Science for resilient livelihoods in dry areas

DEPLOYMENT OF FOOD LEGUME TECHNOLOGIES IN ETHIOPIA

Achievements and Lessons Learned

Editors:
Zewdie Bishaw
Adamu Molla

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Cover picture: Faba bean production fields in South Wollo Zone (Left); Chickpea production fields in East Shewa Zone (Right).

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Ethiopia; faba bean; chickpea; high-yielding varieties; breeder seed; basic seed; certified seed; quality declared seed; seed producer cooperatives; validation; demonstration; scaling; food security; nutrition security; institutions; production costs; profit; yields; farm income; variety suitability mapping

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About ICARDA
Established in 1977, the International Center for Agricultural Research in the Dry Areas (ICARDA) is a non-profit, Consortium of International Agriculture Research Center that focuses on delivering innovative solutions for sustainable agricultural development in the non-tropical dry areas of the developing world. We provide innovative, science-based solutions to improve the livelihoods and resilience of resource-poor smallholder farmers. We do this through strategic partnerships, linking research to both development and capacity development, and by taking into account gender equality and the role of youth in transforming the non-tropical dry areas.

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Preface

During 2015-2018, ICARDA, implemented two projects with financial support from USAID: (i) Deployment of Malt Barley and Faba Bean Varieties and Technologies for Sustainable Food and Nutritional Security and Market Opportunities in the Highlands of Ethiopia; and (ii) Better Livelihoods for Smallholder Farmers Through Knowledge-based Technology Interventions in the Highlands of Ethiopia: Increasing the Productivity of chickpea in Wheat-based Cropping System. Both projects were aimed at promoting and scaling improved pulse technologies with the overall goal of improving the livelihoods of smallholder farmers. This book, prepared in two sections, describes the approaches, and summarizes the achievements of the faba bean and chickpea scaling projects implemented in partnership with federal and regional research for development partners and stakeholders along the faba bean and chickpea value chains. The project covers a wide range of activities from validating, demonstration, and popularization of legume technologies; production of early generation seed, certified seed and quality declared seed by various enterprises through NARS, public seed enterprises and seed producer cooperatives, unions, farmer groups; and scaling of technologies through partnerships with governmental (zonal, district and kebele development offices, universities) and Non-governmental Organizations operating in target project sites. The book, in each section, in chronological order presents the results of baseline surveys; validation, demonstration and popularization of technologies; early generation, certified seed and quality declared seed production; and scaling of improved technologies.

The editors and authors of different chapters would also like to thank several institutions for providing the valuable information needed to produce this book. These include the Ministry of Agriculture, Ethiopian Institute of Agricultural Research and Regional Agricultural Research Institutes of Amhara, Oromia, Southern Nations, Nationalities, and Peoples and Tigray Regions, Ethiopian Seed Enterprise, Amhara Seed Enterprise, Oromia Seed Enterprise, and several seed producer cooperatives. Special thanks go to the Ethiopian faba bean and chickpea farmers who participated and contributed their resources and time to implement the project far and wide throughout the country.

The financial support from USAID for implementing both faba bean and chickpea projects is greatly acknowledged by ICARDA and implementing partners and stakeholders in Ethiopia.

The views and opinions expressed in this book are purely those of the authors and do not necessarily reflect the views of their organizations.

Editors

Foreword

This BOOK is the outcome of the collaborative endeavors of diverse partners and stakeholders addressing the challenges of seed systems and scaling faba bean and chickpea innovations in Ethiopia. It is the second of two BOOKs which focuses on faba bean and chickpea, the first being on malt barley.

Pulses play a significant role in the integrated crop-livestock farming systems in Ethiopia and provide multiple benefits to the smallholder farmers for farming systems productivity and sustainability. The main pulses produced are faba bean, field pea, chickpea (desi and Kabuli), grass pea, lentil, and lupine in the highlands, and common bean, soybean, and mung bean in the lowlands. Pulses are: (i) sources of protein and micro-nutrients ensuring food and nutritional security, (ii) incorporated into crop rotation to improving soil fertility and health, (iii) low carbon footprint and aids climate change mitigation; and (iv) increase farm incomes improving rural livelihoods as cash crops in the domestic and international markets. Pulses remain one of the major agricultural export commodities generating substantial amount of foreign currency for the country.

Scaling pulse crops innovations can make significant contributions to food and nutritional security, economic growth, social wellbeing, and environmental sustainability. While staple cereals are designated as food security crops in national policy and strategy narratives and enjoyed substantial investments, pulses continue to receive fewer investment resources and policy attention. As a result, the pulse value chains are least developed including technology generation and delivery, production, processing, and consumption. Although some outstanding technologies and innovations are generated by the National Agricultural research System (NARS)-CG partnership, poor technology transfer, limited seed delivery system, poor market linkages both at domestic and international markets remain the challenges limiting the contribution of pulses towards overall food and nutrition security.

The book, Deployment of Legume Technologies in Ethiopia: Achievements and Lessons Learned, provides a synthesis of the research for development activities and rich experiences gained in scaling faba bean and chickpea technologies through effective partnership with broad range of stakeholders operating from federal to regional. zonal and district levels: federal Ministry of Agriculture and regional Bureaus of Agriculture; the federal and regional agricultural research institutes; the federal and regional public seed enterprises; seed producer cooperatives or farmer seed producer groups; and faba bean and chickpea farmers. The experiences and knowledge gained are put in context aimed at decision-makers, not only in Ethiopia but in other developing countries for wider application and spill overs. The book provides useful insights to policy makers, researchers, students, development practitioners and donors involved in international development for generating and moving technologies out to the farmers' fields.

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I FABA BEAN

CHAPTER 1

OVERVIEW OF ACHIEVEMENTS AND BASELINE SURVEY

Achievements of Seed Production and Scaling of Faba bean Innovations in Ethiopia

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Introduction

In Ethiopia, an estimated 14 million smallholder farmers cultivated over 12 million ha in 2014 (CSA, 2015) among which cereals, legumes and oilseeds are the major crops. Pulses were cultivated on 1.6 million ha (12.42%) and producing 2.7 million tons (9.89%) with average productivity of less than 2 tons ha^{-1}. Among pulses, faba bean (*Vicia faba*) is the largest in terms of area and production. It is grown by close to 3.8 million smallholder farmers on 443,108 ha producing 838,944 tons with an average national productivity of 1.9 tons ha^{-1}. Ethiopia is the world's second largest producer of faba bean next to China accounting for 6.96% of global and 40.5% of the African production (FAO, 2014).

At the national level, only 16% of faba bean produced by small holder farmers is brought to the market. Most of the production (63%) is used for home consumption, while the rest is used for seed. In rural areas, where diets are cereal based, faba bean is an important source of household nutritional security. Since faba bean is prepared in many recipes, the quantity of its consumption is very high as compared with other traditional pulse crops. It was shown that addition of 10% of processed faba bean can effectively improve nutrient content and nutrient availability of traditional cereal-based complementary foods for children (Kebebu *et al*., 2013). Faba bean straw mixed with wheat and barley straw is a key ingredient of animal feed in the mixed farming system of the Ethiopian highlands (Wegi *et al*., 2018).

Faba bean also helps to improve soil fertility and soil health and sustain the productivity of barley and wheat-based farming systems through nitrogen fixation and reduction of pests and weeds when used as a rotational crop. For example, in the Arsi highlands, the introduction of faba bean in wheat rotation was found to increase the soil nitrogen balance by 12-58 kg N ha^{-1} compared to wheat mono-cropping that resulted in a negative soil nitrogen balance of 9 to 44 kg N ha^{-1} (Amanuel *et al*., 2000). Abera *et al*. (2015) reported that planting faba bean improved N-status of the soil and nitrogen fertilizer response of maize and thereby improving grain yields.

The Ethiopian National Agricultural Research System (NARS) in partnership with the International Center for Agricultural Research in the Dry Areas (ICARDA) has developed several faba bean varieties with key traits like high grain yield, large seed size and tolerance/ resistance to diseases and parasitic weeds, and adaptation to different production systems. Since 2005, 12 faba bean varieties, with specific and wide adaptations, and associated crop mangement technologies have been developed and released. Some of the faba bean varieties are adapted to high-potential production areas (varieties Gabelcho, Tumsa, Dosha, Degega, Moti and Shallo) and to water-logged highlands (varieties Walki, Hachalu, Lalo, Dagim, Wayu). Most of the recently released varieties were developed through hybridizations involving local collections and ICARDA breeding lines as well as direct selection from local landraces (varieties Lalo, Dagim, Wayu and Dosha).

Generally, small holder farmers are getting less than 40% of the water-limited yield penitential of faba bean in all major growing areas (Mulugeta *et al*., 2019). The major factors responsible for low productivity and significant yield gaps for faba bean include, among others, low dissemination and utilization of improved technologies, lack of and limited supply of quality seed, and poor extension systems for transferring available technologies. The low productivity and production of faba bean have particularly affected the livelihoods of smallholder farmers in the highly populated and vulnerable highland areas in Amhara, Oromia, Southern Nations Nationalities and Peoples (SNNP), and Tigray Regional States. Many vulnerable households in these regions are supported by a Productive Safety Net Program (PSNP), as a response to climate shocks. The project Deployment of Malt Barley and Faba Bean Varieties and Technologies for Sustainable Food and Nutritional Security and Market Opportunities in the Highlands of Ethiopia was launched with the support of USAID. The project has been implemented by ICARDA from 2015 to 2018 with the overall goal of improving the livelihoods of smallholder farmers in the Ethiopian highlands. This Chapter documents an overview of the achievements and lessons learned during the implementation of the project with research for development partners and stakeholders.

Project Goal and Objectives

The overall goal of the project was to improve the livelihoods of smallholder farmers through increased productivity and production of faba bean in mixed farming systems in the highlands of Ethiopia through improved technologies and linkages to markets. The specific objectives were to ensure increased productivity and production of faba bean and enhance the food and nutritional security and market opportunities of smallholder farmers through:

- Demonstration and promotion and scaling out of faba bean varieties, biofertilizers and integrated crop management technologies;
- Ensuring regular production and supply of early generation seed (EGS) of faba bean varieties by NARS;
- Partnership with public seed enterprises and emerging private seed companies, farmer cooperative unions and seed producer's associations for large-scale seed production; and
- Strengthening human resources capacity of partners and stakeholders and provision of critical facilities and create research-extension-farmer-market linkages

Approaches

A framework for scaling has been developed and used for dissemination of crop technologies for a meaningful adoption and impact at scale (Figure 1) as specified for wheat (Bishaw *et al*., 2016) and malt barley (Bishaw and Adamu, 2020). The approaches included:

- Validation, demonstration, and popularization of new faba bean varieties and integrated crop management practices. Farmers (male/female) hosted demonstration plots at which field days were organized for farmers, development agents and subject matter specialists as well as technical and administrative staff from the district, zonal and regional offices, NARS, universities, and CGIAR centers;
- Accelerated early generation seed (breeder, pre-basic and basic) production by NARS during the main and off-seasons. In the absence of formal sector actors, cooperatives or farmer groups were identified, organized, trained and engaged in decentralized seed production using small seed-pack distribution and revolving seed scheme;
- Rhizobia distribution in partnership with a private sector for both seed producers and grain producers to create awareness and demand; and
- Capacity development of project partners and stakeholders including farmers to upgrade knowledge and skills and provision of critical facilities for NARS and seed producers.

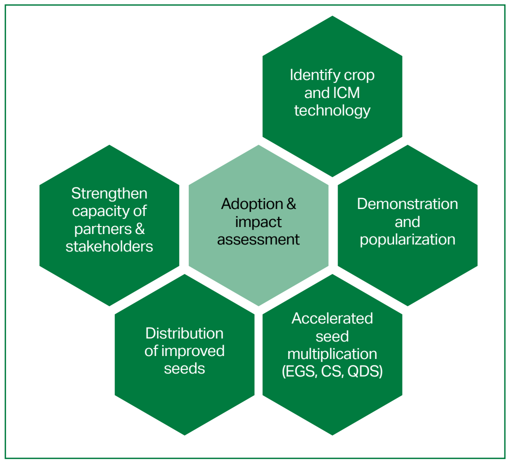

Figure 1. Scaling framework for crop and agronomic technologies

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Partners and Stakeholders

This project has brought on-board several implementing partners and stakeholders of faba bean value chain (Table 1 and Figure 2). Key among them are Federal and four Regional Agricultural Research Institutes (RARIs) and their affiliated research centres; BoA (at regional, zonal, district and kebele levels); federal and regional public seed enterprises; farmer seed producer cooperatives/seed unions/farmer groups; private agro-input supply companies (Menagesha Biotech Industry PLC, MBI, Mekamba, Syngenta); and development agencies/projects (Agricultural Transformation Agency, Integrated Seed Sector Development-Ethiopia). These projects have also used faba bean technology validation results as an input from bilateral projects from ADA (Austrian Development Agency)-ICARDA and Africa RISING.

Table 1. List of research for development partners and stakeholders

Partners	Number of partners	Affiliation	Roles and responsibilities
Holetta and Kulumsa ARCs	*2*	*EIAR*	*Implementing partners for EGS production, demonstration, farmer-based seed production, and scaling of faba bean technologies in collaboration with zonal, district and kebele agricultural development and extension staff*
Adet, Debre Birhan, Gondar & Srinka ARCs	*4*	*ARARI*	
Sinana ARC	*1*	*OARI*	
Areka, Hawassa & Worabe ARCs	*3*	*SARI*	
Alamata & Mekele ARCs	*2*	*TARI*	
Ethiopian Seed Enterprise (ESE), Amhara SE& Oromia SE	*3*	*Federal and regional public seed enterprises*	*Basic and/or certified seed production*
Seed producer cooperatives (SPCs)	*32*	*Farmers' cooperatives and unions*	*Certified seed and/or quality declared seed production*
Seed producer unions (SU)	*4*		
Multi-purpose farmers cooperatives	*6*	*Primary cooperatives*	*Input supply for seed producers and other members of the cooperatives*
Menagesha Biotech Industry PLC	*1*	*Private sector*	*Rhizobium production and marketing*
Syngenta	*1*	*Private sector*	*Herbicides for weed control*
Mekamba PLC	*1*	*Private sector*	*Hermetic bags for post-harvest storage*
Zonal, district and kebele agricultural development offices in 4 regional states	*75*	*Amhara (23), Oromia (23), SNNP (10) and Tigray (6) Regional States*	*Collaboration with partner ARCs implementing demonstration, farmer-based seed production, and scaling of faba bean technologies*
Seed quality control and quarantine offices	*4*	*Amhara, Oromia, SNNP and Tigray Regional States*	*Field inspection and seed testing and technical support for certification*

Farmer seed-producers were linked to projects and institutions working in their respective areas. For example, Sustainable Land Management Project, Wollo University and District Agricultural Development Offices purchased seed from farmer seed producers in South Wollo Zone of Amhara Regional State. Agricultural Growth Programs operating in the target districts provided funds for seed purchase by district Offices of Agricultural Development for further dissemination of faba bean varieties.

