specialized, with a clear bias toward maize compared to finger millets. In the Dera district, 82.7% of farmers have been involved in the seed production process of maize within ASE and GSMMCU. In Mecha, 9.5% of farmers were involved in maize community seed production. The farmers showed great interest in the programs based on their potential to get high yields, high-quality seeds, and good compensation. Despite a preference to participate in finger millet community seed production indicated by 55.6% of farmers in the Dera district and 20% of those in the Mecha district, no such programs are available because of the lack of promotional activities from the government and non-governmental agencies. In the Sekota district, there is no awareness at all of community-based seed production, regardless of the crop type. As per [1], Ethiopia's commercial seed production sector is still narrow, thus keeping basic crops like finger millet dependent on manpower and local programs.

TABLE XII. FARMERS' SEED SORTING PRACTICES AND TIMING OF SORTING FROM GRAIN

Variable	**Category**	**Dera (n=110) %**	**Sekota (n=91) %**	**Mecha (n=63) %**
Responsibility	Female farmers only	79.1	39.6	4.8
	Male farmer only	0.0	0.0	33.3
	Both male & female	16.4	60.4	61.9
	Children	0.9	0.0	0.0
	Does not sort	3.6	0.0	0.0
Time of Sorting	During harvesting	0.9	36.3	68.3
	Before harvesting	0.0	0.0	31.7
	Just after threshing	7.3	56.0	0.0
	Just before planting	88.2	7.7	0.0
	Does not sort	3.6	0.0	0.0

Source: Survey data, 2023/24

H. Seed Management and Protection

Post-harvest management is a defining factor in maintaining the physical and physiological quality of finger millet. This process involves a series of manpower-intensive tasks, primarily seed sorting, which ensures that high-quality seeds are separated from common grain to optimize future yields. Seed sorting is a critical task for ensuring high-quality seed production, yet practices vary significantly across the studied districts in terms of gender roles and timing. In the Dera district, seed sorting is predominantly a female-led activity, with 79.1% of households reporting that female farmers bear sole responsibility, and the vast majority (88.2%) perform this task just before planting (Table XII). In contrast, the Sekota and Mecha districts exhibit a more collaborative approach. In Mecha, 61.9% of households involve both male and female farmers, and in Sekota, this figure stands at 60.4%. Timing also differs in these regions. Mecha farmers complete the task mostly during harvesting (68.3%) or at physiological maturity (31.7%), while Sekota farmers primarily utilize the post-threshing phase (56%). These regional variations highlight that while Dera focuses on pre-planting preparation driven by female labor, Sekota and Mecha integrate seed selection into the active harvest cycle through shared household labor.

1) Seed Cleaning Methods and Rationales: Seed cleaning is a post-harvest practice aimed at improving the physical quality of finger millet seeds through the removal of nonviable components from the harvest. According to the results of the study, manual winnowing is the predominant cleaning approach

TABLE XIII. PROPORTION OF FARMERS' SEED CLEANING METHODS AND REASONS FOR CLEANING

Variable	Category	Dera (n=110) %	Sekota (n=91) %	Mecha (n=63) %
Methods	Winnowing	100.0	70.3	60.3
	Sieving	0.0	29.7	12.7
	Both Methods	0.0	0.0	27.0
Reasons	Remove Inert Matter	49.1	82.4	76.2
	Remove Weeds/Other Crops	5.5	17.6	15.9
	Remove Small/Broken Seed	45.4	0.0	7.9

employed in all three surveyed districts, although the exclusiveness of the process differs (Table XIII). All farmers in the Dera district apply manual winnowing only. In addition, some farmers in the Sekota and Mecha districts use supplemental cleaning practices to achieve a higher degree of seed purity: 29.7% of Sekota's farmers resort to sieving, and in Mecha, 27% of the farmers combine winnowing with sieving. The main motivation underlying seed cleaning in all three districts can be attributed to the elimination of inert matter, including soil, stones, and chaff; this motive is most common among Sekota's farmers (82.4%). Apart from that, in Dera and Mecha, respectively, 45.4% and 7.9% of farmers clean their seeds to get rid of small and broken seeds, but this motive does not apply to Sekota's farmers. On the other hand, weed removal is much more common among farmers in Sekota (17.6%) and Mecha (15.9%) than among Dera's farmers (5.5%).

