Agriculture, Forestry and Fisheries
2024, Vol. 13, No. 4, pp. 116-125
https://doi.org/10.11648/j.aff.20241304.13

Research Article

Empowering Smallholder Sorghum Farmers for Resilience: Lessons from a Community-Based Seed Multiplication Scheme in West Hararghe, Ethiopia

Solomon Zewdu Altaye[1, *], Habte Nida[2], Derara Sori[2], Temesgen Begna[1], Temesgen Teressa[1], Hailu Gichile[1], Ashenafi Getahun[1], Muktar Mohammed[3]

[1]Chiro National Sorghum Research and Training Center, Ethiopian Institute of Agricultural Research, Chiro, Ethiopia
[2]Melkassa Agricultural Research Center, Ethiopian Institute of Agricultural Research, Adama, Ethiopia
[3]Faculty of Agriculture and Forestry, Oda-Bultum University, Chiro, Ethiopia

Abstract

Sorghum is a vital crop for food security in Ethiopia. Sorghum landraces are particularly crucial in crop-livestock mixed farming, however, the extended growing periods (6-8 months) required for these landraces make the crop vulnerable to recurrent drought events associated with delayed rain, dry spells, and drought during critical stages. The landraces are usually planted in March or April depending on the onset of rainfall and harvested around November but often fail due to drought. In such situations, early-maturing improved varieties are an option for farmers but access to seeds of these improved varieties is a challenge. Unlike the landraces, the improved early maturing varieties are planted around the first weeks of July and harvested in November. The formal seed system multiplies only a limited amount of improved sorghum seed, which is rarely available to smallholder sorghum growers, mostly as part of a government package for targeted programs. Therefore, a community-based seed multiplication (CBSM) scheme was introduced to address seed shortages among smallholder sorghum farmers. After a successful experiment in 2015 aimed at enhancing seed multiplication by smallholder sorghum farmers, the process was further implemented on a larger scale using the CBSM scheme. Between 2016 and 2017, three CBSM farmer groups consisting of a total of 56 participants were established in three districts of West Hararghe, Ethiopia. Seeds of two early-maturing and drought-tolerant improved sorghum varieties (Dekeba and Melkam) were multiplied on a total area of 49.58 hectares, resulting in 215.6 tons of certified seeds. The study's findings indicate that the CBSM scheme enhanced smallholder farmers' sorghum yields, incomes, and climate resilience by providing high-quality seeds, expanding access to improved seeds, improving crop quality, and empowering communities to manage seed distribution. Partnerships with local organizations and government agencies were vital for success, allowing the scheme to reach more farmers in different regions. The scheme proved successful for smallholder sorghum growers in Ethiopia's dry lowlands, offering lessons applicable to similar challenges elsewhere, and promoting sustainable solutions for smallholder farmers.

Keywords

Improved Sorghum Seed, Seed Security, Drought-Tolerant, Climate Resilience, Sustainable Agriculture, West-Hararghe, Ethiopia

[*]Corresponding author: szaltaye@gmail.com (Solomon Zewdu Altaye)

Received: 17 June 2024; **Accepted:** 4 July 2024; **Published:** 15 July 2024

1. Introduction

Sorghum is a crucial crop in Ethiopia, covering 1.89 million hectares and producing 5.17 million tons of grain [1]. It is essential for food security and is used for various purposes such as food, feed, fuel, and construction materials [2, 3]. Yet, sorghum production faces a major risk from drought stress [4-6], affecting 66% of sorghum-growing regions in Ethiopia with frequent droughts [7]. Drought stress can significantly reduce yields during various growth stages, with reductions of 36% during the vegetative stage and 55% during the reproductive stage [8], with the grain-filling stage being the most impacted [9].

Although traditional sorghum landraces are crucial in mixed crop-livestock farming systems, their longer growing periods of 6-8 months make them vulnerable to frequent drought events caused by delayed rain, dry spells, and drought during critical stages [10]. Farmers in the dry lowlands traditionally plant late-maturing landraces in March or April after a few rain showers, and harvest in November. Nonetheless, dry spells commonly occur around May and June that limit production of the landraces, and often lead to complete crop failure. Under such circumstances, early-maturing improved varieties are an option for farmers, but access to seeds of these improved varieties is a challenge. Unlike the late-maturing landraces, the improved early-maturing varieties are planted around the first weeks of July and harvested around the same time as the landraces but often flower and mature earlier than the landraces. Therefore, efforts are needed to increase access to improved sorghum seeds to enhance food security, increase income, and reduce poverty in such vulnerable production systems [11].

The seed system in Ethiopia plays a critical role in providing smallholder farmers with access to high-quality improved seeds that can increase productivity, income, food security, and resilience [12, 13]. It consists of both formal and informal systems, with the formal system mainly run by public organizations focusing on major crops like cereals and pulses [14, 15]. However, the formal system often falls short of meeting the demand for quality seeds [16-18], leading to a reliance on the informal seed system [19-21], which is based on farmers' production, exchange, and saving of seeds, mostly of local and traditional varieties [22]. Less than 20% of seeds used by farmers in Ethiopia come from the formal system [23]. The formal seed system multiplies a limited amount of sorghum seeds, which are rarely available to smallholder sorghum growers, mostly as part of government packages for targeted programs. As a result, the informal seed system supports over 90% of sorghum seed used by smallholder farmers in the study area [24, 25]. To address these challenges, initiatives like community-based seed multiplication (CBSM) have been implemented [12, 13, 22]. CBSM allows farmers to produce and access quality seeds, empowering them to participate in seed production and marketing [26]. This approach not only improves crop yields and climate resilience [15, 16] but also creates opportunities for farmers to generate additional income [26, 27]. Successful CBSM schemes in Kenya, Malawi, and Tanzania have shown the potential of this approach as a viable alternative to formal seed systems [28], with the potential to establish a more efficient, inclusive, and sustainable sorghum seed system in Ethiopia.