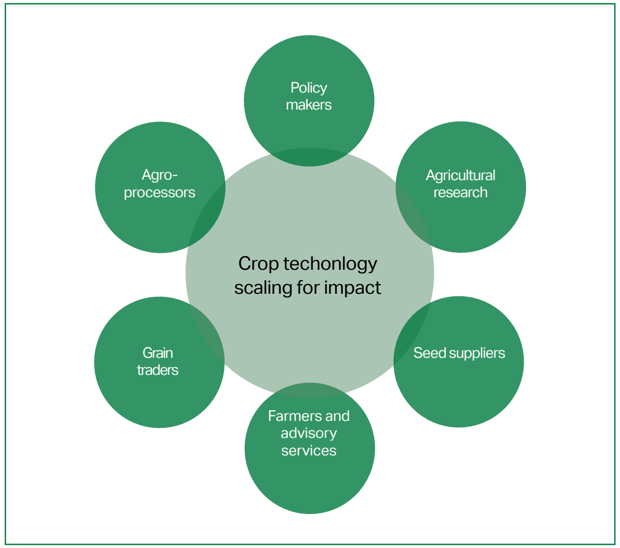

Figure 2. Partnership platform for scaling new crop technologies for impact at scale

Target Regions

The Project focused on four major faba bean producing administrative regional states, namely Amhara, Oromia, SNNP and Tigray, that collectively contribute to the entire faba bean area and production in the country (CSA, 2015). The project covered over 70 districts in Agricultural Growth Plan and Productive Safety Net Program intervention areas (Figure 3).

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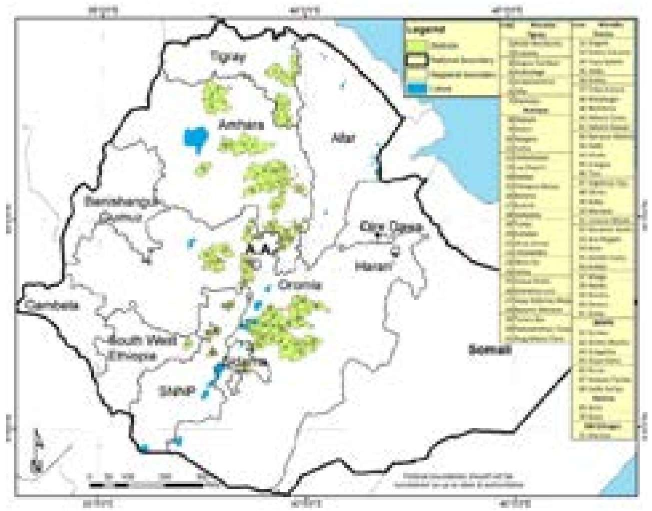

Figure 3. Faba bean seed production and scaling districts in Ethiopia

Achievements

The major achievements of the seed production and scaling of faba bean innovations during 2015-2018 cropping seasons are summarized below.

Validation, Demonstration and Popularization of Technologies

ASeveral high-yielding faba bean varieties with end-user preferred traits and associated production technologies had already been developed, but their adoption was limited due to lack of access to improved seeds and lack of awareness among farmers and limited extension services. To address this, improved faba bean varieties and associated crop-management technologies were demonstrated and popularized under the project (Table 2). NARS and ICARDA coordinated the implementation in target districts using host farmers, farmers' cooperatives, and unions. Field days and trainings were organized to raise farmers' awareness of available technologies and their performance in the project target areas.

Table 2. Summary of faba bean innovations validated, demonstrated, and disseminated by the project: 2015-2018

Variety	Traits	Recommended management practices
Dagim	Small seeded and tolerant to waterlogged Vertisols	Rhizobium inoculation (strain EAL-110)
Walki, Hachalu	Relatively large seeded than Dagim with relative tolerance to transient waterlogging in Vertisols	Herbicides to control grassy weeds and DAP application at planting (100 kg DAP ha^{-1})Fungicide sprays (Ridomil Gold, Bayleton, Mancozeb) to control faba bean gall disease in high altitude areas
Hashenge	Tolerant to parasitic weed (Orobanche sp) and high yielding	Rhizobium inoculation; fungicide (Ridomil Gold, Bayleton, Mancozeb) sprays to control faba bean gall disease; low dose application of glyphosate (1-2 at the rate of 0.3 liter ha^{-1}) at flowering stage to manage parasitic weeds
Moti, Gebelcho, Dosha	High yielding on well drained soils and large seed size preferred for export market	Rhizobium inoculation; fungicide (Ridomil Gold, Bayleton, Mancozeb) sprays to control faba bean gall disease in high altitude areas; NPS application at planting (121 kg NPS ha^{-1})

Demonstration of faba bean innovations

The demonstrations of technologies included two or more bundled components recommended to increase faba bean productivity. A total of 357 demonstrations were conducted on farmers' fields (about 16% female farmers) combining validation and demonstration of new faba bean technologies (Tables 2 and 3). The participation of women farmers in the demonstrations was higher than the proportion of women-headed farm households (12.4%) compared to our project baseline survey. The results of demonstrations revealed that improved technologies gave better grain yield advantage over existing technologies across test locations (Tables 2 and 3). All other positive effects of improved varieties and management practices fall in the yield advantage range of 2 to 1,105%.

Hachalu and Dide'a gave the respective grain yield of 2.02 and 2.06 tons ha^{-1}, yield advantage of 2.0 and 4.0% over the standard check variety, Walki (1.98 tons ha^{-1}) on Vertisols at Goro district in Bale zone of Oromia Regional State. Two observations were noted regarding faba bean production on heavy Vertisols at Moretina-Jiru and Siyadebrina-Wayu districts in North Shewa Zone of Amhara Regional State. The two new improved varieties, Walki (3.93 tons ha^{-1}) and Hachalu (4.1 tons ha^{-1}), gave lower grain yields (91.4% and 95.4%, respectively) compared to Dagim (4.3 tons ha^{-1}), a variety specifically released for heavy Vertisols in these districts and similar areas in the region. Dagim has smaller seed size (161 g per 1000 seed), but it yields higher, and has better tolerance to waterlogged heavy Vertisols. However, farmers were convinced to produce all the three varieties because of seed size and level of resistance to waterlogging. Hachalu (with seed size of 326 g per 1000 seeds) and Walki (259 g per 1000 seeds) which can meet the demand of local and export markets and therefore can be produced on relatively well drained Vertisols using the broad-bed and furrow drainage method.

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Demonstration for the control of a devastating faba bean gall disease showed that seed dressing and twice foliar spray of Bayleton fungicide gave a grain yield of 1.96 tons ha^{-1} whereas thrice foliar spray of Bayleton fungicide gave a grain yield of 0.94 tons ha^{-1} compared to untreated susceptible local faba bean cultivars (0.13 tons ha^{-1}) in Basona-Worana district of North Shewa Zone of Amhara Region (Table 3). Correspondingly this translates to 623.1 and 1,407.7% yield advantage over the untreated faba bean crops, showing the very devastating effect of faba bean gall disease.

Generally, improved technologies have shown their superiority (average yield advantage of 42%) in improving productivity (Table 3) and production as well as meeting the local and export market demands ultimately contributing to improving food, nutrition, income, and livelihood security of smallholder farmers.

Table 3. Summary of results from demonstration of improved faba bean innovations, 2015-2017

Districts	Varieties*	Average varieties yield (t/ha)		Yield advantage (%)	Remarks
		Improved innovations	Local/ standard check		
Ofla	Hashenge	3.3	1.5	120	Orobanche tolerant variety
Goba	Dide'a, Hachalu & Walki	2.04	1.98	3	Vertisols
Moretina-Jiru & Siadebirina-Wayu-	Hachalu, Walki & Dagim	4	4.3	-7.2	Heavy vertisols
Debrelibanos	Dide'a, Hachalu	2.3	0.9	156	Vertisols
Degem	Gora, Tumsa	1.6	0.9	78	Nitosols
Dinsho	Dosha, Gora & Moti	2.1	1.8	17	Light soils
Angacha, Doyogena, Duna & Sodo Zuria	Bobicho-04, Dosha Gebelcho, Tumsa & Walki	2.7	1.8	50	Improved varieties
Dara, Hulla & Melga	Tumsa, Walki	2.2	0.5	340	Improved varieties
Alicho-Wuriro & Gumer	Degaga, Dosha & Walki	3.2	2.7	19	Improved varieties
		2.6	1.8	44	

Note: *Faba bean varieties in bold are standard (improved) checks or otherwise used local landraces.

Table 4. Summary of results from demonstration of crop and pest management technologies, 2015-2017

Districts	**Varieties***	***Average varieties yield (t/ha)***		**Yield advantage (%)**	**Remarks**
		Improved innovations	**Local/ standard check**		
Ofla	*Parasitic weed management (var. Hashenge & Glyphosate sprays)*	2.8	2.6	8	*Orobanche tolerant variety*
Basona-Worana	*Faba bean gall management (Bayleton seed treatment + 2- or 3-time sprays, no control*)*	1.45	0.13	1015	*Fungicide for seed treatment and spray*
Atsibi-Womberta	*Faba bean gall management (var. Moti, biofertilizers & Bayleton sprays, local check*)*	3.48	2.6	34	*Rhizobia, fungicide spray*
Duga Tembien	*Faba bean gall management (var. Walki, biofertilizers & Bayleton sprays, local check*)*	3.2	3.6	-13	*Variety, rhizobia, fungicide spray*
Dinsho & Goba	*Faba bean chocolate spot management (Chlorothalonil, Mancozeb, unsprayed*)*	2.4	1.7	41	*Fungicide spray*
Wolmera & Degem	*Herbicide weed control (Dual Gold at 1 liter ha^{-1}) and two hand weeding**	2.6	2.3	13	*Herbicide and hand weeding*
Wolmera & Tiyo	*Herbicide weed control (Dual Gold at 1 liter ha^{-1}), one or two hand weeding and weedy check**	2.0	1.1	82	*Herbicide and hand weeding*
Dinsho & Goba	*Herbicide weed control (Dual Gold, Gallant Super spray) and unsprayed control**	1.6	1.2	36	*Herbicide control*
Alicho-Wuriro	*Soil fertility management (Rhizobium Strain EAL-110), Biofert-1035, Biofert-1018 or Biofert-110 + NPS and NPS 121kg ha^{-1*})*	2.3	1.5	56	*Rhizobia, fertilizers*
		2.4	1.8	33	

*Note: *Control*

Field days

Farmers lack of knowledge and awareness on profitability of improved faba bean varieties and crop management technologies are some of the constraints limiting their scaling and adoption. Therefore, technology demonstrations, community-based seed productions, and scaling activities of the project were used to raise farmers' awareness of the performance of the improved varieties and accompanying production technologies in their environments. Furthermore, organizing field days enhances their knowledge, accelerates awareness by reaching more farmers to exchange experiences, enhances farmer-to-farmer seed exchange, and improves linkages among value chain actors of faba bean.

Therefore, since the insception of the project in 2015, field days were jointly organized by partner research centers and district offices of agriculture which have worked together in promotion and scaling of improved technologies. In total, about 21,833 farmers (20.4% female) and 4,863 stakeholders (15.3% female) of faba bean value chain participated in various field days. Among the value chain stakeholders are district and zonal political and sectoral authorities, distrtict and zonal experts of agricultural extension, zonal seed quality inspection and certification experts, zonal cooperatives agency experts, agricultural marketing and input supplying unions, seed marketing and input supplying unions, public and private seed enterprises, development agents, and researchers from NARS and ICARDA. This achievement was possible because district and kebele level offices and local development agents from agricultural offices conducted field days; this is in addition to the high-level field days jointly organized by zonal Bureaus of Agriculture and the respective research centers in each target location of the project.

These field days, in addition to creating awareness on the performance of the technologies being promoted and scaled up/out, re-enforced the linkages of faba bean value chain actors for promoting farmer-based seed production and maintaining their sustainability to overcome the prevailing critical shortage of quality-seed supply.

Accelerated Seed Production

The systemic bottlenecks of the legume seed sector are summarized by Bishaw *et al*. (2018). Neither the public nor the private formal sector was able to address the seed demand and supply gap. To increase access of quality seed of improved faba bean varieties, the project made concerted effort for production of different seed classes working with NARS, seed producer cooperatives and farmer groups. The effort included off-season seed production where irrigation is feasible in the lowlands and highlands particularly for early generation seed (EGS).

Early Generation Seed production with NARS

The main limiting factors for faba bean seed supply have been inaadequat availability of breeder and pre-basic seed from the agricultural research centers, and critical shortage of basic and certified seed from the public seed enterprises. This project strived to produce early generation seed for further multiplication to enhance seed availability and access to smalloholer farmers, and large scale technology scaling up/ out during 2015-2018. EGS (breeder, pre-basic, basic) multiplication of existing varieties during the main and off-season at research centers was taken in earnest to produce sufficient basic seed annually.

In total, EGS produced by NARS was 544.1 tons both on-station and on-farm with farmers. About 27.3, 102.2, and 165.1 ha, respectively, of breeder, pre-basic and basic seed were planted, and 34.5, 156.2, and 352.8 tons of seed produced in the same order. Most of the basic seed was produced on the farmers' fields, i.e. 266.6 tons from 123.9 ha with an average productivity of 2.15 tons ha^{-1} mainly due to damage from frost and waterlogging. A total of 473 farmers (17% female) participated in on-farm basic seed production. Land scarcity on-station of partner research centers and shortage of nucleus seed, limited breeder seed production and production of subsequent seed classes. The experiences gained demonstrate that pre-basic and basic seed production could be possible with SPCs and meet the seed certification requirements if sufficient technical backstopping is provided, and their physical facilities and human resources capacities are strengthened.

Certified seed production through formal sector1

Alemu and Bishaw (2016) summarized the problems confronting the faba bean seed system where there is an overall low-level demand for certified seed and a considerable gap between demand and supply. They found that the certified seed produced is of very few old varieties (with weighted average age of 20.5 years) and could only cover 3.97 percent of the total faba bean area in the 2014 cropping season. Apart from a varietal mismatch between demand and supply, low commercial attractiveness, and high grain to seed price ratio were found to be a disincentive for formal sector engagement in seed business, either public or private.