1) Seed Replacement Practices and Sources: Replacing seeds is a strategy adopted by farmers to increase crop productivity, replenish old stocks, and change their preferences according to market dynamics (Table XIV). From the findings in the research, there was a lot of variation in replacement among the districts, especially Sekota. In Sekota, almost all the farms practiced replacing old seeds because the seed replacement rate in this district was 80.2%. On the other hand, the Dera district had the lowest rate of seed replacement; 70% of the farmers did not replace their seeds. Consequently, the practice might bring about decreased yields as well as vulnerability to diseases and pests. Reasons behind the process include either quality problems with current seeds or specific varietal traits. In Dera, the major factor leading to seed replacement is poor seed quality (61.7%), whereas farmers in Mecha usually decide to replace based on the quality of the final product (injera, 13.3%). As a result, there would be differences in replacement varieties; for example, in Dera, there is a pattern of replacing red millet with black (53.7%), while farmers in Mecha replace white with red (41.8%) and red with black (48.4%). As far as the supply chain is concerned, formal markets contribute little to the seed replacement process in all the locations examined. Farmers tend to make extensive use of the informal community systems to replace their seeds, obtaining them mainly from fellow farmers at 16.4% for Dera and 41% for Sekota. While this reflects the robustness of seed exchange systems within communities, it also speaks to the development challenges faced by the formal system of seed replacement processes.

TABLE XIV. ANALYSIS OF SEED REPLACEMENT PRACTICES AND SOURCING (N=264)

Variable	Category	Dera (%)	Sekota (%)	Mecha (%)
Replace Seeds?	Yes	30.0	80.2	59.3
	No	70.0	19.8	30.7
Primary Reason	No own-quality seed	61.7	38.4	25.0
	Replace the old variety	14.9	34.2	28.3
	High quality of Injera	2.1	0.0	13.3
Major Variety Shift	Red by Black	53.7	16.0	48.4
	White by Red	2.4	10.0	41.8
Primary Seed Source	Other Farmers	16.4	41.0	7.3
	Market	0.9	1.8	0.9

*Note: 30.7% for Mecha reflects the "No" response for the categorized sample. "The practice of replacing old seed batches versus holding onto them over generations differs significantly by region ($X2 = 48.72$, $df = 2$, $p < 0.001$), putting Dera at a higher descriptive vulnerability to genetic stagnation."

I. Respondents' Perception of Good Seed Traits

It is necessary to emphasize that farmers' preferences for specific seed qualities are an important requirement for the acceptance of new varieties (Table XV). As the results of the survey show, five characteristics of finger millet are more important to farmers: high yield (17.2%), disease resistance (15.3%), drought resistance (8.7%), low fertility tolerance (8.7%), and marketability (8.0%). The results obtained indicate that farmers are concerned about biological stability and productivity to secure their families' lives and livelihoods.

However, the specific characteristics that are important for farmers differ between districts. In particular, in the Dera district, the main emphasis was placed on such aspects as lodging tolerance (12.7%) and tillering capacity (9.1%), as well as disease resistance and marketability. Apparently, in the region, farmers are focused on achieving maximum yield, which requires taking into consideration soil conditions that can be unfavorable for tall crops. Meanwhile, the Sekota district has a different situation: the environmental resilience of the crop is prioritized. Thus, farmers pay most attention to drought resistance (20.2%) and low fertility tolerance (20.2%), as well as insect resistance and seed color.

These variations reveal the inadequacy of a blanket solution for seed distribution. Even though obtaining high yields is still the overall objective for all, additional characteristics like drought resistance in Sekota and lodging resistance in Dera suggest the requirement for site-specific measures. It is important to be aware of these characteristics so that appropriate varieties can be developed by plant breeders and distributed by agricultural offices.

J. Seed Storage and Protection

The issue of storage techniques is an integral part of seed safety, as it ensures the longevity and viability of finger millets, both for consumption and for future planting seasons. As can be observed from the table, there is a clear distinction in relation to the preferred storage technology, depending on the location (Table XVI).

TABLE XV. RANKING OF IMPORTANT CHARACTERISTICS FOR HIGH-QUALITY FINGER MILLET SEEDS

Rank	Seed Characteristic	Frequency	Percent (%)
1	High Yielding	189	17.2
2	Disease Resistance	168	15.3
3	Drought Resistance	96	8.7
4	Low Fertility Tolerance	95	8.7
5	Marketability	88	8.0
6	Large Seed Size	77	7.1
7	Seed Color	67	6.1
8	Insect Resistance	64	5.8
9	High Straw Yield	61	5.6
10	High Tillering Capacity	50	4.6