In the present study, the Chiro and Melkassa research centers in Ethiopia's National Sorghum Research Program are targeting seed insecurity among smallholder sorghum farmers by using a CBSM scheme to address early maturing sorghum (Melkam and Dekeba) seed insecurity. The study's findings indicate that this scheme is a feasible option for smallholder and subsistence sorghum growers in the dry lowlands of Ethiopia, enhancing seed availability, incomes, and climate resilience. Moreover, by promoting early-maturing and drought-tolerant sorghum genotypes with seed access, the scheme helped farmers adapt to climate challenges through a late-sowing strategy, offering valuable insights for policymakers and sorghum farmers.

2. Materials and Methods

2.1. Description of the Study Areas

West Hararghe Zone in Ethiopia (Figure 1) covers 1,723,145 hectares and is divided into lowlands, midlands, and highlands based on altitude. The area receives varying amounts of rainfall, with lowlands getting less than 700 mm annually and midland/highlands receiving around 1,200 mm [29]. The main farming systems in the Zone are pastoral, agropastoral, and mixed agriculture, with crops like sorghum, maize, wheat, barley, linseed, and groundnuts are the main crops based on their area coverage, and sorghum is a dominant food and feed crop in the area [30].

Smallholder farmers traditionally plant late-maturing local sorghum varieties in late March or early April, depending on the onset of rain, and harvest around November. The smaller amount of rainfall and the erratic nature of the early season months have now become a major constraint to the major arid lowland sorghum growing areas including the study areas [31]. May and June are transition months between the early and main rainy seasons, often dry with little rain. A continuous rainy season at this time is crucial for traditional sorghum to enter the main rainy season. Dry spells in May and June can limit growth, leading farmers to replant with early-maturing genotypes in July and harvest in November if early-maturing varieties are available [10]. Due to this reason, farmers in dry lowlands with bimodal rainfall with small or erratic patterns who used to rely on traditional long-cycle landraces are facing a challenge and are now adopting a production system based

on the main rainy season (July sowing) and early maturing varieties. However, limited access to improved sorghum seeds [32, 33] is discouraging smallholder sorghum farmers from adopting new technologies.