From the outset, the project had no direct role or objective in large-scale certified seed production except to fill the gap in basic seed supply for further multiplication of certified seed by public or private sector seed suppliers. The project anticipated that the public or private seed suppliers would directly access pre-basic seed from NARS to produce their own basic seed or link with NARS-cum-farmer seed producer groups to get access to basic seed for undertaking certified seed production using their own resources. Significant efforts were made to establish sustainable linkages in certified seed production of faba bean with federal and regional public seed enterprises (PSEs), and emerging private sectors. Although the PSEs were not able to fully accommodate the certified seed production plan envisaged in the project, they have accessed a limited amount of EGS of some varieties from NARS partners involved in the project and produced certified seed within the centrally managed production plan under the Ministry of Agriculture and Natural Resources which is not included in this report.

Farmer-based seed production and scaling

Farmer-based seed production schemes through SPCs or farmer groups has been a priority intervention of the project aimed at improving smallholder farmers' access to quality seed of new varieties in the project areas. Decentralization provides an opportunity to make available and access seed at a lower cost and closer proximity to smallholder farmers, encouraging them to observe, adopt and use the technology with positive impact on their livelihoods. Since the seed is produced in their community, smallholder farmers can see the field performance of the improved varieties and develop confidence to adopt and use it.

The project made tremendous efforts to produce basic and certified seed by strengthening and/or establishing farmers' seed producer cooperatives (SPCs) or farmer seed producer groups. The project worked diligently to establish sustainable farmer-based seed production in the project target areas. This effort enabled the project to work with 32 farmer seed producers and marketing cooperatives (SPCs), four farmers' multi-purpose cooperatives (MPCs), and six Seed Unions (SU) to enhance seed production and marketing with combined membership of 8,010 (11% female) individuals. Each union is comprised of 23 to 43 MPCs and/or SPCs. Some of these cooperatives and farmers' groups were linked, not only to Unions, but also in some cases to public seed enterprises and local agro-processors. For example, the eight cooperatives working with the DBARC in North Shewa were linked with Wodera Multipurpose Union and Tegulet Seed Producers Union. Ten SPCs in Arsi working with KARC, experienced no seed marketing problem as there has been strong demand from various research centers, NGOs (e.g. Self Help Africa), contract seed production with the Ethiopian Seed Enterprise. However, efforts have been made to improve the linkage arrangements with seed cooperative unions for future sustainability.

Some of these SPCs have established contractual agreements for basic or certified seed production and marketing with PSEs. This contractual arrangement not only accelerated seed production but also opened market opportunities for SPCs and enhanced their sustainability. Therefore, the certified/quality seed production was totally coming from farmer-based seed production through small seed-pack distribution and production using SPCs/farmers groups, revolving seed scheme, farmer-to-farmer seed exchanges, and partner organizations that used project farmers as seed source. Through this approach, the project planted 4,889.5 ha of faba bean, produced 11,938.9 tons of certified/quality seed and directly involved 27,944 beneficiary farmers. The performance of farmer-based faba bean seed production was higher than the target and proved to be a feasible approach to improve timely access and less costly for deployment and scaling of technologies.

Farmer seed producers were linked to projects and formal sector institutions working in their area. For example, Seed Business Network, Wollo University, Self Help Africa, ILRI-Africa RISING, public seed enterprises, ATA (Agricultural Transformation Agency), purchased faba bean seed from project partner seed producer cooperatives and farmers in South Wollo, and North Shewa Administrative Zones of Amhara Regional State, Arsi Zone of Oromia Regional State, and Tigray Regional State. Similarly, Self Help Africa, ILRI-Africa RISING project, GIZ-IP, Tigray Seed Enterprise, and Agricultural Growth Programs purchased faba bean seed from project partner SPCs and farmers in Arsi Administrative Zone of Oromia Regional State and from Southern Administrative Zone of Tigray Regional State for further dissemination of faba bean varieties. The Sustainable Land Management project also purchased faba bean seed and distributed to farmers in South Wollo of Amhara Regional State.

The project envisaged distributing small seed packs for farmer-based seed production using SPCs both for seed production and scaling activities. The small seed-pack distribution was handled in two ways (Bishaw and Adamu, 2020): First, all farmers who receive the seed take the full responsibility to produce and market the seed directly through formal and informal sectors based on demand from users. Second, farmers pay back the quantity of seed provided to them in kind as revolving seed fund which can be used to produce quality seed for local distribution by district Office of Agriculture. The latter exercise termed as 'scaling' as it aimed at reaching more farmers with the new technology. Farmers were supervised by district Offices of Agriculture and ARCs and are linked to regional seed certification laboratories to produce and market certified/ quality seed of new fab bean varieties.

Distribution of small seed-packs for seed production:

The project distributed small seed-packs for seed production using SPCs or farmer groups. Farmers have been supervised by Office of Agriculture (OoA) at district level and linked to regional seed certification laboratories to produce quality seed of new varieties for marketing to formal sector (public/private seed enterprises, seed unions) or informal marketing within or beyond their villages through cash, and exchange with other farmers or for own use. New seeds that were provided every year since 2015 in the form of small packs for distribution to reach more farmers enhanced the dissemination of seeds of improved varieties and accompanying technologies and continues to expand in the form of diffusion in each community and district.

Distribution of revolving seed fund for quality seed production:

All farmers who received small seed-packs pay back the quantity of seed provided to them in kind as revolving seed fund which can be used to produce quality seed for local distribution by district Office of Agriculture. Farmers were supervised by district Offices of Agriculture and ARCs and linked to regional seed certification laboratories to produce and market quality seed of new faba bean varieties.

For on-farm seed production, 454.26 tons of certified/quality declared seed of faba bean seed was provided to farmers covering 2,407.97 ha of land, of which revolving seed constitutes 42.90%. A total of 9,146 farmers (13.91% female) participated in certified and/or quality seed production through small seed pack which was planted on 2,284.1 ha. An estimated total of 5,428.15 tons of certified/quality faba bean seed was produced. The 123.87 ha planted for seed production failed due to frost damage and waterlogging and gave no yield.

Farmer-to-farmer seed exchange:

In addition, farmer-to-farmer seed exchange enhanced the seed diffusion and technology scaling up to reach a greater number of farmers. Although not fully tracked, these approaches deployed about 505.8 tons of seed to plant on 2559 ha of land by an estimated 18,553 direct beneficiary farmers, producing 6,397.5 tons of quality seed/ grain. The performance of farmer-based faba bean seed production was above target and proved to be a feasible approach to improve timely access and enhance low-cost deployment of technologies.

Biofertilizer Distribution

Rhizobium inoculants are important biological inputs to reduce fertilizer input while improving productivity of faba bean. Rhizobium inoculants are also important in the barley-based cropping system to improve fertilizer-use efficiency of malt barley and improve productivity while maintaining malt-quality of barley. The project distributed 44,767 packs of rhizobium inoculant (strain EAL-110) to partner research centers for distribution to target farmers in the project areas. About 38,608 rhizobium inoculant packs distributed (86.2%) reaching 25,441 farmers (14.2% female) while the rest was not distributed as some farmers practiced early dry planting. More than one pack (one pack for a quarter of a hectare) was provided for each farmer, but some farmers planted larger area to cluster the fields to produce quality seed reducing the number of beneficiary farmers, whereas the area covered with the new technology remained the same.

Strengthening Capacity of Partners and Stakeholders

Strengthening of the capacity of technical staff of NARS and Offices of Agriculture and farmers, and provision of critical physical facilities has been key to the success and sustainability of the project.

Human Resources

Technical staff and subject matter specialists: Short-term Training of Trainer (ToT) courses on faba bean integrated crop management, seed technology and technology transfer to key stakeholders were organized for researchers and subject--matter specialists from development organizations who in turn provided hands-on practical training for farmers and development agents during the project period. The participants in ToT courses were primarily subject matter specialists (researchers and development agents) from the 12 partner research centers; and district and zonal agricultural extension experts in project target sites. A total of ten courses were organized (six by ICARDA and four by partner research centers), training 386 participants (10.1% female). The ToT activities were important since staff turnover was high in existing and new target districts of the project. Moreover, partner research centers also organized short-term courses for enhancing implementation of the project working with district office of agriculture.

Farmers and private sector seed producers: Poor crop management is the most important yield reducing factor that limits productivity of improved varieties across agro-ecologies in Ethiopia. Weeds, diseases, and insect pests not only reduce yield but also reduce seed quality in field and in store if not adequately controlled. Knowledge on local seed business (production, marketing and enterprise management and sustainability) is also limited among smallholder farmers and development practitioners in project target areas. Since 2015, twelve partner research centers in cooperation with the extension staff trained 11,750 farmers (15.3% female) and 2,122 development staff of stakeholders (18.1% female), which included development agents, extension experts, and junior researchers. This success was achieved since district and kebele agricultural extension staff had organized training activities, apart from those organized by the respective partner research centers, to promote the dissemination of improved faba bean technologies. The training activities that were provided during September and October were mainly practical where the crops were in the field. Training activities cover broader topics and include available improved faba bean technologies; seed technology (production, processing, storage, marketing, quality assurance, sustainability of farmer-based seed production and marketing, seed enterprise development and management), pest management (safe use of inputs, disposal, use of personal protective equipment); and importance of bio-fertilizer and utilization.

Provision of critical facilities for NARS and seed producers

After identifying critical gaps of facilities required for NARS and seed producer cooperatives, a concerted effort was made to provide support. The project provided two field vehicles; nylon net for construction of 13 insect-proof screen houses (each with 840 m^2) for faba bean breeding, variety maintenance and breeder seed production were provided to NARS; 100 Purdue Improved Crop Storage (PICS) bags to NARS to promote chemical free crop storage practice; three water pumps for irrigated seed production; and 10 multipurpose mobile threshers (1-3 tons hr^{-1}) for partner research centers, and 25 for seed producer cooperatives. Hands-on practical training to use threshers was given by the suppliers to unions and NARS technicians (Picture 1). Multi-crop threshers enable farmers for timely threshing and escape erratic rainfall which usually comes in February to March and spoil seed quality while the harvested crops are heaped in the field. Many partner cooperatives still lack facilities such as seed cleaners and proper seed storage which are required to produce high quality seed acceptable by seed certification agencies.

Picture 1. Multi-crop thresher demonstrated to subject matter specialists from research and agricultural development offices.

Faba bean Variety Suitability Mapping for Scaling:

The use of suitability maps of faba bean varieties for scaling to non-project target areas saves resources and accelerates technology dissemination. Maps for seven faba bean varieties were developed for scaling purpose (Nigussie *et al*., 2019a and b). The land suitability analysis included climate layers (rainfall and temperature during the growing period), length of growing period), topography (altitude and slope data), soil types and soil properties (pH, depth, texture, and drainage). Even though there are still limitations in availability of detailed data, these maps could serve as a guide for prioritizing varieties to target locations to increase impact potential and minimize or avoid the occurrence of negative responses. The faba bean varieties selected for land suitability mapping are presented in Table 3 and Figure 2.

From the suitability map, it can be noted that none of the commercial varieties have wider adaptation closer to the present faba bean area cultivated in the country. Some of the improved varieties selected from landraces may have specific or narrow adaptation. Faba bean varieties such as Moti and Walki have relatively large and highly suitable land area, which is closer to the present land area under faba bean cultivation. This suggests that there are potentials to develop well adapted varieties and expand faba bean production.

Area (ha) under different category of land suitability for faba bean varieties in Ethiopia

Variety	Highly suitable (85-100%)	Moderately suitable (60-85%)	Marginally suitable (40-60%)	Not suitable (0-25%)
Dosha	23,672	5,021,556	135,512	107,837,480
Gabelcho	192,836	9,409,608	305,368	103,110,408
Gora	107,740	7,168,148	871,828	104,870,504
Moti	325,660	15,290,300	674,588	96,727,672
Dagim	53,968	4,609,844	140,736	108,213,672
Hachalu	136,200	8,833,392	197,736	103,850,892
Walki	264,884	7,473,576	409,256	104,870,504

Table 3.

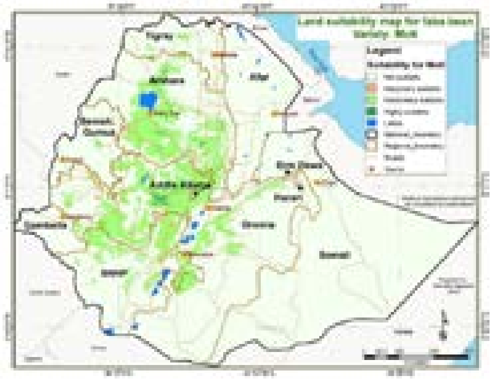

Figure 2. Land suitability map for Moti variety of faba bean

Project Coordination and Management

Monitoring, evaluation, and learning (MEL) has been an important component of this project. The aim was to ensure efficiency and effectiveness in project implementation. Project Steering Committee (PSC) meetings, Annual Review and Planning meetings, Quarterly, Annual and Biannual reports, monitoring field visits and indicator based FTFMS annual reports have been key monitoring and evaluation processes implemented during the project period (2015-2018). The primary data collectors are the implementing NARS partners. Consistency among data collection activities have been maintained through training workshops, annual review and planning meetings, monitoring field visits, and feedback on written reports. Field visits and meetings are presented below.

Project Steering Committee Meetings and Field Visits: The PSC members of the project included the Crop Research Directors of the five implementing partner research institutes (EIAR, ARARI, OARI, SARI and TARI); two representatives from the USAID mission in Ethiopia and centrally funded project management; and five members from ICARDA Headquarters and its Sub-Saharan Africa (SSA) Regional Program Office (Picture 2).

Picture 2. PSC meeting to review project progress and implementation at ICARDA, 2015

During the project period, six PSC meetings were held to review progress and evaluate the performance of the project, approve yearly work plan and budget, and provide guidance for project implementation. The PSC recommended that biological and social data collection for demonstrations should be strengthened, analyzed, reported, and presented in the annual review and planning meeting. Each partner research center was also advised to try and follow up for timely implementation of local level field days by kebele development agents to reach a greater number of farmers in the vicinity to participate and evaluate the technology in demonstration fields, on-farm seed production or out and up-scaling activities.

The PSC meeting on 29 March 2017 reviewed the achievements of the project and learned that the project was at accelerating stage. The PSC was of the opinion to endorse the support for funding the second phase of the project to keep the momentum of the project achievements in up-scaling of faba bean and malt barley technologies. The final PSC meeting on 29 March 2018 reviewed the implementation of previous recommendations and the participants were highly impressed by the achievements of the project in Phase I and reached a consensus and unanimous support for the request to be submitted for Phase II of the project.

The PSC also made field visits to Southwest and West Shewa and Arsi Zones of Oromia Region in 2015 (Picture 3); and North Shewa Zone of Amhara Region in 2016 (Picture 4) when the target crops were in the field.