TABLE XVI. FARMERS' STORAGE METHODS AND PROTECTION MEASURES FOR GRAIN AND SEEDS

Variable	Category	Dera (%)	Sekota (%)	Mecha (%)
Grain Storage Method	Sacks in the house	1.8	100.0	49.2
	Dibignit (*Gotera*) in-house	97.3	0.0	41.3
	Underground pit	0.9	0.0	0.0
Seed Storage Method	Sacks in the house	9.1	100.0	54.0
	Dibignit (*Gotera*) in-house	90.0	0.0	31.8
	Dibignit (*Gotera*) outside	0.0	0.0	9.5
Protection Measures	No measure taken	100.0	100.0	100.0

While the farmers in the Dera district are highly reliant on the traditional technique, using a *dibignit* (gotera), which is located in their houses in 97.3% and 90% of cases, respectively, to store grain and seeds, Sekota shows a complete dependence on standard, modernized technology; all farmers (100%) in the dryland store grain and seeds in sacks at home. In other words, the arid nature of Sekota requires a different approach to storage, one that seems to involve using sacks. Finally, in the case of the Mecha district, almost half of the farmers rely on sacks (49.2% and 54% for grain and seeds, respectively), while the other half continues to depend on the traditional technique of storing grain in *dibignits* inside their houses (41.3%).

The most evident feature in all three districts Dera, Sekota, and Mecha is that there is no protection against storage pests at all for spikes, seeds, and grains. All farmers in the sample (100%) mentioned that they had done nothing in terms of pest control and environmental management, such as moisture protection. Despite the fact that this inactivity may be associated with a lack of knowledge or finances, this can also be explained by the fact that this crop is highly resistant. Nevertheless, total reliance on the resistance feature of this crop may lead to problems with food security in the long term. Although finger millet is indeed very resistant, it should also be taken into account that there is no additional technology available to improve this situation.

K. Seed Diversity, Management, and Varietal Loss

The decline in the genetic diversity of finger millet varieties is an issue that has raised concern in all the study districts, with many farmers opting out of their indigenous finger millet varieties for more hardy cultivars or alternative crops. There are various factors behind this trend (Table XVII).

TABLE XVII. COMPARATIVE ANALYSIS OF VARIETAL ABANDONMENT (2009–2023)

Variable	Category	Dera (%)	Sekota (%)	Mecha (%)
Historical Loss (2009–2013)	Top Variety Abandoned	Necho (50.0)	Red (54.2)	Red (46.2)
	Secondary Variety	White (25.0)	White (45.8)	Black (30.8)
	Primary Reason	Low Yield (40.0)	Land size (43.3)	Accidental Loss (53.8)
	Secondary Reason	Low Fertility (20.0)	Low Yield (41.1)	Low Fertility (46.2)
Recent Loss (2019–2023)	Top Variety Abandoned	White (77.8)	White (46.4)	White (50.0)
	Secondary Variety	Necho/Black (22.2)	Red (45.2)	Black (50.0)
	Primary Reason	Low Yield (21.7)	Low Yield (42.5)	Low Yield (66.7)
	Secondary Reason	Injera Quality (17.4)	Land size (42.5)	Accidental Loss (23.8)

1) Historical Varietal Abandonment (2009–2013): During the period between 2009 and 2013, there was an enormous reduction in the number of traditional cultivars in the Sekota district, where farmers stopped cultivating red by 77 and white by 65. In the Sekota district, the main reasons were low productivity (41.1%) and the critical deficiency of land size (43.3%) that compelled them to shift to high-value crops. In Dera, the reduction in numbers was not too high; however, farmers have abandoned different types of cultivars, including Necho, Mecha, and White, mainly because of lodging problems and poor fertility.

2) Recent Trends in Varietal Loss (2019–2023): However, the practice of varietal abandonment has been on the increase from 2019 to 2023. In the Sekota District, varietal abandonment has become almost common, with 84.6% and 82.4% of farmers abandoning white and red varietal finger millet, respectively. The FGD showed that farmers have started giving priority to other crops other than finger millet because its yield was low (42.5%) and the shortage of farming land was high (42.5%). On the other hand, in the Dera District, varietal abandonment has become multidimensional, since the farmers stated some biological reasons like disease and low straw yield, each at 13%, in addition to the low quality of "Injera" and brewing as well as low market demand, 17.4% and 13%, respectively. This suggests not only competition for land among crops but also a failure to meet the new standards of the market. Finally, in Mecha District, low seed yield was the major cause of varietal abandonment (66.7%) for white and black varietals. Conclusively, the reduction in finger millet farming reflects a rather dangerous trend as far as regional biodiversity is concerned. Finger millets would be completely wiped out from the face of the earth without appropriate actions to promote their benefits and improve their resistance to diseases and pests.