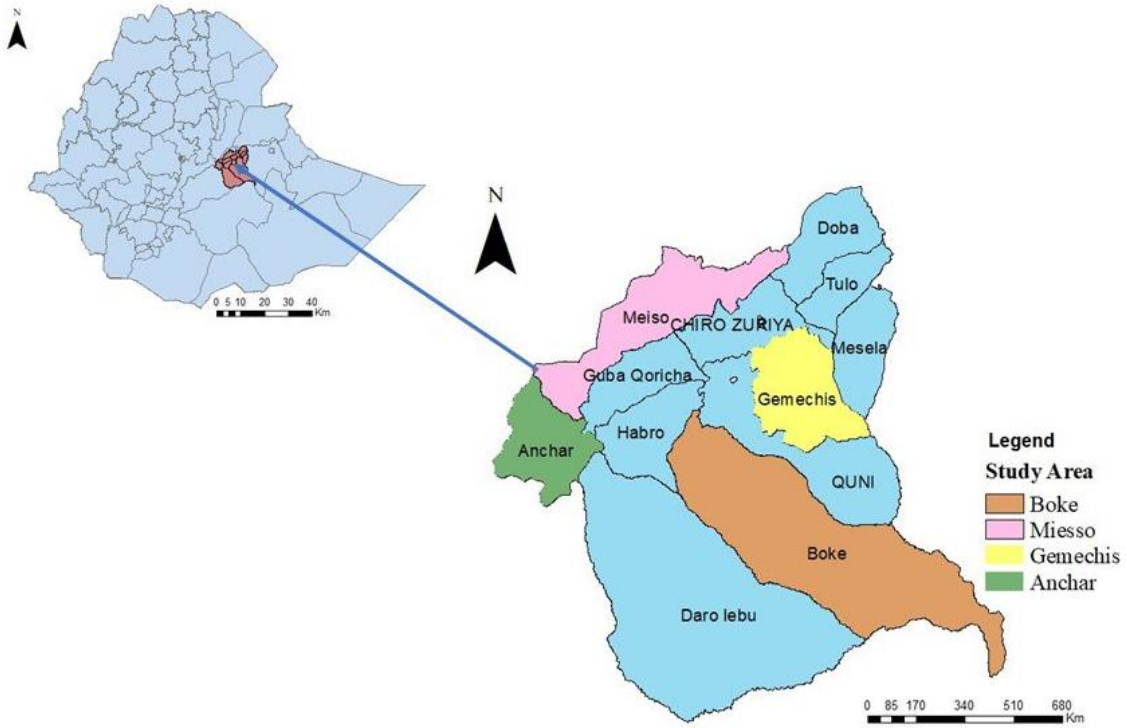

Figure 1. *Map of Ethiopia, West Hararghe zone, and study districts.*

2.2. Site and Farmers Selection

Due to the proximity to the Mieso research substation, the CBSM was initiated with a pilot sorghum seed multiplication in the Mieso district, Argiti kebele during the 2015 cropping season and later expanded to neighboring districts in the 2016 and 2017 cropping seasons. In the 2016 season, the CBSM was expanded to two more districts, Gemechis (Kaseja kebele) and Boke (Lelu kebele), involving 14 and 17 farmers, respectively covering a combined area of 16.29 hectares. During the 2017 season, 25 farmers from Anchar district (Anenno kebele) joined the CBSM, multiplying sorghum seeds on 12 hectares of land, and the CBSM in Gemechis (Kaseja kebele) and Boke (Lelu kebele) were also repeated similar to that in 2016, resulting in a total of 56 CBSM farmers in the three districts. All CBSM sites were very strategic locations in representing sorghum production areas and were easily accessible so that other farmers could see and learn, or could be used for demonstration purposes. The CBSM sites were also chosen based on their suitability for the production of sorghum seeds using supplemental and full irrigation schemes during the off-season. Since the participants' land ownership was nearly half a hectare, the three sorghum seed multiplication groups (one at each location) were formed by joining nearby farms into clusters.

2.3. Planting and Crop Management

In the initial pilot season in 2015, two improved sorghum varieties (Melkam and Dekeba) were planted at Argiti kebele, Miesso district during the main growing season (planted in early July and harvested in November), on an area of 1 and 1.5 hectares, respectively. In Gemechis, Boke, and Anchar districts, Melkam and Dekeba were multiplied in the off-seasons of 2016 and 2017. The off-season planting work was completed from mid-March to early April in 2016, while the 2017 planting work was completed from early to mid-January. Off-season seed multiplication in these three districts was carried out under supplemental irrigation. Breeder seed and fertilizer were provided to the farmers by the National Sorghum Improvement Program. Proper management, particularly timely application of fertilizer and weeding, rouging of off-types, and other crop management packages were applied carefully. The participant farmers received on-the-job training from research technicians and local development agents.

2.4. Monitoring and Evaluation, and Knowledge-Sharing Platform

The chosen CBSM sites were suitable for monitoring and evaluation as well as knowledge-sharing platforms. Because

of the cluster approach, it was also easy to offer technical assistance to members. Regular visits were conducted to the multiplication locations, including various stakeholders like researchers, development agents, and farmers. The CBSM was evaluated at each location in each season during maturity through field days and exchange visits. Three field days were organized: the first in 2015 in the Mieso district at Argiti area, the second in Gemechis district at Kasehija area in 2016, and the third in Anchar district at Anenno area in 2017. Government officials, Parliament members, top management officials from EIAR, officials at Zonal and district levels, along with experts from various sectors, researchers, farmers, and other stakeholders all took part in field day visits. Moreover, Zonal and district officials, along with field facilitators and CBSM team leaders, took part in a study visit to learn from and engage with CBSM teams in the designated areas.

2.5. Seed Processing, Certification, and Marketing

Harvesting, piling, and threshing activities were carefully carried out to preserve the quality of the seeds. Seed certification and quality assurance consisted of overseeing harvesting and post-harvest activities, taking samples, conducting tests, labeling seed batches, and ultimately issuing certificates for seed batches meeting the specified standards. The sorghum research program closely supervised the CBSM in all locations, ensuring that the necessary management practices were implemented accurately, resulting in seeds that met the eligibility requirements for certification by Haramaya University.

In addition, sorghum seed producers were introduced to the idea of a contractual CBSM system to establish sustainable production and market opportunities. In the initial pilot season in 2015, farmers were required to adhere to all quality seed multiplication practices in exchange for receiving seeds, fertilizers, training, and payment of 850 Birr per quintal of quality seed produced through the sorghum research program. During the 2016 and 2017 seasons, although there wasn't a formal contract, two local farmers' associations showed interest in purchasing all the improved sorghum seeds produced by the farmers. Nevertheless, because of the drive of numerous farmers to grow the varieties for household consumption, there was a rise in seed demand from within the community. As a result, nearly all of the seeds multiplied by the CBSM scheme were bought by nearby farmers in the years 2016 and 2017.

2.6. Data Collection and Analysis

Data on the land area used, amount of certified sorghum seed produced and sold, and income earned from the pilot seed multiplication in Mieso district in 2015 and 2016, and the CBSM in 2016 and 2017 off-season in Gemechis, Boke, and Anchar districts were collected.

3. Results

3.1. Field Performance, Seed Yield, and Marketing

In 2015, two farmers in the Mieso district successfully multiplied Melkam and Dekeba varieties in the Argiti area during the pilot season. They harvested 4.9 tons and 6.6 tons of seeds from 1.0 and 1.5 hectares of land, respectively, achieving high yields (Table 1). Proper management, including timely fertilization and weeding, contributed to their success. The pilot project showed that with technical support and market access, farmers can achieve significant results. The field performance of these farms was comparable to research-managed fields (Figure 2A). The project received extensive media coverage and attracted interest from various stakeholders, motivating other farmers to participate. The farms were evaluated through field days and exchange visits (Figure 2B), leading to increased interest in seed multiplication and cultivation among farmers in the study area and beyond.