In 2015, the PSC appreciated the project achievements and made some of the recommendations:

- Given the critical role of early generation seed production for the success of the project, the PSC recommended that each ARC should strive to produce enough EGS for further multiplication.
- Given the importance of seed quality it is recommended that the project works closely with public seed certifying agencies so that all seed produced by partner ARCs and farmers should be certified and meet minimum standards.

Picture 3. PSC visit to faba bean seed multiplication in South West Shoa Zone, Oromia Region, 2015

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In 2016, PSC members appreciated:

- The effort of the project in strengthening the partnership with NARS, which is an exemplary for other projects.
- The timely facilitation of seed certification activities by the DBARC of Amhara Region Agricultural Research Institute.
- And noted farmers' interest and demand for faba bean technologies being promoted.
- The effort of linking seed producer farmers to seed producer and marketing cooperatives and linking the cooperatives to seed unions, which was found to be an effective learning experience for them.

Picture 4: PSC visit to fab bean seed multiplication field in North Shewa Zone, Amhara Region, 2016

Annual Review and Planning Meetings: Four annual review and planning meetings were undertaken, including a project launching national consultative and planning meeting of 2015. Every year, on average, 56 participants attended the planning meeting (Picture 5). The participating organizations included: 13 partner agricultural research centers from federal and regional research institutes; public and private seed aenterprises; MoANR/BoAs; seed quarantine, inspection, and certification; agriculture clustering and commercialization, input suppliers; ATA, ISSD; Syngenta and MeKamba Agro-Chemical Companies; Menagesha Biotech Industry PLC; USAID; and ICARDA headquarters. The attendees actively participated in a plenary session of reviewing achievements on the first day, followed by working group discussions to develop the plan of work and budget for one and half day, and concluded with a presentation and discussion in a plenary session on the second half of the third day. These meetings were helpful in bringing all value-chain actors onboard, share responsibilities and spearhead implementation towards achieving the project's goal of improved livelihood and nutrition security of smallholder farmers.

Picture 5. Annual review meeting of the project in 2017, Addis Ababa, Ethiopia

Monitoring, evaluation and learning field visits: The ICARDA project management team (PMT) made regular monitoring, evaluation and learning visits to the implementing partners to assess the progress of the project, provide technical support and document the achievements on the ground. The visits included field visits to technology demonstration plots, field days, seed production fields, and seed storage facilities.

- These monitoring field visits helped in collecting important feedbacks that were brought up at annual review and planning meetings, steering committee meetings, and training workshops to create a common understanding and to improve effectiveness in implementation endeavors of the project.

- The project team also witnessed that the district and kebele agricultural extension staff had organized training activities and field days, apart from those organized by the respective partner research centers, to further promote the dissemination of improved faba bean and faba bean technologies. Such MEL experiences helped the project team to record such activities and share with other partners to collect and report training activities and field days organized by district and kebele extension staff. Collection and reporting of such information highly improved the projects' performance in capacity building activities.

Success Stories

- **Building sustainable local seed supply through farmer mobilization:** Linkages with district Office of Agriculture and farmers' groups enabled decentralized on-farm quality seed production and certification. However, it needs further support and strengthening of the linkages amongst stakeholders in the seed value chain to ensure sustainability.
- **Integrated faba bean gall disease management:** Faba bean gall disease reached epidemic levels and faba bean varietal choice, and the volume of seed produced and marketed has been limited. The project applied an integrated faba bean gall disease management (tolerant variety Walki and judicious fungicide spray) to revive faba bean production. The diffusion of the technology has been going on at speed since 2015 even though it is still not matching the scale of faba bean gall disease spread in the country. It is expected the development practitioners expand the experience to contain the threat of the disease.
- **Integrated faba bean parasitic weed management:** Orobanche became a threat for faba bean production in northern Ethiopia where farmers had abandoned the crop for over three decades (Gebru and Mesganaw, 2021). An integrated Orobanche management including the tolerant variety 'Hashenge', N fertilization and low dosage of glyphosate; enabled to reintroduce faba bean production in the northern highlands of Ethiopia. The project achieved a very promising technology diffusion rate responding to the high demand from farming communities in the hot spot districts of South Wollo (Picture 6) and South Tigray Administrative Zones. Given the scale of Orobanche infested areas, which remains large, there is a need for further efforts, especially in production of enough seed of the improved variety, to match the high demand.

Picture 6. Faba bean seed multiplication (var Hashenge) in Kutaber district. South Wollo Zone, Amhara Region, 2017

- **Scaling up of waterlogging tolerant faba bean varieties on Vertisols:** Vertisols has high potential to improve crop productivity and increase production in Ethiopia. However, its potential is highly limited due to waterlogging. Scaling-up of improved technologies such as use of waterlogging tolerant varieties accompanied by improved soil drainage using broad-bed and furrows re-introduced faba bean production that was abandoned in heavily waterlogged Vertisol areas. This is an impressive contribution in the effort of improving productivity and production on the Vertisols (Picture 7), covering about 8 million hectares of the highlands of Ethiopia.

Picture 7. Faba bean seed production (var Walki) in Were Illu district, South Wollo Zone, Amhara Region, 2017

- **Farmer-to-farmer seed exchange:** This is important and much advocated by the project as one of the strategies of technology diffusion among smallholder farmers. Although not fully tracked by partner research centers, agricultural extension services and development agents, the achievements in the project period show that 4,904.3 tons of certified/quality seed of faba bean was produced through farmer-to-farmer seed exchange.
- **Functional partnership established with stakeholders:** During project implementation effective partnership was established with district Offices of Agriculture and Administration at local level and key public and private sector stakeholders at federal and regional states. This is expected to bring about lasting changes in raising agricultural production while maintaining environmental sustainability and improving the livelihoods of smallholder farmers.

Lessons Learned and Way Forward

- Biofertilizers are important biological inputs which reduces the need for inorganic fertilizers while improving productivity of faba bean and subsequent cereal crops like barley, wheat or tef. Concerted efforts should be made to promote and popularize the use of biofertilizers along other complimentary inputs.
- Land suitability mapping of faba bean varieties revealed varietal choices to fit agro-ecological niches (productivity, disease resistance, earliness) and social economic needs (markets, consumption). Development of niche varieties suitable to diverse agro-ecologies and farming systems are required since breeding for developing resilient variety across variable environments depresses potential productivity. This approach goes with ensuring decentralized farmer-based seed production scheme.
- Dissemination of Orobanche tolerant variety help resurrect faba bean production in hot spot areas in South Wollo and South Tigray regions where farmers abandoned the crop for over three decades. The Hashenge variety is well accepted and adopted by farmers and spreading rapidly through farmer-to-farmer seed exchange. A concerted effort should be made in integrated Orobanche management to sustain faba bean production in the hot spot areas.
- Decentralized seed production through SPCs, Seed Unions and farmers groups, and farmer-to-farmer seed exchange scheme ensured availability of, access to and use of seed technologies compared to the formal public or private seed sector. Policy reforms should continue recognize and promote the diversity of seed business models (formal, intermediate, and informal) and diversity of seed certification schemes (certified seed and QDS) for ensuring sustainable faba bean seed system. Moreover, strengthening capacity of quality control and quarantine services is also important investment to ensure timely seed quality control and certification.

- Regardless of the innovative approach of decentralizing early generation seed production by NARS, breeder and pre-basic seed production is still a challenge since research centers have no sufficient land for this purpose. Moreover, off-season seed production enabled to avoid outcrossing and accelerate quality seed production for main season scaling used as a strategy to fill the gap. This needs policy level decision since most research centers remain the sole source of EGS.
- Establish a functional faba bean value chain, developing market preferred varieties, and provision of incentives to both seed and grain producers and exporters may require forging an effective public-private partnership to ensure competitiveness and sustainability of the sector.
- Established a fruitful linkage with research for development projects to create synergy in dissemination of new agricultural innovations. Farmers become source of seed for some of the projects operating in the target areas.
- Suitability mapping enabled to Identify improved varieties with broader adaptation than their current production, which is important for expanding faba bean cultivation in the country.

Conclusion and recommendations

The project demonstrated the scaling frameworks and catalyzed the partnership platform among research for development stakeholders along the crop value chain to transform faba bean production in Ethiopia. The project also created awareness and demand, which in turn stimulated adoption of improved faba bean technologies. It is expected that research for development partners and stakeholders work together and take these progresses and achievements forward.

Demonstrations of improved faba bean varieties and integrated crop management technologies proved successful in raising productivity and increasing production in project target areas, but the partial adoption of the full package of improved technologies by smallholder farmers remains an outstanding and persistent reason for a significant yield gap in the farmers' fields. Concerted efforts should be made in making available the full technology packages to realize the potential productivity and production.

Adequate planning of EGS with RARIs including decentralized production to overcome the chronic problem of source seed and strengthening and consolidating decentralized seed production with SPCs will anchor the faba bean seed sector in a sustainable footing.

Faba bean is an important cash crop for farmers and a valuable export commodity for exporters and the government. Strengthening capacity and linkage among actors in faba bean value chain is essential to maintain quality standards and competitiveness in the international markets. This needs further effort to strengthen capacity, create linkage among actors, bulk production and aggregation, and marketing of faba bean.

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Faba Bean Value Chain Analysis in the Highlands of North Shewa Zone

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Introduction

Pulses in Ethiopia occupy 13% of cultivated land and account for approximately 10% of the agricultural value addition, which are critical to smallholder livelihoods as a source of cash income and household consumption (Yirga *et al*., 2019). According to CSA (2015), food legumes are widely cultivated in potential mid and high-altitude areas of the country with elevations of 1800-3000 masl, receiving annual rainfall of 700-1100 mm.

Faba bean is a multi-use crop and is consumed as dry seeds, green vegetable, or as processed food. Its products are a rich source of high-quality protein in the human diet, while its dry seeds, green haulm and dry straw are for animal feed (Sainte, 2011). It is mainly used as human food in developing countries and as animal feed in industrialized countries.

Despite the importance of faba bean in the highlands and mid-highlands of Ethiopia in terms of both area coverage and volume of annual production, the average yield under smallholder farmers is not more than 1.89 tons ha^{-1} (CSA; 2015), though there are varieties with yield of over 2 tons ha^{-1} (MoA, 2018). Faba bean production is insufficient because of low yield where farmers are growing local varieties that are susceptible to diseases, insect pests, drought, and high summer temperatures (ICARDA, 2008).

Faba bean grows in the highland and mid-highland areas of North Shewa under rainfed and irrigation. It is used for crop rotation with cereals especially wheat, and barley. Farmers are demanding higher-yielding varieties to maximize their production and improve their livelihoods. In Basona-Worena and Tarmaber districts of North Shewa, farmers allocate large share of their farmlands to produce faba bean. According to the report of the district offices of agricultural development, faba bean is the most important field crop grown by the farmers in the study areas with allocation of 30% and 35%, in Basona-Worana and Tarmaber districts, respectively.

Faba bean is also important cash crop for farmers and generates foreign currency to the national treasury. In 2015, Ethiopia was the second in Africa and the tenth largest exporter of pulses crops in the world. Nearly 16% of Ethiopian pulses exported by pulses exporters worth US$ 240 million in 2015 which is 2.2% of global exports with an annual growth rate of 16% (Atnaf, 2015). Therefore, studying agricultural value-chain of faba bean helps for an understanding of the commodity and to take concrete measures that increases its contribution.

The production system of faba bean in North Shewa zone has not yet been well studied. Therefore, this study was conducted to identify and evaluate the potential actors of faba bean and their market-power relationships, and to assess the economic performance and state of market participation by the different value-chain actors.

Methodology

Study area description

The study areas were purposively selected in 2014/15 considering the hectarage for faba bean production. Basona-Worena and Tarmaber districts are adjacent in location and found in North Shewa Zone of Amhara region (Figure 1). Most areas of the districts are highlands (2400 up to 3100 masl) with bimodal distribution pattern. They receive an annual average rainfall of 929 mm with the respective annual average maximum and minimum temperatures of 21.4 and 9.0^{o}C, respectively. Light soils predominate in the areas (Woreda Office of Agriculture unpublished document). Rainfed barley-faba bean production system is predominant; other widely grown crops include wheat and field pea.

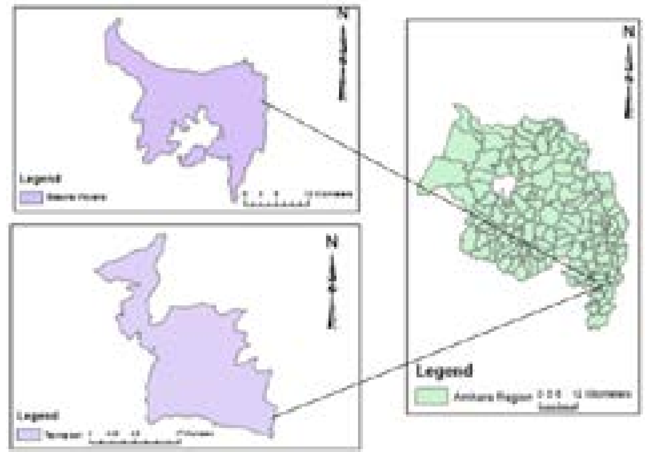

Figure 3. Maps showing the relative position of the study target districts in Amhara region

Data collection and sampling

Cross-sectional data were gathered through individual interview, key informant interview, and focus group discussions. Producer data were collected from 550 randomly selected farmers based on probability of proportionality. The farmers were selected from the respected areas using Cochran (1963) formula indicated in equation 1.

$$n = \frac{z^{2} * p(1-p)}{e^{2}} \quad \text{......................} \quad (1)$$

Where n = the sample size, z^2 = the abscissa of the normal curve that cuts of an area α at the tails (1-α) equals the desired confidence level of 95% the area under the normal curve i.e. z= 1.96, p is expected prevalence or proportion, e is acceptable sampling error that is 5%. In this study, p=6.25%, n=3437, z=1.96 with 95% confidence interval were the obtained values.

Value chain mapping, actors, and activity mapping matrix and market governance methods were used to identify the actors' involvement in the value chain. Value-chain mapping relationship was set using 30 key informant farmers, who have experiences in the production of faba bean, representing different socio-economic classes in terms of age, wealth, sex, and other social classifications. In addition, 24 small grain traders, processors, retailors and extension workers from offices of agriculture and NGOs were set in two different groups from each district for the focus group discussions. The two focus groups discussed the issues separately, and data were gathered based on the checklists developed. The producer groups discussed about the production and marketing practices, market channels, challenges, and opportunities of faba bean production at community level and their own experiences in their respective areas. The processors and trader groups discussed about the supply and demand gaps, the services provided, the market prices at different levels, faba bean supply trends, and the challenges. Finally, an in-depth value-chain interviews were conducted, and value chain actors reached consensus in the workshop. After the workshop, enough insight on functioning of the value-chain obtained and key actors identified. The detail cross sectional data were collected from 550 representative smallholder farmers using structured questionnaires.