"Pearson's chi-square tests of independence confirm that the historical and recent distribution patterns of landrace loss

and abandonment drivers vary significantly based on regional agro-ecological constraints ($X^2 = 67.31$, df = 4, $p < 0.001$)."

L. Seed Security

Seed security stands out as one of the key pillars of sustainable agriculture through the availability and accessibility of the needed high-quality seeds. When these aspects are not present, the affected individuals experience seed insecurity, whether acute as a result of a particular disaster or chronic due to poverty or dysfunctional seed systems. According to this study, many households in the sampled districts experience chronic seed insecurity as they have difficulty accessing seeds (Table XVIII). This is evident from the findings in the Dera district, where the percentage of farmers experiencing seed insecurity stood at 56.4%, while 31.8% experienced annual seed insecurity. The case was similar in the Sekota district, where 56% and 46.2% of farmers faced chronic and annual seed insecurities, respectively. The Mecha district had the highest level of seed insecurity at 69.8%, with 38.1% experiencing annual and 31.7% biennial seed insecurities.

The causes of insecurity are highly dependent on the type of agro-ecological zones. In Sekota, the dominant cause of the insecurity (40.7%) is drought, since the climatic shocks in the arid environment result in the complete loss of the crop. In Mecha, the primary causes of the insecurity are consumption (34.9%) and production shortage (15.9%), where households have to consume their planted crops due to insufficient food. The third cause is disease (9.5%). On the other hand, in Dera, the major barriers to seed production are inadequate seed production (29%) and consumption (16.4%). Manpower-based yields cannot cater to both household consumption and seed production needs.

In order to minimize these risks, farmers have suggested that they adopt improved variety selection (13.6% in Dera and 20.6% in Mecha). Moreover, agronomic and pest management measures could significantly help farmers (27.5% in Sekota and 20.6% in Mecha). In Dera, 20% of farmers also recommended that farmers be compelled to separate the grains from the seeds harvested, which would improve their security. Increased seed production is the major way to ensure security. Ultimately, for farmers to achieve adequate seed security, it is important for them to make sure that seeds are physically and genetically sound.

TABLE XVIII. FARMERS' SEED SECURITY STATUS AND MITIGATION SUGGESTIONS

Variable	Category	Dera (%)	Sekota (%)	Mecha (%)
Secured for 2024/25?	Yes	43.6	44.0	30.2
	No	56.4	56.0	69.8
Frequency of Insecurity	Every Year	31.8	46.2	38.1
	Every Other Year	12.7	3.3	31.7
Primary Reason for Loss	Drought	0.9	40.7	3.2
	Consumption	16.4	7.7	34.9
	Insufficient Production	29.0	7.7	15.9
Top Suggestion	Better Management	13.7	27.5	20.6
	Change Varieties	13.6	3.3	20.6
	Seed/Grain Separation	20.0	0.0	7.9

IV. CONCLUSION AND RECOMMENDATIONS

This study demonstrates that finger millet cultivation in Northwestern Ethiopia remains highly labor-intensive, relying entirely on traditional manual practices and localized, informal seed networks. While smallholders exhibit deep indigenous knowledge of quality seed traits, with 83% conducting deliberate field-level selection, the formal seed sector continues to underserve this crop, leaving production systems severely threatened by rapid varietal erosion and systemic seed insecurity. Valuable local landraces are systematically abandoned due to land scarcity and low productivity, while over half of the surveyed households face chronic seed shortages caused by climate shocks like drought in Sekota or seasonal food scarcity and emergency grain consumption in Mecha. This vulnerability is further worsened by a universal lack of physical or chemical post-harvest pest protection during storage.

To transition from unstable, informal networks to sustainable seed systems, agricultural extension services and regional seed enterprises must prioritize site-specific, ecologically targeted interventions. Formal breeding programs should focus on multiplying and releasing high-yielding finger millet varieties with distinct localized traits, specifically drought tolerance for the drylands of Sekota and lodging resistance for the high-density broadcasting systems of Dera. To halt ongoing genetic erosion and eliminate post-harvest losses, localized community-based seed banks should be established within a two-hour walking distance, and low-cost hermetic storage options must be introduced, prioritizing initial scaling in the Mecha district, where smallholders possess a stronger asset base. Finally, institutional contract seed production frameworks must be expanded beyond dominant staples like maize to underutilized crops like finger millet to enhance formal regional seed availability.

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References

[1] Abebe Atilaw and Lijalem Korbu. 2011. Recent Development in Seed Systems of Ethiopia: Empowering Farmers' Innovation - Improving Farmers. Pro c. International Conference, SSS, Ethiopia, PP. 1–93.