After the pilot seed multiplication in 2015, the CBSM model was implemented on a wider scale during the off-season (planting from March to April) in 2016 and 2017, and the sorghum variety Dekeba multiplied in two districts (Gemechis and Boke) in a total area of 16.29 ha that is owned by 31 farmers (Table 1). The field performance was excellent and comparable to the 2015 Argiti farms (Figures 2 C and D). In 2016 and 2017, a total of 73.3 tons and 66 tons of certified Dekeba seeds were produced in these two districts respectively (Table 1). Unlike Argiti in 2015, there was no contractual agreement between farmers and the two research centers or the farmer unions. During the planting period, farmers were not bothered by possible market losses. This may be due to the low investment of farmers, but most likely because they chose to use the seeds for food, in case the seed market is not attractive to them. Moreover, due to the earliness of the variety, if the plan is unsuccessful, the farmers intend to use it as animal feed due to the scarcity of feed from January to July. Farmers were fortunate that they have not signed a binding contract and the sorghum seed prices in the region have increased rapidly during the season. Moreover, some farmers in the districts were actively participating in the scheme as well as in planting the varieties for household consumption. For this reason, local demand for the seeds produced has increased, with an estimated price of 1600 to 2000 Birr per 100 kg of seed. At that time, the farmer union Burka Galetti offered the farmers 1,500 Birr for 100 kilograms of seeds, but farmers were reluctant to sell to them at this price. Seeds from all outputs from the Gemechis and Boke districts were sold to neighboring farmers at an estimated total price of 630,000.00 and 652,750.00 Birr, respectively (1 USD = 22.0 Birr) (Table 1).

The CBSM continued in 2017 for the third consecutive season including a fourth district (Anchar) (Table 1). This

expansion was due to the impressive achievements obtained during the previous years, 2015 and 2016. As a result, during the 2017 season, further demand and increased momentum came from the farmers, the farmers' union, and the irrigated crop extension unit in the West Hararghe zone, and the scheme almost continued with lower participation of the sorghum research program when compared to beginning in 2015. The number of farmers increased from 31 in 2016 to 56 in 2017, and the area of seed multiplication increased from 16.29 ha in 2016 to 28.29 ha in 2017 (Table 1). A total of 56 farmers in three CBSM groups were reached in the study (Table 1). A total of 49.58 ha was covered by improved sorghum seed in three years, 215.6 tons of certified improved sorghum seed were produced, and of the total multiplication, 203.8 tons of seed were sold with 3.4 million Birr (Table 1).

3.2. Impacts of the CBSM Scheme

The community-based sorghum seed multiplication has positively impacted smallholder farmers by ensuring high-quality seed availability, leading to enhanced crop yields and improved livelihoods. The scheme has provided smallholder farmers access to new varieties, seed multiplication techniques, quality seeds, and new markets, improving yields, income, and seed security for themselves and neighboring farmers. In total, 215.6 tons of certified seeds have been produced that could cover 13,377.3 ha, benefiting over 27,000 farmers in the study areas and beyond. The production of seeds in the local area has allowed for easier and cheaper access to quality sorghum seeds for both CBSM participants and farmers in the vicinity. The scheme has also raised farmers' earnings per unit of land and encouraged sustainable cultivation in regions with unpredictable precipitation. Farmers who are involved have observed increased production levels in contrast to farmers utilizing local sorghum varieties, with potential gains of up to 4.38 tons per hectare. Farmers in the study area practiced growing long-cycle local sorghum traditionally, which typically takes about 7-8 months to mature and is threatened by an unreliable rainfall pattern.

Besides the excellent seed production, a large amount of biomass was also generated, especially from Melkam, giving the participant farmers ample feed for their animals. Sorghum Stover plays multiple important roles beyond grain production, including livestock feed, firewood, and construction. These roles are crucial for livelihoods in dry lowlands and regions where livestock feed is limited.

3.3. Field Visits, Knowledge, and Experience-Sharing Platforms

Field visits were organized in the district of Mieso in the Argiti area in 2015 (Figure 2 A and B), in the district of Gemechis in the Kasehija area in 2016 and 2017 (Figure 2 C and D), and in the district of Anchar in the Anenno area in the year 2017 (Figure 2 E and F). The visits were organized in the presence of senior government officials, invited parliament members of the Federal Democratic Republic of Ethiopia, members of the Ethiopian Institute of Agricultural Research (EIAR) top management, local officials and experts at the zone and district levels, researchers, farmers, and other stakeholders. The successful experience of the CBSM groups created a good impression among all participants and was quite important to extend the experience and lessons learned to the neighboring farmers and the rest of the sorghum-growing areas. Overall, the CBSM has proven to be a successful model for improving smallholder sorghum seed production and the local supply of good quality sorghum seeds in dry lowland sorghum production ecosystems.

3.4. Strengthening Partnerships and Linkages Among Stakeholders in the Seed Value Chain

Considering the effective outcomes of the CBSM scheme for improved sorghum in the specified districts, Chiro National Sorghum Research and Training Center drafted a Memorandum of Understanding (MoU) upon request from the West Hararghe Zone Agricultural Development Office for the West Hararghe Agricultural Development Partnership and Linkage Advisory Council and its members. The MoU was prepared based on key principles identified in the agricultural extension strategy of Ethiopia [34, 35]. The main agricultural support service providers in the zone, which include the zonal agricultural development office, research centers, universities, farmers' unions, and non-governmental organizations have agreed to maintain close ties and actively participate in fulfilling the responsibilities set out in the MoU. They officially signed the agreement in 2017 with members from various institutions like Zonal Agriculture and Natural Resources, Chiro National Sorghum Research and Training Center, Oda Bultum University, Mechara Agricultural Research Center, Burka Galeti Farmers Union, Odabultum Farmers Union, and Care Ethiopia- Chiro Branch (Figure 3A).