Data analysis

Descriptive statistics of mean, frequency, percentage were employed to describe the socioeconomic variables, as well as production and market transaction activities. To analyze marketing performance of the actors involved in the value chain of faba bean, similar steps used by Tegegn (2013) were applied. Marketing margin was calculated by taking the difference between faba bean producers' price and retail price. This was calculated mathematically as the ratio of producers' price to consumers' price as expressed in equation 2.

$$\textit{Producers share} = \frac{\textit{Producer price}}{\textit{Consumer price}} = 1 - \frac{\textit{Marketing margin}}{\textit{Consumer price}} \quad \ldots\ldots\ldots\ldots (2)$$

We computed Gross Marketing Margin (GMM) with Net Marketing Margin (NMM). According to Mendoza (1995), marketing margins should be understandable as the gross marketing margins. Gross marketing margin is calculated as indicated in equation 3.

$$GMM = \frac{\textit{Farm gate price - Retail price}}{\textit{Retail price}} *100 \ldots\ldots\ldots\ldots (3)$$

Total Gross Marketing Margin (TGMM) is important to analyse the margins given by the difference between producers' (famers) price and the consumers' price, as indicated in equation 4.

$$TGMM = \frac{\textit{Consumer price - Producer price}}{\textit{Consumer price}} *100 \ldots\ldots\ldots\ldots (4)$$

The benefit share of actor (j) is computed from TGMM of the actor at that stage and is calculated as given in equation 5:

$$GMM_j = \frac{SP_j - PP_j}{TGMM} *100 \ldots\ldots\ldots\ldots (5)$$

Where, SPj is selling price at jth stage and PPj is purchase price at jth stage.

Results and Discussion

Socio-economic characteristics

In this study, the most common household characteristics identified and found important for agricultural activities include sex, age, family size, level of education, farming experience, and access to extension service. The result showed the proportion of female-headed households constitute about 20% of the total sample households. Households' age, education status, family size and farming experiences (Table 1) are important characteristics that describe the compositions, determine agricultural production activities in the agrarian family, and provide a clue to the structure of the sample and the population. The mean age of the household head was about 43.9 years. The average family size of the household was 5.24. The study areas have a potential for short season rainfall (belg), main season rainfall (meher), and irrigated production during the off-season. This enables farmers to produce different agricultural products throughout the year. All farmers produce agricultural products including faba bean in the main season and more than half of them participated during belg season. The average year of farmer's production experience was 19.5 years in the meher season and 13.9 years for using irrigation (Table 1).

Table 1. Socioeconomic characteristics of households

Variables	*Number of respondents*		*Percent (%) response*
Sex			
Male	440		80
Female	*110*		*20*
	N	Mean	SD
Age	*550*	*43.89*	*12.3*
Literacy rate	*550*	*3.15*	*3.38*
Family size	*550*	*5.24*	*2.05*
Farming experience in meher season	*550*	*19.5*	*12.56*
Farming experience in belg season	*329*	*19.31*	*12.02*
Farming experience using irrigation	*129*	*13.88*	*11.97*

Landholdings and land use

The average size of land and types of land use by farmers are presented in Table 2. Farmers had average land holding size of 1.3 ± 2.97 ha, of which 1.05 ±1.06 and 0.24 ±0.06 ha was allocated for crop production, grazing land and forage production, respectively. The average land area allotted for faba bean among crops being produced by the household was 0.35±0.25 ha. Since the area is a milk shed for dairy products and good market access for milk, farmers also allocated land for forage production for livestock. Tree plantation became sources of cash and farmers grow trees on farmlands for the purpose of income generation.

Table 2. Household's landholding size and uses

Land size and allocation	Number of respondents	Mean	SD
Crop production (ha)	549	1.05	1.06
Faba bean area share from crop land (ha)	317	0.35	0.25
Grazing and forage development (ha)	180	0.24	0.06
Tree plantation (ha)	120	0.14	0.04
Homestead (ha)	549	0.001	0.00
Other uses (ha)	120	0.17	0.16
Average landholding size (ha)	**550**	**1.34**	**2.97**

Faba bean production practices

From the total (317) faba bean producer farmers 52% of the households used seed of improved faba bean varieties (30% of total of 550 sampled farmers), followed by weed management and row planting practices with the respective proportion of about 33 and 17% (Table 3). The study also revealed that only 1.26% of respondent farmers use faba bean in crop rotation system. This is a big challenge to maintain soil fertility and improve farm productivity in the prevailing crop production system that uses very low external inputs.

Table 3. Farmers' faba bean production practices

Farming practice	*Number of respondents*	*Percent (%) response*
Crop rotation	4	1.26
Row planting	54	17.04
Weed management	104	32.81
Seed cleaning and treatment	9	2.84
Seed of improved variety	164	51.73
Recommended seed rate	39	12.30
Soil fertility management	37	11.67

The major faba bean production challenges in the area are low productivity, disease, frost and lack of early maturing varieties. Farmers prefer high yielding varieties for high potential areas and early maturing varieties for frost prone areas. The faba bean improved varieties under production in the study areas included Walki and Gabelcho (Figure 2). From the users of improved faba bean varieties, 96% of them grew Walki variety for its higher productivity and the small proportions of them produced Gabelcho because of low productivity compared to Walki. However, Walki is susceptible to newly emerged faba bean gall disease unless managed properly.

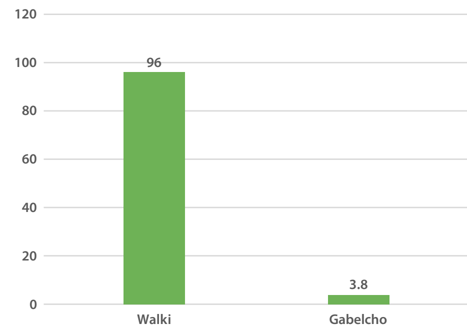

Figure 2. Improved faba bean varieties grown in the study areas (%)

Input use

Most farmers do not apply chemical fertilizer for faba bean production (Table 4). However, about 86% of farmers apply compost/manure (Table 4). Use of herbicides for weed control in faba bean production is very limited.

Table 4. Application of agricultural inputs for crop production

Inputs	*Crops*			
	Faba bean		*Other crops*	
	Number of farmers	*%*	*Number of farmers*	*%*
Urea	*0*	*0*	*253*	*48*
DAP/NPSB	*24*	*12*	*230*	*44*
Compost	*178*	*86*	*89*	*18*
Herbicide	*4*	*2*	*218*	*42*

Farmers' perceptions

During the focus group discussions and key informant interviews, the participants discussed the production trends and importance of faba bean. The participants indicated continuous changes in area coverage, volume of production, and productivity of major crops over the past five years. Farmlands shifted from faba bean to malt barley production and the area coverage of faba bean has declined. Smallholder farmers perceived that pulse crops including faba bean have multiple benefits of improving food security, as an affordable source of protein, low input and labor demand, and low costs of production compared to cereals. Small amount of chemical fertilizer is enough to produce faba bean. Faba bean can have an income benefit for smallholders, both in terms of crop diversification and high profit margins compared to cereals and contributes to improve soil fertility. The decline in production trend of faba bean resulted from lack of improved technologies such as early maturing and disease resistant varieties or disease and weed management technologies.

Area coverage and volume of production

Farmers in the study areas have limited crop commodity alternatives for their production environment. The production and area coverage of faba bean in the study area declined because of biotic and abiotic stresses. The devastating damage caused by the newly emerged disease called faba bean gall significantly contributed to the declining trends in faba bean production. Unpublished district agricultural office reported that faba beam area coverage was 5312,5 and 2418 has, respectively for Basona-Worana and Tarmaber districts with production of 11166 and 4836 tons of production in the same order. Focus group and key informant interviews on the purpose of faba bean production and utilization revealed that farmers use faba bean for home consumption, market, and seed reserves (Figure 3).

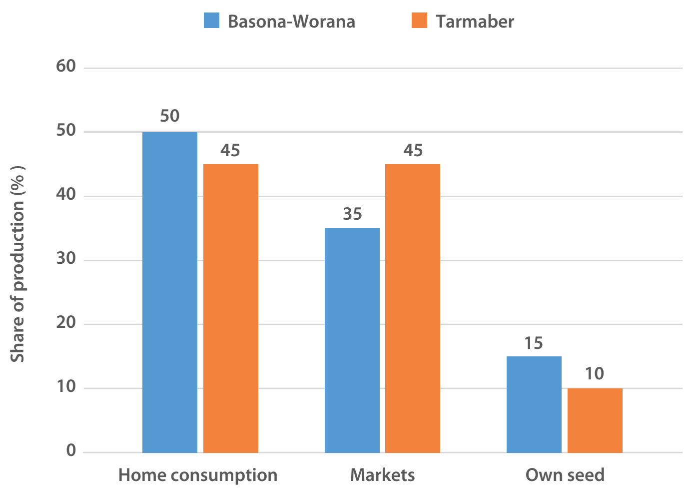

Figure 3. Faba bean production and their use in the study areas

Relationships among value chain actors in production and marketing

The relationships among the faba bean value chain actors in production and marketing are presented in Table 5. The results showed that private sectors are involved in production, transportation, processing, input supply, product distribution, and consumption of faba bean products. The public sectors are involved in input supply, capacity development, and facilitation roles in the value chain. NGOs are involved in both input supply and facilitation activities in their respective interest areas. Farmers primarily involved in the production and marketing of faba bean. Traders and processors acted at different levels of value addition processes.

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Table 5. Activities and value-chain actors' analysis matrix of faba bean

Actors	Roles in the value chain	Limitations	Existing challenges
Farmers	Production of crops	Low quality and quantity of supply	Pest and diseases of faba bean
Multipurpose cooperatives and unions	Input supply and marketing faba bean	Low financial capacity for marketing	Low attention to marketing involvements
Grain traders	Input supply, marketing, and transportation	Operate individually and not organized	Product adulteration, not trusted by farmers
Processors (local baltina, restaurants, hotels)	Marketing, roasting, splitting, and crushing faba bean to kik and flour	Low attention for quality products and production improvement	Not interested to partnership linkages
Seed enterprise	Seed supply and seed marketing	Not enough seed for improved varieties	Low attention for faba bean seed
Extension workers	Facilitation, awareness creation of farmers	Low capacity, many task burdens	Low attention for market linkages
Research institutes (DBARC, ILRI, ICARDA)	Capacity building, input supply, facilitation, technical support	Limited area, low exposures	Project focused and limited in scope
NGOs (SUNARMA, Adhino, CCF)	Input supply, market linkages, technical support	Limited area coverage, specific interest	Not linked to other actors
Public sectors (OA and AGP)	Facilitation, technical support, and input supply	Limited intervention	Not linked to other actors
Consumers	Consumption of the produce	Needs direct market links with producers	Low demand for value added produce

The value chain map of faba bean in the study areas is presented in Figure 4. The map shows the actors and their relationships, and economic activities at each stage in relation to physical and monetary flows. Faba bean products pass through different phases of production, processing, and marketing to reach the final consumers. The downward arrow shows the flow of products, and the upward arrow shows the flow of money while the information flow is going in upward and downward direction. The value chain mapping of faba bean indicated that there is technical support to improve farmers' knowledge in crop production and management through the existing extension system. Seed enterprises, research institutes, and some NGOs have delivered seed, while cooperatives and agro-dealers supplied other inputs like fertilizers and pesticides. Buyers of the produces (processors, supermarkets, hotels and restaurants, cooperatives, and traders) participated in marketing of faba bean.

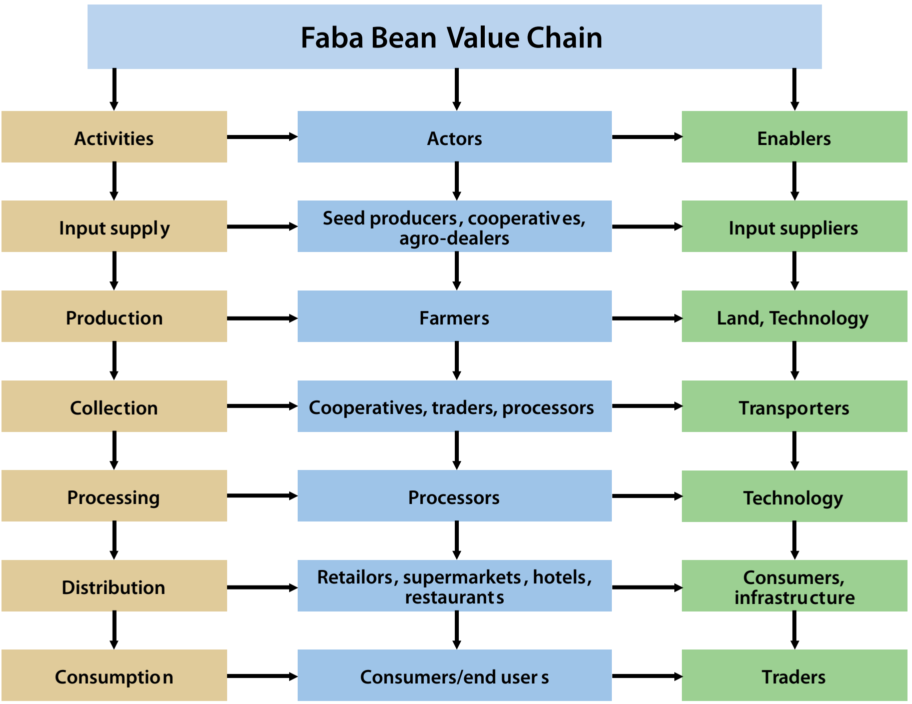

Figure 4. Mapping faba bean value chain

The value chain functions starting from preparation of farms, sourcing inputs, production extending to post-harvest handling and marketing. Farmers are the key actors in the value chain. The major activities, which are performed by faba bean producers include plowing, sowing, fertilizing, weeding, pest/disease control, harvesting, and post-harvest handling (cleaning and storage). The larger quantities of faba bean are sold during and soon after the harvest to cooperatives, grain traders, processors, and retailers and then to consumers of the area within the same production year. The local processors obtained the produce mainly from grain traders and cooperatives. The consumers access the processed faba bean produces in various forms as grain, flour (shiro), splits (kik) and food. This analysis shows that retailers had relatively large market governance power and they handle about 35% of produce, followed by farmers cooperatives (25%) and grain traders (20%).