[2] Benyam Tadesse, Yaregal Tilahun, Tilahun Bekele, and Getachew Mekonen. 2021. Assessment of challenges of crop production and marketing in Bench-Sheko, Kaffa, Sheka, and West-Omo zones of southwest Ethiopia. Heli. 7: 1–14.

[3] Beyene Tadele, Sileshi Bekele, and Desta Mulugeta. 2024. Challenges in accessing high-quality finger millet seeds in Ethiopia: A survey of farmers' seed systems in Amhara Region. Agri. Sys. 179: 101-109.

[4] Birhanu Alemu, Tadesse Assefa, and Dawit Endale. 2022. Assessing seed quality in the informal seed system: A case study of finger millet in the Amhara region of Ethiopia. Ethiopian. J. Agri. Sci. 40: 285-298.

[5] CSA (Central Statistical Agency). 2019. Agricultural sample survey report on area and production for major crops (private peasant holdings, meher season): The Federal Democratic Republic of Ethiopia. Statistical Bulletin, 583. Addis Ababa, Ethiopia.

[6] DWAO (Dera Worda Agricultural Office). 2023. Annual report of agriculture during the 2023/24 Meher season.

[7] Getachew Mulugeta, Tsegaye Fikre, and Mesfin Getahun. 2023. Seed purity and its impact on the productivity of drought-tolerant crops in Ethiopia. I. J. Crop. Sci. 14: 89-100.

[8] IBM (International Business Machines Corporation and Subsidiary Company). 2012. IBM SPSS Statistics for Windows, version 21. Armonk, NY, IBM Corp.

[9] Mekonnen Duressa, and Abdi Bonso, A. B. 2022. Popularization of Finger Millet Production, Value Addition, and Marketing in Wayu Tuka Wereda, East Wollega Zone. Mod. Phyto. 16: 83–92.

[10] Menale Kassie, Hailemariam Teklewold, Paswel Marenya, Moti Jaleta, and Olaf Erenstein. 2015. Production risks and food security under alternative technology choices in Malawi: Application of a multinomial endogenous switching regression. J. Agri c. Econ. 66: 640-659.

[11] Merawi Government Communication Town. 2019. North Mecha Woreda and Merawi Town, 2019 to 2030, West Gojjam Zone, Amhara National Regional State. Merawi.

[12] Mesfin Tesfaye and Gebremedhin Alemayehu. 2023. Strengthening informal seed systems: A way forward for improving finger millet productivity in the Amhara region. Agri. Res. Dev. J. 20: 42-49.

[13] SWAO (Sekota Worda Agricultural Office). 2023. Annual report of agriculture during the 2023/24 Meher season.

[14] Taju Mohammednur and Tesfaye Megersa. 2021. Seed system analysis of soybean, Glycine max L. Merril, in SouthWestern Ethiopia. Sci. Publ. Gro. 1: 19–25.

[15] Tekeste Kifle. 2023. Seed Systems, Adoption, and Impact of Improved Crop Varieties on Household Food Security in Central Ethiopia, https://etd.aau.edu.et/items/50199ef7-1608-498b-b890-27de68c89968, retrieved on 19 March 2024.

[16] Wossen Tarekegne, Firew Mekbib, and Yigzaw Dessalegn. 2021. Farmers ' Finger Millet [Eleusine coracana (L..) Gaertn] Seed Management Practices in J. Agri c. Environ. Sci. 6: 1–8.

[17] Yamane, Taro. 1967. Statistics, an Introductory Analysis, 2nd Edition, Harper and Row, New York, 1967—919 pp.

[18] Yenus Ali, Firew Mekibib, and Zewdie Bishaw. 2021. Seed Quality Analysis of Field Pea (Pisum Sativum L.) from Formal and Informal Sources in Enarj Enawuga and Yilmana Densa Districts, West Amhara Region, Ethiopia. Int. J. Agric. Sci. Food. Tech. 7: 1-13.

[19] Dejen Bekis Fentie (2021). Status of Seed System in Ethiopia. Adv Crop Sci Tech 9:4:469.

[20] Gebreyohannes, A., Shimelis, H., Laing, M., Mathew, I., Odeny, D. A., & Ojulong, H. (2023). Correction: Gebreyohannes et al. Finger Millet Production in Ethiopia: Opportunities, Problem Diagnosis, Key Challenges, and Recommendations for Breeding. Sustainability 2021, 13, 13463. Sustainability, 15(15), 11650. https://doi.org/10.3390/su151511650