The successful results of the CBSM in improved sorghum in the designated areas laid the foundation for future interventions and collaborations in related projects and research and/or development endeavours through the establishment of partnerships and links among different stakeholders.

4. Discussions

Sorghum is vital for food security in Ethiopia. Sorghum landraces are particularly crucial in mixed crop-livestock mixed farming. These landraces have extended growing periods, making them vulnerable to drought events. Planting in March/April and harvesting in November often fails due to drought, leading farmers to opt for early-maturing improved varieties. However, accessing these seeds is challenging. To address this, a CBSM scheme was introduced in West Hararghe, involving 56 farmers and focusing on two drought-tolerant

sorghum varieties. The scheme successfully produced 215.6 tons of certified seeds, providing smallholder sorghum growers with reliable resources to enhance seed quality, increase access to high-quality seeds, boost income, and improve climate resilience. This innovative approach demonstrates the potential for benefiting other open-pollinated crops and improving farmers' livelihoods through stakeholder involvement in the seed value chain. In the following subsections, we briefly discuss some of the benefits and key lessons learned from the CBSM scheme in the study areas.

4.1. The CBSM Scheme Helps Farmers Access Quality-Improved Sorghum Seeds, Practices, Increasing Yields, Income, and Seed Security

A pilot seed multiplication carried out involving two farmers in the Mieso district in 2015, has demonstrated that farmers with limited resources can successfully multiply and market improved sorghum seeds with the provision of adequate assistance and resources (Table 1). Following this successful pilot seed multiplication (Figure 2 A and B), the CBSM model was replicated on a larger level, resulting in the formation of three CBSM farmer groups consisting of 56 members across three districts in West Hararghe, Ethiopia for the years 2016 and 2017 (Table 1). The CBSM scheme has empowered farmers by providing them with quality seeds and knowledge and skills on how to multiply seeds, resulting in increased production and income. The initiative also improved seed security, enhanced access to quality seeds, and increased production and climate change resilience, benefiting smallholder farmers and enhancing food security. Similar schemes have demonstrated the potential to enhance the availability and affordability of high-quality seeds to smallholder farmers [15, 16] while enabling farmers to use better-quality seeds, new varieties, and other production techniques to increase their production [27, 36].

Table 1. *Seed yield and I come earned by farmers involved in CBSM of two improved early maturing varieties during the 2016 and 2017 off-season using supplemental irrigation in Mieso, Gemechis, Boke, and Anchar districts of West Hararghe zone, Oromia.*

District	Number of farmers	Variety	Year	Area (ha)	Seed yield (tons)	Seed sold (tons)	Income (Birr)
Mieso	2	Melkam and Dekeba	2015	2.5	11.5	11	93,500
			2016	2.5	10.8	10.5	157,500
Gemechis	14	Dekeba	2016	8	36	34	595,000
			2017	8	32	30	525,000
Boke	17	Dekeba	2016	8.29	37.3	35.3	617,750
			2017	8.29	34	32	560,000
Anchar	25	Melkam	2017	12	54	51	892,500
Total	58			49.58	215.6	203.8	3,441,250

Another key benefit of the CBSM scheme was that it provided smallholder sorghum farmers with access to markets that they might not otherwise be able to reach. By producing high-quality, certified sorghum seeds, farmers were able to sell their products to other farmers in the study area and beyond, generating income. Almost all the sorghum seeds produced (93.4%) were sold to neighboring farmers, ensuring seed security at the local level. Furthermore, the smallholder farmers who participated in the scheme benefitted from increased seed prices and local demand and were able to sell at higher prices than offered by the farmers' union, empowering participant farmers for additional income without being bound by agreements (refer to section 3.1). Other studies have shown that CBSM empowers farmers in seed production, marketing, and quality control, enabling them to sell surplus seeds, increase income, and reduce poverty [26, 27]. Local markets are key seed sources for sorghum growers [25], with farmer-to-farmer seed exchanges enhancing seed security at the community level [36-38].

The CBSM in this study presents a promising solution for smallholder farmers to access quality seeds and highlights the importance of linking informal and formal seed systems for agricultural sustainability. Integrating CBSM into formal seed systems, aligning production with farmers' preferences, and emphasizing quality standards are essential for sustainable agriculture [21, 37]. Informal seed systems are important for smallholder farmers who struggle to access quality seeds [16, 39], often resorting to lower-quality farmer-saved seeds [19-21]. In Ethiopia, less than 20% of farmers use seeds from formal systems [23], and seed companies only produce a limited

amount of sorghum seeds, mostly for government programs. Thus, implementing CBSM allows farmer groups to produce high-quality seeds for sale, fulfilling the country's seed needs and improving sorghum production [16, 39]. Similar initiatives in Kenya, Malawi, and Tanzania demonstrate that CBSM can serve as a viable alternative to formal seed systems [28].

4.2. The CBSM Scheme Promotes the Use of Early-Maturing Improved Sorghum with Seed Access, Improving Climate Resilience

The CBSM scheme facilitated informal access to improved sorghum varieties, Melkam and Dekeba, for smallholder and subsistence farmers in remote areas, particularly those prone to drought. Various activities such as field days, farmer-to-farmer exchange visits, and training sessions helped farmers recognize the value of these varieties, leading to the sale of certified seeds to neighboring farmers. This scheme not only increased yields and income for participants but also ensured seed security for nearby smallholder sorghum farmers. The CBSM scheme generated 215.6 tons of certified seeds, potentially covering 13,377.3 ha of land and benefiting over 27,000 farmers in the study areas and beyond. By promoting early-maturing and drought-tolerant sorghum genotypes with seed access, the scheme helped farmers adapt to climate challenges through a late-sowing strategy [10]. Moreover, the improved sorghum varieties also provided ample biomass yields for livestock, addressing feed shortage issues in the study area.