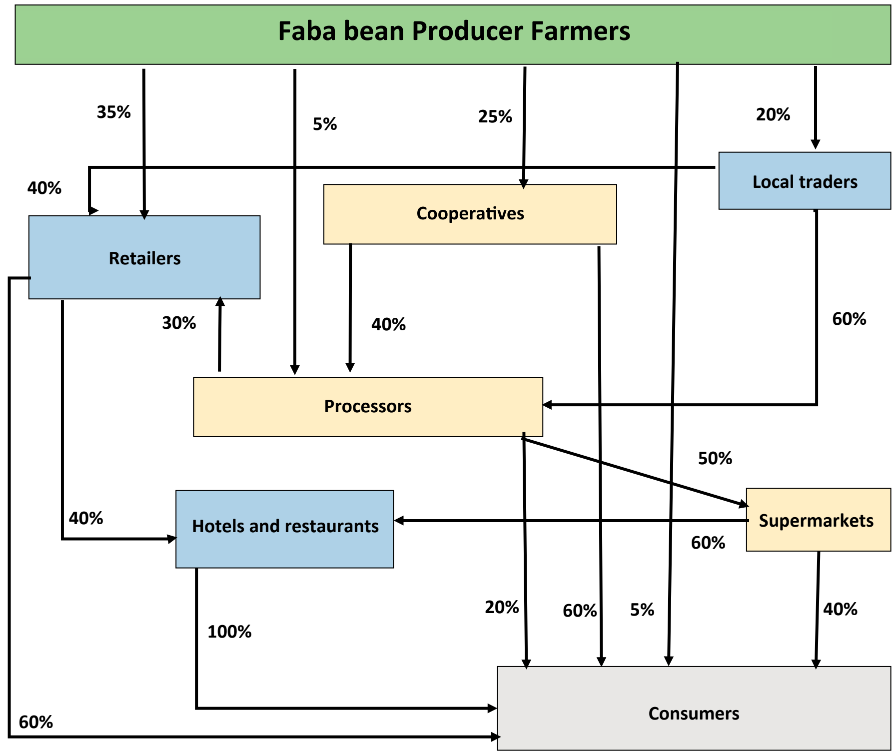

Figure 5. Mapping faba bean marketing channels

Cost-benefit analysis of faba bean in the value chain

The production costs were collected from farmers production practices and use of inputs and technology packages. The major average production cost bean per hectare emanates from high seed rate leading to higher seed cost, and pesticide costs for disease control (Table 7). Faba bean had higher benefit from low fertilizer input and the associated costs, and high grain market price. Farmers in Basona-Worana district earned higher net income from better productivity and higher market price of faba bean (Table 6). Market prices varied from 12,000 to 15,000 ETB t^{-1} during high and low grain supply periods depending on the production volume. The average farm-gate price of grain yield immediately at harvest were 13,700 and 14,000 ETB t^{-1} in Tarmaber and Basona-Worana districts, respectively.

Table 6. Average cost and benefit of faba bean production in Basona-Worana and Tarmaber districts, North Shewa

Cost items	Production costs (ETB ha^{-1})	
Seed	2200	
NPS fertilizer	938	
Labor	3200	
Pesticides	700	
Transportation	1200	
Bio-fertilizer	120	
Baggage	240	
Draft power	2400	
Total cost	10998	
Benefits	Basona-Worana	Tarmaber
Yield (t ha^{-1})	2.1	2.0
Gross benefit (ETB ha^{-1})	29,426.35	27,400
Net benefit (ETB ha^{-1})	**18,428.35**	**16,402**

Note: Kebeles in the two districts are adjacent and have common markets

Many actors involved in faba bean processing activities produce different end-products for different uses. The end products pass through various steps from production to consumption. Faba bean is consumed as whole grain, kik[2] wot, or shiro[3] wot[4] (sauce) in the local market (Table 7). The end products depend on the grain or seed sizes. Shiro wot (sauce) prepared for food from small seeded faba bean types fetch higher net return compared to shiro flour per se. Kik produced from large seeded faba bean had the lowest net return in the value chain. In general, when the value addition of faba bean increased, the net benefit from the commodity also increased along the value chain. Local processors (baltina[5]) used small seeded faba bean grain to produce flour, which is locally called shiro. Large seeded faba bean processed for splits in to kik and graded for food items locally called foul[6].

Farmer's cooperatives and traders buy the grains from the producer farmers and resale the grain for local processors to make shiro and kik. The processors grade their produce and sell to the local consumers, and bars and restaurants (Table 8).

Table 7. Processed faba bean product costs and value chain benefits

Food products	Production costs (ETB kg^{-1})	Product price (ETB kg^{-1})	Net return (ETB kg^{-1})
Split (kik)	24.00	35.00	11.00 (45.8%)
Flour (shiro)	24.80	40.00	15.20 (61.3%)
Food (shiro sauce)	120.00	200.00	80.00 (66.7%)

[2] Split of faba bean seeds
[3] Flour of roasted faba bean grain for sauce
[4] Sauce made from shiro for eating purposes
[5] Local processers making grain into flour used for sauce
[6] Stewed faba bean seed

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Challenges along the value chain

Farmers' group discussions and household survey responses revealed that common set of constraints span the production, collection, transportation, and demand sinks of faba bean value chain.

Production practices: Faba bean productivity is below the potential due to low investment, especially on use of chemical fertilizers, pesticides, and improved seeds. Poor agronomic practices like application of sub-optimal seed and fertilizer rate, time of planting, poor weed management and lack of proper drainage practices in waterlogged areas also contributed to low productivity of faba bean. There is a decline in faba bean production due to faba bean gall disease, African ball worm, high input costs, limited availability of seed and frost.

Knowledge, awareness and technology transfer: Limited awareness and familiarity with the available improved varieties and technologies hindered the technology transfer to improve productivity. Low level of technology adoption of the improved varieties, weak market linkages, and poor partnership among the actors contributed to low productivity.

Aggregation and trade: The produce supply and marketing were severely affected by the supply side constraints such as poor quality, low quantity, and seasonal shortages. This affected sustainable flow of the products along the value chain and further weakened interactions among value chain actors. Seasonal supply variation of the grain also limited the continuous flow and availability of the commodities. Price fluctuation and the limited involvements of farmers' cooperatives in the value chain also contributed to the challenges of aggregation and trading.

Conclusions and Recommendations

Faba bean is one of the major crops grown in the study areas and occupied considerable share of farmlands. Low productivity of faba bean resulted from low investment and improper agronomic practices such as lack of disease resistant improved faba bean varieties, low fertilizer application, poorly drained waterlogged soils, and weed management practices. Faba bean production and supply trends declined due to disease and insect pest infestations. Price fluctuation throughout the year affected its sustainable supply. Processors earned high rate of returns from faba bean and had high market governances compared to smallholder farmers. Retailers have high market governance role in which large volume of faba bean transacted through this value chain actors.

Strengthening the partnership among faba bean value chain actors will smoothen the value chain processes and maximizes the benefits. Provision of sustainable and adequate market access and information to the farmers is important to improve the farmers' awareness. Technology generation to manage faba bean gall disease and insect pest damages is one of the major intervention areas to improve productivity and production of faba bean. Reducing high market governance of traders and processors to motivate smallholder farmers for improving production and supply is important.

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CHAPTER 2

FABA BEAN TECHNOLOGY VALIDATION AND DEMONSTRATION

Participatory Evaluation of Faba Bean Varieties in Hadiya, Kembata-Tembaro and Wolayita Zones of Southern Ethiopia

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Farmers in Duna and Sodo Zuria districts as well as farmers' cooperatives in Angacha and Doyogena districts, Southern Nations Nationalities and Peoples Region (SNNPR) are demanding high-yielding faba bean varieties to maximize yield and expand production and thereby increase their income and improve their livelihoods. However, most of the improved faba bean varieties have not yet been evaluated and demonstrated in these areas. In participatory approach, farmers evaluate and select varieties under their local farming practices. Participatory evaluation methods have been successfully applied in faba bean (Daniel *et al*., 2016), common bean (Gurumu, 2013), sweet potato (Urgessa *et al*., 2014), bread and durum wheat (Zebrhe and Yikaalo, 2015) and chickpea (Bereket and Abdirazak, 2018) resulting in increased acceptance of crop varieties by farmers. Therefore, this study was conducted to evaluate faba bean varieties with desirable traits under farmers' condition to identify high yielding and farmers' preferred varieties, and to create linkage and awareness among stakeholders of faba bean in Hadiya, Kembata-Tembaro and Wolyta zones of the SNNPR.

Materials and Methods

Study locations

The study was carried out in faba bean growing areas of Angacha and Doyogena, Duna and Sodo Zuria districts of Kembata-Tembaro Hadya and Wolayita zones, respectively during the 2016/2017 main cropping season (meher).

The site at Angacha represents mid to high altitude at 1501-3000 masl. Average annual rainfall is from 1000 mm to 1400 mm and the mean annual temperature ranges from 12°C to 16°C for Angacha (Abebe, 2013).

Doyogena lies at a latitude of 7°18'25"N-7°21'49"N, longitude 37°45'33"E-37°48'51"E with an altitude ranging from 2300 to 2800 masl. It receives mean annual rainfall of 1200 to 1800 mm and mean annul temperature of 16°C; and the soil type is red and black clay loams (Tsegaye Fitebo, 2014).

Duna (Andegna Otoro kebele) is located at 7°20'.25"N; 37°35.554''E with an altitude of 2,666 meter above sea level (masl). It receives mean annual rainfall of 1196.22 mm and the temperature ranges from 10°C to 18°C in a wet season and 20°C to 25°C in a dry season (Tadesse, 2015).

The sites in Waraza Lasho kebele of Sodo Zuria woreda lies at latitude 6°51'36"N and longitude 37°45'41"E with an altitude of 1961 masl. Average annual rainfall ranges between 1051.9 mm and 1341.5 mm and annual mean temperature is 15.3°C for Sodo Zuria (Seifu, 2013).

Experimental materials and design

Field experiments were conducted under on-farm conditions at four target sites. Five released faba beam varieties (Dosha, Walki, Bobicho-05, Tumsa and Gabelcho) were evaluated with a local cultivar as a control.

The experiments were laid out in a randomized complete block design (RCBD) on three farmers' fields (with three replications) at four districts. The experimental land size of each farmer was 21 m x 17 m with a plot size of 10 m x 5 m for each variety. The spacing between rows and plants was 40 cm x 10 cm. Other management practices were done as per the recommendations for each location.

Variety evaluation

The variety evaluation and demonstration trials were carried out through participatory approach by involving individual /or a group of farmers; seed multiplying farmers' cooperatives; agricultural extension officers, Agricultural Transformation Agency (ATA), Durame Seed Quality Control and South Seed Enterprise during field days/visit. Moreover, farmers and relevant stakeholders have evaluated and ranked the varieties at different growth stages of the crop. The activity was jointly monitored by researchers, woreda agricultural experts, cooperative and development agents (DA's).

Training

A total of 180 stakeholders (farmers; development agents and extension staff) of both sexes (male=162, female=18) were trained in the four target districts namely Duna, Doyogena, Sodo Zuria and Angacha. The training enabled farmers and development agents to have awareness on management and proper handling of the available technology packages.

Field days

A total of 390 participants (farmers; cooperatives, union, ATA experts, extension staff) of both sexes (male=335, female=55) participated in the field days in the four target districts namely Duna, Doyogena, Sodo Zuria and Angacha. Farmers, representatives from cooperatives and other stakeholders, individually or in a group ranked the faba bean varieties in the different sites. They finally agreed on the key criteria used by farmers to evaluate and select the faba bean varieties; these were grain yield, disease resistance, grain size and lodging resistance.

Farmer's Evaluation

Farmers who participated and evaluated the trial were representatives of the area and have long experience in farming. Selection criteria of farmers were set based on an extensive discussion during flowering, maturity and harvesting stage of the crop. The criteria farmers used in identifying the suitable varieties depends on their perception of the existing constraints and opportunities for faba bean production in the test areas.

Data collection and analysis

The agronomic performance, farmers' preferences, and perceptions of agricultural experts of faba bean varieties were collected from field trials and through interviews and group discussions with farmers organized during field visits and field days. Farmers' and agricultural experts' perception and opinions were collected through group discussions. A checklist was used for interviewing the participants of the field day to assess farmers real interest of the varieties to make decision for promotion and scaling. Farmers' preferences and selection criteria based on phenological characters such as plant height, stem strength, maturity time, seed number, seed size, grain yield and straw yield (animal feed) were collected. The ranking procedure was explained to participants regarding each selection criterion. Individual farmers and cooperative members scored each variety for individual traits considered important by them and ranking of varieties were done on a scale of 1 to 6; and 1 being the highest score representing superiority and 6 being very poor (the lowest rank).

All data collected from farmers in different districts were synthesized and compiled for analysis of variance using SAS package. Means were separated using the Least Significant Differences (LSD) at 0.05 probability level.

Results and Discussion

Grain yield of faba bean varieties

Analysis of variance (ANOVA) revealed significant ($P < 0.01$) differences for grain yield among the faba bean varieties (Table 1). Mean grain yield of varieties ranged from 1933.3 kg ha^{-1} for local variety to 3466 kg ha^{-1} for Tumsa with overall mean value of 2744.4 kg ha^{-1} at Duna. The grain yields obtained from Dosha, Tumsa, Bobicho-05 and Gabelcho were significantly ($P < 0.05$) higher than that of the local variety. At Angacha, mean grain yield (kg ha^{-1}) ranged from 3200 for variety Dosha to 1933.3 for local variety. In Doyogena district, the highest grain yield was recorded on Dosha (3733.3 kg ha^{-1}) followed by Bobicho-05 (3533.30 kg ha^{-1}); whereas the lowest was recorded on local variety (2200 kg ha^{-1}). Similarly, at Sodo Zuria, varieties Walki (1866.7 kg ha^{-1}), Gabelcho (1800 kg ha^{-1}) and Tumsa (1733.3 kg ha^{-1}) gave higher grain yield than the rest of the varieties (Table 1).

Table 1. Mean grain yield of faba bean varieties across test districts in 2016/2017 cropping season

	Grain yield (kg ha^{-1})							
Varieties	Duna	Angacha	Sodo Zuria	Doyogena	Mean	RR	FR	YA (%)
Bobicho-05	2866.7	3133.3	1666.7	3533.3	2800	2	2	54.1
Walki	2266.7	2200	1866.7	2666.7	2250	5	5	23.8
Tumsa	3466.7	2600	1733.3	3266.7	2766.7	3	4	52.3
Dosha	3000	3200	1583.3	3733.3	2879.2	1	1	58.5
Gabelcho	2933.3	2666.7	1800	3466.7	2716.7	4	3	49.5
Local	1933.3	1933.3	1066.7	2200	1816.7	6	6	-
Grand mean	2744.4	2622.2	1619.4	3144.4	2532.6			
CV (%)	18.56	12.11	10.35	14.58	15.27			
LSD	926.85	577.85	305.18	834.13	319.24			
F-ratio	**	**	NS	**	**			

Note: YA= yield advantage over local; RR = Researcher's rank; FR= Farmers' rank

The grain yields obtained from Dosha (2879.2 kg ha^{-1}), Bobicho-05 (2800 kg ha^{-1}), Tumsa (2766.7 kg ha^{-1}) and Gabelcho (2716.7 kg ha^{-1}) were significantly (P< 0.01) higher than that of the local variety (1816.7 kg ha^{-1}); and these improved varieties had the respective yield advantage of 58.5%, 54.1%, 52.3% and 49.5 % over the local variety (Table 1).