Figure 2. *Field performance of sorghum varieties (Melkam [A and E], and Dekeba [C]), and field day visits with stakeholders on the CBSM in Mieso district at Argiti area in 2015 (A and B), Gemechis district at Kasehija area, 2016 (C and D), and Anchar district at Anenno area, 2017 (E and F).*

Figure 3. *A discussion panel was held on the success and key lessons learned from the sorghum CBSM scheme in the study areas, and an agreement signing event (Figures A and B) on a binding draft document for strengthened partnerships and linkage among the West Hararghe Agricultural Development Partnership Advisory Council and representatives of its members, held at Chiro National Sorghum Research and Training Center, May 2017.*

4.3. The CBSM Scheme's Success Requires Active Stakeholder Engagement in the Seed Value Chain

The success of CBSM schemes depends on engaging all stakeholders in the seed value chain, including formal and informal systems [15, 40]. Formal systems provide technical support and quality control, while informal systems ensure seed availability to farmers at the right time and price [15, 40]. It is also essential to diversify seed sources, use climate-resilient crops, and connect seed demand to local production based on farmer preferences. Sustainability depends on engaging all stakeholders, prioritizing locally adapted seeds and smallholder quality standards [21, 37], and collaborating within the seed value chain [27, 41].

Success factors for multiplying high-quality sorghum seeds include strategic site selection, farmer collaboration, forming clusters, and continuous monitoring. Proper site selection, forming community interest groups, and working with farmer clusters are crucial for logistical efficiency and increased participation [15, 37]. Training, on-the-job support, regular monitoring, and inspection are essential, with partnerships with the National Sorghum Program ensuring a constant supply of quality source seeds.

Seed quality control, certification, proper packaging, and effective marketing are vital for sustainability. Smallholder farmers should be introduced to contract systems for production and market opportunities, while partnerships in the seed value chain need strengthening. Undefined roles in the seed value chain in West Hararghe [42] require identifying roles and strengthening partnerships and linkages among key stakeholders, which should be undertaken from time to time to ensure the success and sustainability of CBSM groups (Figure 3A and B). Thus, stakeholder engagement in both formal and informal seed systems is crucial for the success of CBSM schemes [15, 40], and incorporating CBSM into formal seed systems also promotes long-term sustainability [37, 43].

5. Conclusions

The study's findings indicate that the CBSM scheme supports smallholder sorghum farmers by ensuring seed security for drought-tolerant genotypes and improving access to quality seeds. This enhances smallholder farmers' ability to withstand drought stress, increase productivity, and ensure food security. The scheme also builds local capacity for seed production and distribution, benefiting farmers by providing access to new markets. By selling high-quality certified seeds, farmers can generate income for reinvestment in their farms and communities. Active participation from all partners in the seed value chain is crucial for the scheme's success, highlighting the importance of collaboration to address seed security and climate-related challenges in smallholder sorghum farmers. With investment and support, such schemes could contribute significantly to building sustainable and resilient food systems, addressing key challenges in agriculture and food security, and helping policymakers and farmers tackle seed security and climate-related issues effectively.

Abbreviations

CBSM	Community-Based Seed Multiplication
EIAR	Ethiopian Institute of Agricultural Research

Acknowledgments

The authors are grateful to the West Hararghe Zonal and District-level agricultural and development experts, Burka Galetti Farmers' Union, participating farmers, and the sorghum improvement research program staff at Chiro and Melkassa Centers for their hard work. They also thank the Agricultural Growth Program-II for partially funding the field-day events.

Author Contributions

Solomon Zewdu Altaye: Conceptualization, Data curation, Funding acquisition, Methodology, Project administration, Resources, Supervision, Validation, Writing – original draft, Writing – review & editing

Habte Nida: Funding acquisition, Resources, Supervision, Writing – review & editing

Derara Sori: Data curation, Project administration, Writing – review & editing

Temesgen Begna: Data curation, Project administration, Writing – review & editing

Temesgen Teressa: Data curation, Project administration, Writing – review & editing

Hailu Gichile: Data curation, Project administration, Writing – review & editing

Ashenafi Getahun: Data curation, Project administration, Writing – review & editing

Muktar Mohammed: Resources, Supervision, Writing – review & editing

Data Availability Statement

The data supporting the outcome of this research work has been reported in this manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] CSA. Report on Area and Production of Major Crops (Private Peasant Holdings, Meher Season), in *Agricultural Sample Survey 2017/18 (2010 E. C.), The Federal Democratic Republic of Ethiopia, Central Statistical Agency*. 2018: Addis Ababa, Ethiopia.