Farmers' evaluation

Agronomic performance such as grain yield, stand establishment, branch number, pod number per plant, seed number per pod, plant height, earliness/maturity, disease resistance, leaf shedding, aphid resistance, stem strength, large seed size and straw yield (livestock feed) as well as marketability, and suitability for intercropping were identified as the most important farmers' selection criteria.

Grain yield was considered as the most important selection criteria for each faba bean variety, which agrees with the results reported by Bekele (2016) and Daniel *et al*. (2016). Preference scores varied greatly among the farmers for each variety in each district (Table 2). Based on mean overall score, the most preferred varieties were Tumsa, Dosha, Bobicho-05, and Gabalcho in Duna district; Dosha, Bobicho-05, Gabelcho, and Tumsa in Doyogena district; Walki, Bobicho-05, Dosha, and Tumsa in Sodo Zuria district; and Bobicho-05, Dosha, Gabelcho, and Tumsa in Anagacha district (Table 2). In the Sodo Zuria district, farmers selected Walki as the best choice.

Dosha was the most preferred variety across districts followed by Bobicho-05, Gabelcho, and Tumsa (Table 2). The local variety was the least ranked because of its low productivity. Variety Dosha ranked first because of its higher productivity, stem strength, disease resistance, and tillering capacity. Farmers always ranked the improved varieties as superior to the local variety for grain yield and disease resistance in all

the test locations. In pair-wise ranking, Dosha was again the most preferred variety, whereas the local variety was the least preferred by farmers (Table 3). Overall preference score based on data from all sites showed the most preferred varieties were Dosha, Bobicho-05, Gabelcho and Tumsa, while the least preferred one was the local variety (Table 2 and 3). Walki had an average preference in terms of mean score, but the scores were inconsistent among the groups of farmers. This result indicated that Dosha, Bobicho-05, Gabelcho, and Tumsa were farmers' and researchers' best preferred and top performed varieties that can be considered as potential varieties to be widely produced while Walki variety was specifically recommended for Sodo Zuria district.

Table 2. Ranking and scoring of faba bean variety selection criteria (1-15) by farmers at four districts

Varieties	Duna			Angacha			Soddo Zuria			Doyogena			Overall rank
	Total score	Mean score	Rank	Total score	Mean score	Rank	Total score	Mean score	Rank	Total score	Mean score	Rank	
Bobicho-05	47	3.1	4	27	1.8	1	32	2.1	1	39	2.26	3	2
Walki	51	3.4	5	76	5.1	6	32	2.1	1	58	4.1	5	5
Tumsa	30	2.0	1	64	4.3	5	46	3.06	2	54	3. 86	4	4
Dosha	33	2.2	2	27	1.8	1	47	3.1	3	26	1.73	1	1
Gabelcho	43	2.9	3	45	3.0	3	46	3.06	2	34	2.26	2	3
Local	64	4.3	6	60	4.0	4	70	4.66	4	70	4.66	6	6

Note: Scoring of farmers selection criteria was based on a ranking scale from1-6, with 1 as the most important to 6 as the least important for each trait

Table 3. Pairwise ranking of faba bean varieties based on farmers' selection criteria

Characters	Bobicho-05	Gabelcho	Walki	Tumsa	Dosha	Local variety
Bobicho-05	X	Bobicho-05	Bobicho-05	Bobicho-05	Dosha	Bobicho-05
Gabelcho		X	Gabelcho	Gabelcho	Dosha	Gabelcho
Walki			X	Tumsa	Dosha	Walki
Tumsa				X	Dosha	Tumsa
Dosha					X	Dosha
Local variety						X
Total score	4	3	1	2	5	0
Rank	2	3	5	4	1	6

Lessons learned

- Training stakeholders (farmers, development agents) on available technologies is a useful approach and their participation in the selection of improved technological interventions is necessary for successful implementation of scaling activities.
- The timely supply of any improved agricultural technology/input is crucial for its use and adoption.
- Participatory on farm evaluation on farmer's fields was a good approach compared to past on-farm research activities.

Conclusions and Recommendations

Participatory on farm evaluation and demonstration of improved faba bean varieties was conducted in Duna, Angacha, Doyogena and Sodod Zuria districts of Southern Ethiopia to create awareness and increase faba bean productivity and production. Farmers used different parameters to evaluate the tested faba bean varieties. In this study, both farmers' and breeders' evaluation confirmed that Dosha, Bobicho-05, Tumsa, and Gabelcho varieties were superior in grain yield compared to the local cultivars; thus, they are recommended for production in the test locations. The highest yielding and most preferred variety, Dosha, showed 58.5% yield advantage over the local variety across the test locations, but it was outyielded by Walki variety at Sodo Zuria district. All improved faba bean varieties outyielded the local variety in all test locations. However, according to farmers' preference, improved faba bean varieties Dosha, Bobicho-05, Gabelcho, and Tumsa are recommended for production in all test locations while Walki is recommended for Sodo Zuria district among the test locations.

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Demonstration of Improved Faba bean Varieties on Vertisols in North Shewa Zone

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Faba bean grows under rainfed and irrigated conditions in North Shewa Zone of Amhara Regional State. However, the production and productivity of faba bean on Vertisols areas of North Shewa is declining due to chocolate spot, gall and other faba bean diseases and lack of improved varieties. Moreover, the available local varieties in the hands of the farmers have small seed sizes. Therefore, it become evident to create awareness and demand by demonstrating improved faba bean varieties with larger seed size for production on Vertisols to meet domestic and international export market demands.

Materials and Methods

Description of study locations

The on-farm demonstration activities were carried out at Siyadeberina-Wayu, and Moretina-Jiru districts in 2016 and 2017 meher cropping seasons. These areas are characterized by a unimodal rainfall pattern and receive an average annual rainfall of 929 mm. The annual average maximum and minimum air temperatures are 21.4 and 9.0 ^{o}C, respectively. Vertisols are the dominant soil types. The crops widely grown in the study areas include wheat, tef, faba bean, and lentil. The altitude of the study locations ranges from 2560 to 2670 meters above sea level (masl).

Experimental materials and crop management

The experiment was carried out using three faba bean varieties, Walki, Dagim and Hachalu, on six farmers' plots; farmers were considered as replications. The seed rates were 240, 250 and 140 kg ha^{-1} for Walki, Hachalu and Dagim, respectively. The fertilizer application rate was 100 kg NPS ha^{-1}. Plot size for each variety was 10 m by 10 m on each farmer's field. Planting was done by hand broadcast on BBF (broad bed furrow) based on the farmers' practice during the first week of July. Other agronomic practices like weeding were carried as deemed necessary. In both years, harvesting was done by quadrant sampling (five quadrant from each plot) when the crop matured in the second week of November.

Training and field day

At the initial stage of the activities, 67 (22 female) farmers and development agents were trained on the agronomic practices and attributes of the faba bean varieties. Field monitoring and evaluations were done by farmers, development agents and researchers at different crop growth stages. At crop maturity, field days and variety evaluation were organized by inviting different stakeholders and farmers. Farmers were randomly selected from each stratum of the community.

Data collection and analysis

Socio-economics data like farmers' preference, and farmers' and stakeholder's perception on the varieties were collected. Agronomic data like plant height, tiller number, number of pods per plant, number of seed per pod, and yield were also collected to evaluate the performance of the varieties.

Farmers evaluated the three varieties against each other by pre-setting the criteria. A total of 115 (37 females) farmers and 15 (7 females) experts participated during evaluation of the test varieties across the study sites. The results were presented to and discussed in two groups during 2016 and 2017.

Social data and farmers' preferences were analyzed by using pair-wise matrix and preference ranking techniques. Economic data were analyzed by cost-benefit analysis, while the agronomic data were analyzed by simple descriptive statistics.

Results and Discussion

Farmers' preference

The major selection attributes identified by farmers in 2016 cropping season were frost tolerance, number of tillers/branches per plant, flower abortion, number of pods per plant, number of seeds per pod, and seed size (Table 1). The main interest of farmers for faba bean production were varieties which have a greater number of tillers/branches per plant, pods per plant, seeds per pod, and large seed size. Based on these attributes, farmers preferred the varieties Walki followed by Hachalu (Table 2).

Table 1. Pair-wise ranking matrix of selected criteria in 2016 meher production season

Attributes	NPPP	Frost tolerance	Tillering	NSPP	Seed size	Flower abortion	Scores	Rank
NPPP		NPPP	TL	NPPP	NPPP	NPPP	4	2
FT			TL	NSPP	SS	FA	0	6
TL				TL	TL	TL	5	1
NSPP					NSPP	NSPP	3	3
SSB						SS	2	4
FA							1	5

Note: NPP= number of pods per plant, FT=frost tolerance, TL=number of tillers/branches per plant, NSPP= number of seeds per pod, SS= seed size, FA= flower abortion

Table 2. Farmer's preference ranking matrix summary sheet of faba bean in 2016 meher production season

Varieties	Farmers' selection attributes and scoring values							Rank
	NPPP	FT	TL	NSPP	SSB	FA	Mean	
Walki	2.56	2.22	2.67	2.52	2.04	2.56	2.43	1st
Hachalu	1.67	2.67	1.89	1.63	2.89	1.93	2.11	2nd
Dagim	1.78	1.89	1.48	1.85	1.07	1.48	1.59	3rd

Note: Scoring value 3- Best; 1- Poor; NPPP= Number of pods per plant; FT= Frost tolerance; TL= number of tillers/branches per plant; NSPP= Number of seeds per pod; SSB= seed size/boldness; FA= Flower abortion

In 2017, farmers also identified major attributes and prioritized them based on their relative importance (Table 3). Based on farmer's evaluation, the main preferences for faba bean production were number of tillers, number of pods per plant, number of seed per plant, seed size and adaptability (moisture, environment, soil). Based on the criteria prioritized (Table 3) farmers preferred Hachalu followed by Walki in most attributes (Table 4). Table 5 shows seed size was the most important preference of farmers.

Table 3. Pair wise ranking matrix of selected criteria for evaluating faba bean varieties in 2017 meher production season

Attributes	SS	NPPP	PH	AD	BM	NSPP	TL	Scores	Rank
SS		NPPP	SS	AD	SS	NSPP	TL	2	5
NPPP			NPPP	AD	NPPP	NSPP	TL	3	3
PH				AD	PH	NSPP	TL	1	6
AD					AD	AD	AD	6	1
BM						NSPP	TL	0	7
NSPP							TL	3	4
TL								5	2

Note: AD=adaptability, NPPP= number of pods per plant, PH=plant height, SS = seed size, BM=biomass, NSPP=number of seeds per pod, TL=number of tillers/branches per plant

Table 4. Farmers' preference ranking matrix summary sheet of 2017 meher production season

Varieties	Farmer's selection attributes and scoring values								Rank
	SS	NPPP	PH	AD	BM	NSPP	TL	Scores	
Walki	1.9	2.28	1.95	1.76	1.81	1.95	2.38	2	2nd
Hachalu	1.81	1.81	1.66	1.71	2.09	1.09	1.66	1.7	1st
Dagim	2.28	1.9	2.38	2.19	2.09	2.95	1.95	2.25	3rd

Note: Scoring values are 1- best, 3-poor; AD=adaptability; PH=plant height; TL=number of tillers/branches per plant NPPP= number of pods per plant; NSPP=number of seeds per pod; SS = seed size; BM=biomass

Table 5. Comparison of farmer's preference and agronomic data of faba bean during 2017 meher production season

Varieties	Agronomic data of varieties							Rank
	PH	TL	NPPP	NSPP	SS	GYLD	BMY	
Hachalu	108.96	1.63	15.76	2.90	325.86	4070.40	8130.40	1
Walki	102.00	2.00	15.20	2.63	259.33	3927.13	7902.86	2
Dagim	2.28	1.9	18.53	2.93	160.66	4307.66	8254.00	3

Note: NPPP= number of pods per plant, FT=frost tolerance, TL=number of tillers/branches per plant, NSPP= number of seeds per pod, SS= seed size in terms of 1000 seed weight (g), BMY= biomass yield (kg ha^{-1}), GYLD=grain yield (kg ha^{-1})

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Cost-benefit analysis

In our study, seed rates varied among the varieties based on seed size such as 140 kg ha^{-1} for Dagim, 240 kg ha^{-1} for Walki and 250 kg ha^{-1} for Hachalu. The data collected from the local market showed that the cost of seed during planting also varied for varieties: 16 ETB kg^{-1} for Dagim, and 20 ETB kg^{-1} for each of Walki and Hachalu varieties; while the price of grain was 14 ETB kg^{-1} for Dagim variety, and 16 ETB kg^{-1} for each of Walki and Hachalu varieties in January 2018. Table 6 showed that, the highest net benefit (33,674.4 ETB ha^{-1}) was for Hachalu followed by Dagim (32,096.6 ETB ha^{-1}) and Walki (31,810.4 ETB ha^{-1}). Therefore, farmers preference was in conformity with the results from the cost-benefit analysis.

Table 6. Summary of cost-benefit analysis for demonstration of faba bean varieties in 2017 meher production season

Cost and benefit components	Dagim	Walki	Hachalu
Total grain yield (kg ha^{-1})	4,307.66	3,927.13	4,070.40
Adjusted grain yield (kg ha^{-1})	3,876.90	3,534.40	3,663.40
Benefit from grain (ETB ha^{-1})	54,276.60	56,550.40	58,614.40
Seed cost (ETB ha^{-1})	2,240	4,800	5,000
Labor cost (ETB ha^{-1})	8,640	8,640	8,640
Land rent (ETB ha^{-1})	10,000	10,000	10,000
Fertilizer cost (ETB ha^{-1})	1,300	1,300	1,300
Total costs (ETB ha^{-1})	22,180	24,740	24,940
Net benefit (ETB ha^{-1})	32,096.60	31,810.40	33,674.40

Conclusion and Recommendation

Scaling up of large-seeded faba bean variety, Hachalu, for production on the highland Vertisols of North Shewa Zone of Amhara Regional State and similar areas is recommended to diversify faba bean varietal choices.