[2] Wanous, M. K., Miller, F. R. and Rosenow, D. T. Evaluation of visual rating scales for green leaf retention in sorghum. Crop science, 1991. 31(6): p. 1691-1694 https://doi.org/10.2135/cropsci1991.0011183X003100060063x

[3] Dykes, L. Sorghum phytochemicals and their potential impact on human health. Sorghum: Methods and Protocols, 2019: p. 121-140 https://doi.org/10.1007/978-1-4939-9039-9_9

[4] Queiroz, M. S., Oliveira, C. E., Steiner, F., Zuffo, A. M., Zoz, T., Vendruscolo, E. P., Silva, M. V., Mello, B. F., Cabral, R. C. and Menis, F. T. Drought stresses on seed germination and early growth of maize and sorghum. Journal of Agricultural Science, 2019. 11(2): p. 310 https://doi.org/10.5539/jas.v11n2p310

[5] Abreha, K. B., Enyew, M., Carlsson, A. S., Vetukuri, R. R., Feyissa, T., Motlhaodi, T., Ng'uni, D. and Geleta, M. Sorghum in dryland: morphological, physiological, and molecular responses of sorghum under drought stress. Planta, 2022. 255: p. 1-23 https://doi.org/10.1007/s00425-021-03799-7

[6] Bobade, P., Amarshettiwar, S., Rathod, T., Ghorade, R., Kayande, N. and Yadav, Y. Effect of polyethylene glycol induced water stress on germination and seedling development of rabi sorghum genotypes. Journal of Pharmacognosy and Phytochemistry, 2019. 8(5): p. 852-856.

[7] Geremew, G., Adugna, A., Taye, T., Tesfaye, T., Ketema, B. and Michael, H. Development of sorghum varieties and hybrids for dryland areas of Ethiopia. Uganda Journal of Agricultural Sciences, 2004. 9(1): p. 594-605.

[8] Assefa, Y., Staggenborg, S. A. and Prasad, V. P. Grain sorghum water requirement and responses to drought stress: A review. Crop Management, 2010. 9(1): p. 1-11 https://doi.org/10.1094/CM-2010-1109-01-RV

[9] Enyew, M., Carlsson, A. S., Geleta, M., Tesfaye, K., Hammenhag, C., Seyoum, A. and Feyissa, T. Novel sources of drought tolerance in sorghum landraces revealed via the analyses of genotype-by-environment interactions. Frontiers in Plant Science, 2022. 13 https://doi.org/10.3389/fpls.2022.1062984

[10] Tirfessa, A., Getachew, F., McLean, G., van Oosterom, E., Jordan, D. and Hammer, G. Modeling adaptation of sorghum in Ethiopia with APSIM—opportunities with G×E×M. Agronomy for Sustainable Development, 2023. 43(1): p. 15 https://doi.org/10.1007/s13593-023-00869-w

[11] Sirany, T., Tadele, E., Aregahegn, H. and Wale, D. Economic Potentials and Use Dynamics of Sorghum Food System in Ethiopia: Its Implications to Resolve Food Deficit. Advances in Agriculture, 2022. 2022: p. 4580643 https://doi.org/10.1155/2022/4580643

[12] Mulesa, T. Politics of Seed in Ethiopia's Agricultural Transformation: Pathways to Seed System Development. Frontiers in Sustainable Food Systems, 2021. 5: p. 742001 https://doi.org/10.3389/fsufs.2021.742001

[13] Zerssa, G., Feyssa, D., Kim, D. G. and Eichler-Lobermann, B. Challenges of Smallholder Farming in Ethiopia and Opportunities by Adopting Climate-Smart Agriculture. Agriculture, 2021. 11: p. 192 https://doi.org/10.3390/agriculture11030192

[14] Thijssen, M. H., Bishaw, Z., Beshir, A. and Boef, W. S. d. Farmers, seeds and varieties: supporting informal seed supply in Ethiopia. 2008, Wageningen: Wageningen International. 348-348.

[15] Alemu, D. Farmer-based seed multiplication in the Ethiopian seed system: Approaches, priorities and performance, in *AFC Working Paper 036*. 2011, Future Agricultures Consortium: Brighton. p. 13-13.

[16] Sisay, D. T., Verhees, F. J. H. M. and van Trijp, H. C. M. Seed producer cooperatives in the Ethiopian seed sector and their role in seed supply improvement: A review. Journal of Crop Improvement, 2017. 31(3): p. 323-355 https://doi.org/10.1080/15427528.2017.1303800

[17] Bishaw, Z. and Louwaars, N. Evolution of seed policy and strategies and implications for Ethiopian seed systems development, A. T. Wold, et al., Editors. 2012, Ethiopian Institute of Agricultural Research: Addis Ababa, Ethiopia. p. 31-60.

[18] Mekbib, F. Farmers' Seed System of Sorghum (Sorghum bicolor (L.) Moench) in the Center of Diversity: I. Seed Sources, Distribution, and Networking. Journal of New Seeds, 2007. 8(3): p. 23 https://doi.org/10.1300/J153v08n03_05.

[19] Seboka, B. and Deressa, A. Validating farmers' indigenous social networks for local seed supply in central rift valley of Ethiopia. The Journal of Agricultural Education and Extension, 1999. 6(4): p. 245-254 https://doi.org/10.1080/13892240085300071

[20] Atilaw, A. and Korbu, L. Recent development in seed systems of Ethiopia. in *Empowering Farmers' Innovation - Improving Farmers' Access to Seed*. 2011. Addis Ababa, Ethiopia.: Ethiopian Institute of Agricultural Research.

[21] Abebaw, A., Adane, M., Birhanu, A., Dessalegn, T. and Mazengia, Y. Assessment of Seed Systems in North Western Ethiopia; with Special Emphasis on Community Based Seed Multiplication Scheme. World Scientific News, 2015. 12: p. 100-110.

[22] Tufa, A., Meuwissen, M., Lommen, W. J. M., Oude Lansink, A., Tsegaye, A. and Struik, P. Improving seed potato quality in Ethiopia: a value chain perspective. 2016. p. 101-118 https://doi.org/10.3920/978-90-8686-825-4_5

[23] FarmAfrica. Cooperative Based Seed Multiplication Systems. 2020.

[24] McGuire, S. J. Vulnerability in Farmer Seed Systems: Farmer Practices for Coping with Seed Insecurity for Sorghum in Eastern Ethiopia. Economic Botany, 2007. 61(3): p. 211-222 https://doi.org/10.1663/0013-0001(2007)61[211:VIFSSF]2.0.CO;2

[25] McGuire, S. J. Getting Genes: Rethinking seed system analysis and reform for sorghum in Ethiopia. 2005.

[26] Tebeka, Y. A., Katungi, E., Rubyogo, J., Sserunkuuma, D. and Kidane, T. Economic performance of community based bean seed production and marketing in the central rift valley of Ethiopia. African Crop Science Journal, 2017. 25: p. 189 https://doi.org/10.4314/acsj.v25i2.5

[27] Nateebwa, M., Okiror, J. and Mangheni, M. Effectiveness of community based seed multiplication in enhancing farmers' knowledge and access to improved bean seeds in western Uganda. African Crop Science Journal, 2017. 25: p. 321 https://doi.org/10.4314/acsj.v25i3.6

[28] Walsh, S., Remington, T., Kugbei, S. and Ojiewo, C. O. Review of community seed production practices in Africa Part 1: Implementation strategies and models. 2015.

[29] Kassa, Y., Beyene, F., Haji, J. and Legesse, B. Impact of Integrated Soil and Water Conservation Program on Crop Production and Income in West Harerghe Zone, Ethiopia. International Journal of Environmental Monitoring and Analysis, 2013. 1(4): p. 111 https://doi.org/10.11648/j.ijema.20130104.11

[30] CSA. Report on Area and Production of Major Crops (Private Peasant Holdings, Meher Season), in *Agricultural Sample Survey 2014 / 2015 (2007 E.C.), The Federal Democratic Republic of Ethiopia, Central Statistical Agency*. 2015: Addis Ababa, Ethiopia.

[31] ExpoGroup. Ethiopia: Improved sorghum varieties a solution to persistent drought. 2017.

[32] EIAR. Ethiopian Strategy for Sorghum. 2014: Addis Ababa, Ethiopia. p. 28-28.

[33] Shako, M., Dinku, A. and Mosisa, W. Constraints of Adoption of Agricultural Extension Package Technologies on Sorghum Crop Production at Smallholder Farm Household Level: Evidence from West Hararghe Zone, Oromia, Ethiopia. Advances in Agriculture, 2021. 2021: p. 6674606 https://doi.org/10.1155/2021/6674606

[34] Kassa, B. and Alemu, D. Agricultural Research and Extension Linkages: Challenges and Intervention Options. Ethiopian Journal of Agricultural Science, 2017. 27(1): p. 21.

[35] MoANR. Ethiopia's Agricultural Extension Strategy: Vision, Systemic Bottlenecks and Priority Interventions. 2017, Ministry of Agriculture and Natural Resources (MoANR): Addis Ababa, Ethiopia. p. 52.

[36] Tiwari, T. P., Virk, D. S. and Sinclair, F. L. Rapid Gains in Yield and Adoption of New Maize Varieties for Complex Hillside Environments through Farmer Participation: Part I, Improving Options through Participatory Varietal Selection (PVS). Field Crops Research, 2009. 111(1-2): p. 6 https://doi.org/10.1016/j.fcr.2008.11.008

[37] Tirtha Bdr, K., Wangchuk, D., Namgay, W., Rinzin, C. and Lhap, D. Community Based Seed Production—A Sustainable Seed Production Model for Subsistence of Bhutanese Maize Farmers. Journal of Food Science and Engineering, 2015. 5(2): p. 76-84 https://doi.org/10.17265/2159-5828/2015.02.004

[38] Sarah Haaij, Marianne Heselmans, Ellen Mangnus, Manon Stravens and Tielens, J. Farmers gain access to and control over seeds, in *Seed Special Winter 2017*, E. Mangnus and J. Tielens, Editors. 2017, Stichting Vice Versa: Mauritskade 63, 1092 AD Amsterdam, Netherlands.

[39] Hirpa, A., Meuwissen, M. P., Tesfaye, A., Lommen, W. J., Lansink, A. O., Tsegaye, A. and Struik, P. C. Analysis of seed potato systems in Ethiopia. American journal of potato research, 2010. 87(6): p. 537-552 https://doi.org/10.1007/s12230-010-9164-1

[40] Argaye, S. The Role of Formal, Informal and Intermediary Seed System for Food Security in Ethiopia. International Journal of Novel Research in Life Sciences, 2019. 6(5): p. 57-65.

[41] Donovan, J., Rutsaert, P., Spielman, D., Shikuku, K. M. and Demont, M. Seed value chain development in the Global South: Key issues and new directions for public breeding programs. Outlook on Agriculture, 2021. 50(4): p. 366-377 https://doi.org/10.1177/00307270211059551

[42] Bula, H., Soboka, D. and Ahmed, K. Prospects and Challenges in Seed Sector Development: Lessons from Eastern Ethiopia. European Business & Management, 2019. 5: p. 51 https://doi.org/10.11648/j.ebm.20190504.11

[43] Almekinders, C. J. M. and Louwaars, N. P. The Importance of the Farmers' Seed Systems in a Functional National Seed Sector. Journal of New Seeds, 2002. 4(1-2): p. 15-33 https://doi.org/10.1300/J153v04n01_02