Demonstration of Improved Faba Bean Technologies in Bale Zone

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Bale zone is characterized by mixed farming systems where most crop areas are under cereal production. The current cereal monoculture practiced in the cereal-based cropping systems puts the sustainability of the crop production system of the area at risk. It may result in serious agricultural production constraints such as yield reduction due declining soil fertility and regular incidence of persistent pests (diseases, weeds, and insect pests), leading to total crop loss unless corrective measures are taken in coordinated efforts. Thus, crop diversification can be a measure for sustainable crop production. Faba bean is the best break crop for wheat production. Research results revealed that bread wheat grown after faba bean crops gives higher grain yield than after a cereal crop with a yield advantage of 15% (Sinana ARC Profile, 2014).

NARS has been making continuous efforts in developing varieties and ensuring the availability of early generation seed for both formal and informal seed producers and distributors. In this endeavor, more than 30 high-yielding faba bean varieties have been released and/or registered in Ethiopia. Among these, Dosha and Gora for Nitosols, and Dide'a and Hachalu for Vertisols were recently released for production with full-recommended packages. Thus, participatory demonstration, evaluation, and validation of the varieties with the participation of farmers and other stakeholders were undertaken in Bale Zone in 2017 main cropping season. The main objectives of the study were to:

- Evaluate the yield performance of improved faba bean technologies under farmers' condition in Bale zone and recommend the preferred ones.
- Create awareness on the importance of and demand for improved faba bean technologies among farmers and participant stakeholders.
- Improve farmers' knowledge and skills on faba bean production and management packages.
- Collect farmers' feedbacks on the performance of faba bean technologies for further development of better technologies for faba bean production.

Materials and Methods

Description of the study area

The pre-extension demonstration and validation of improved faba bean technologies was carried out in Dinsho and Goba districts of Bale zone. Dinsho district lies between 2444–4250 masl with the annual rainfall of 965.03–1314 mm, and the respective minimum and maximum temperature of 7.07°Cand 15.33°C. The dominant soil types are Nitosols and Cambisols. The altitude of Goba district is 1517–4378 masl with the annual rainfall of 937.3 -1342.44 mm, and the respective minimum and maximum temperature of 6.53°C and 19.58°C. The dominant soil types are Pellic Vertisols (Sinja Area) and Chromic Luvisols (Adamu, 2018).

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The dominant farming system of both districts is crop-livestock mixed farming system. The major crops grown by farmers in the districts are wheat (bread, durum and emmer), barley (food and malt), maize, field pea, faba bean, linseed, garlic, onion, and potato. Faba bean is used as a break crop for rotation and food and cash crop for farmers in the districts.

Site and farmer selection

The pre-extension demonstration on improved faba bean technologies was conducted at four sites (two sites at Dinsho for Nitosols and two sites at Goba for Vertisols), being one site per kebele. Two kebeles were selected from each district based on their accessibility and production potential of the crop. Kebeles were considered as replications.

Host farmers were selected based on personal integrity and good history of compatibility with groups, having suitable and sufficient land to accommodate the demonstrations, accessibility for supervision, initiatives to implement the activity in high-quality, good in field management, willingness, and transparency to share innovations to others. Besides, resource rich, medium and poor category of farmers including men, women and youth farmers were considered.

Inputs used and experimental design

Recently released faba bean varieties, namely, Dosha and Gora with one standard check (Moti) were planted at two kebeles of Dinsho district (for Nitosols area), whereas Dide'a and Hachalu with standard check (Walki) were planted at two kebeles of Goba district (for Vertisols area) in 2017 meher cropping season. Plot size of each variety was 10 m by 10 m in each farmland of host farmer. Planting was done by drilling the seeds in rows spaced at 40cm with the recommended seed rate of 120-180 kg ha^{-1} based on seed size of the varieties. Shallow planting of 5cm depth was used in the presence of sufficient soil moisture. The recommended fertilizer rate of 100 kg ha^{-1} NPS was applied at planting. Weeding was done twice: the first at one month after planting with cultivation and the second at two months after planting. Farm operations (land preparation-ploughing four to five times using oxen plough) were carried out by host farmers, whereas activities such as land leveling, planting, first and second weeding, cultivation, harvesting, threshing, cleaning, and other laboratory works were handled by SARC researchers and technical assistants. In these districts, the planting time of faba bean was late July to early August, and the harvesting time was in late December to early January.

Technology demonstration and evaluation

A total of 112 farmer participants from two districts (92 farmers, 14 development agents and supervisors, and 6 experts) and three researchers participated on the selection of the varieties at maturity stage of the crop. First, the evaluators were grouped into small manageable sizes (one group had 10 members including one group leader and one scribe). At each demonstration kebele, brief orientation was given to the evaluators about how to integrate researchers' criteria to their own criteria for selecting the test varieties in order of their importance; how to carefully assess each variety by considering each criterion and using rating scale; how to organize the collected data; how to make group discussion and reach consensus; and finally, how to report the results through their group leader.

Training

Training was given by SARC multidisciplinary team consisting of pulse breeder, agronomist, weed scientist, pathologist, entomologist, seed scientist, economist and extensionist in both Dinsho and Goba districts.

Data collection and analysis

Both qualitative and quantitative data were collected using appropriate methods such as direct field observation/measurements and focused group discussion (FGD). Agronomic data such as stand, tillers/branches per plant, pods per plant, seeds per plant, disease score, podding date, maturity date and yield data per plot in all locations were recorded. Farmers' preference of the demonstrated technologies was also identified and recorded.

The statistical package SPSS was used for data analysis. Pair-wise ranking matrix was used to rank the varieties in order of their importance. The agronomic data were analyzed using GENSTAT computer software. Yield advantage of each of the test varieties over the respective standard check was estimated as:

$$\text{Yield advantage (\%)} = \frac{\text{Yield of test variety}}{\text{Yield of standard check variety}} = \text{x}100$$

Results and Discussion

Training

A total of 138 individuals (104 farmers, 14 development agents and supervisors, 12 agricultural experts and 8 researchers) participated in the training, out of which 10% was women farmers. The topics of the training covered available improved faba bean technologies and utilization, faba bean (both in quantity and quality) production and management packages, major faba bean pests and their control measures, and the importance of faba bean for crop rotation practices in the project areas as well as FRG/ FREG approaches, technology evaluation and selection criteria.

Yield performance and farmers' preference

At Dinsho, the mean yield of Dosha variety was 2.38 tons ha^{-1}, which was a 31.94% yield advantage over the standard check variety, Moti (Table 1). Moreover, Dosha was the most preferred fab bean variety by farmers (Table 2).

Table 1. Comparative yield advantage of the demonstrated faba bean varieties at Dinsho

Mean yield of standard check variety (tons ha^{-1})	Mean yield (tons ha^{-1}) of tested varieties and yield advantage (%) over standard check			
Moti	Dosha	%	Gora	%
1.800	2.375	31.94	1.825	1.39

Table 2. Rank of the demonstrated faba bean varieties based on farmers' selection criteria at Dinsho

Varieties	Rank	Farmers' preference reasons across sites at Dinsho
Dosha	1st	Average number of tillers/branches per plant (5), pod per plant (46), seed per plant (137), adaptation, disease free, no lodging
Gora	2nd	Average number of tillers/branches per plant (5), pod per plant (41), seed per plant (119), big seed size, disease free, no lodging, sweet green pod
Moti	3rd	Average number of tillers/branches per plant (4), pod per plant (37), seed per plant (115), big pod and large seed size, and disease and lodging problem

The one-way ANOVA result showed that there was significant difference among the tested faba bean varieties for pods per plant, seeds per plant, and mean yield among the demonstrated varieties although the difference in number of tillers/branches per plant was not significant (Table 3).

In Goba district, yield of the tested faba bean varieties, Dide'a and Hachalu, was comparable to that of the standard check, Walki with the respective productivity of 2.06, 2.02 and 1.98 tons ha^{-1}. However, farmers ranked Dide'a as the first preferred faba bean variety for production in Goba district (Table 4).

Table 3. Performance of demonstrated improved faba bean varieties at Dinsho

Varieties	Tillers per plant (No.)	Pods per plant (No.)	Seeds per plant (No.)	Mean yield (tons ha^{-1})
Dosha	5.5	46^{a}	136.5^{a}	2.375^{a}
Gora	4.5	40.5^{b}	119^{b}	1.825^{b}
Moti	4	37^{b}	115^{b}	1.800^{b}
$LSD_{0.05}$	ns	3.9	5.4	1.7
CV (%)	12.4	3.0	1.4	2.6

Table 4. Rank of demonstrated faba bean varieties based on farmers' selection criteria in Goba district

Varieties	Rank	Farmers' preference criteria across sites
Dide'a	1st	Average number of tillers/branches per plant (6), pod per plant (56), seed per plant (168), strong stalk, disease free, no lodging
Hachalu	2nd	Average number of tillers/branches per plant (6), pod per plant (52), seed per plant (156), and disease and lodging problem
Walki	3rd	Average number of tillers/branches (7), pod per plant (49), big pod size and has more seed per plant 1(96), and disease and lodging problem

The selection criteria set by the farmers were tillering/branching capacity, stem strength - resistance to lodging, disease tolerance, pods per plant, seeds per pod, seeds per plant, and seed size, which also need future attention in the breeding program of faba bean improvement. At both districts, however, the productivity of the demonstrated varieties was low as compared to the expected potential because of the waterlogging problem during the production season.

Conclusions and Recommendations

Due to the indeterminate nature of faba bean, all demonstrated varieties had more vegetative growth with low pod setting because of the higher amount of rainfall in 2017 production season. which resulted in low yield. However, based on farmers preference, the improved faba bean variety, Dosha, for Nitosols of Dinsho district, and variety Dide'a for Vertisols of Goba district are recommended for wider scaling.

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On-Farm Demonstration of Improved Faba bean Varieties in Silte and Gurage Zones

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Participatory variety demonstration and selection is a good practice to enable farmers select the variety that fits well to their preferences and environmental conditions. Experiences show that participatory varietal demonstration has been applied on many crops including faba bean (Goa and Kambata, 2017). Danial *et al*., (2007) reported that farmers' selection criteria vary with environmental conditions, traits of interest, cultural practice, use and marketability of the product.

Farmers in Alicho-wuriro district (Silte zone) and Gumer district (Gurage zone), Southern Nations Nationalities and Peoples Region (SNNPR) demand better yielding varieties to maximize and expand their production, which consecutively increases income and improve the livelihood of their families. Therefore, this activity was initiated to demonstrate and evaluate improved faba bean varieties with the participation of farmers to fit in their socio-economic and environmental conditions in two districts of the SNNPR, Gurage and Silte.

Materials and Methods

Description of the study area

This study was conducted in Alicho-wuriro and Gumer districts during the meher cropping season of 2015 to 2017.

Alicho-wuriro district is located at 7° 58' N latitude, and 37° 29' E longitude with an altitude of 2453 to 2984 meter above sea level, and the respective average annual total rainfall and average temperature of 825 mm and 13.26 °C. The Gumer district is located at 7° 54' N latitude, and 38° 04' E longitude with an altitude of 2450 to 2825 masl, and the respective average annual total rainfall and average temperature of 1015.1 mm and 14.45°C.

The dominant type of soil in both districts is well-drained loam and clay loam. The most common cultivated crops in the study areas are food barley, bread wheat, field pea, Irish potato, carrot, head cabbage, and enset. Food barley, enset and faba bean are the staple food crops in both study districts.

Site and farmer selection

Sites and kebeles were selected based on their potential for production of faba bean. Similarly, farmers were selected with collaboration of agricultural office experts, kebele officials and developmental agent by considering different selection criteria such as farmer's interest to the technology and willingness of managing the field as required. Accordingly, 20 farmers were selected from both districts (10 farmers from each district). After selection, training was organized for farmers, development agents and experts at each district.

Experimental treatments and design

Improved faba bean varieties, Dosha and Walki, were compared against the standard check variety, Degaga. The plot size of each variety was 10 m x 10 m. Planting was done at the beginning of June each year at the seed rate of 150 kg ha^{-1} with the respective inter- and intra-row spacing of 40 cm and 10 cm. Fertilizer was applied at the rate of 121 kg ha^{-1} NPS and 50 kg ha^{-1} urea. Weeding and other management practices were done as required. Harvesting was done manually in mid-November and yield was adjusted to 10 % moisture content for data measurement.

Data collection and analysis

Average data on plot bases were collected for plant height, number of pods per plant and seed per pod, and grain yield, which were subjected to statistical analysis using SPSS version 20 software. Paired sample t-test was used to determine the level of statistically significant differences between the varieties. Farmers' preferences were analyzed by using simple ranking method in accordance with the given value (De Boef and Thijssen, 2007), as indicated below.

$$Rank = \sum \frac{N}{n}$$

Where N, is value given by group of farmers for each variety based on the selection criteria and n is number of selection criteria used by farmers.

Results and Discussion

Grain yield performance

Combined ANOVA showed that there was a highly significant ($p<0.01$) variation among faba bean varieties for plant height and number of pods per plant, but there was no statistically significant difference for grain yield (Table 1).

Table 1. Summary of ANOVA results of four traits of faba bean

Source of variation	Probability level for faba bean traits			
	PH	PPP	SPP	GY
Year	0.6700	0.6700	0.5400	0.5600
Location	0.9500	0.8700	0.6500	0.0300
Variety	<0.0001	0.0030	0.0400	0.1500

Note: PH = plant height, PPP = number of pods per plant, SPP = number of seeds per pod, GY = grain yield

Average grain yield of demonstrated faba bean varieties over years and locations showed that the highest yielding variety, Dosha, increased yield by 17.8% over the lowest yielding variety Walki and by 1.9% over the standard check variety, Degaga (Table 2).

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Table 2. Summary of ANOVA results of four traits of faba bean

Varieties	Grain yield (tons ha^{-1})		
	Minimum	Maximum	Average
Dosha	2.59	4.10	3.24
Walki	2.17	3.21	2.75
Degaga (standard check)	2.60	3.67	3.18

Farmers Preference

Farmers set out four selection criteria to rank the varieties. These criteria include plant height, number of pods per plant, number of seeds per pod and grain yield. Based on the selection criteria, Dosha variety was preferred by host farmers and other neighboring farmers during the field days organized in the year 2015 to 2017 (Tables 4 and 5). Therefore, both the yield performance and farmers' preference results suggest that faba bean variety, Dosha, can be promoted at wider scale for production in both test locations and similar areas.

Table 3. Farmers' preference criteria, relative score and rank of faba bean varieties in Gumer district during 2015-2017 cropping season

Variety	Selection criteria, relative score and rank of faba bean varieties						
	PH	PPP	SPP	GY	TS	Mean	Rank
Degaga	4.3	6.3	7.1	7.9	25.6	6.4	2nd
Dosha	4.8	7.5	8.1	8.9	29.4	7.4	1st
Walki	3.8	5.4	4.8	6.5	20.5	5.1	3rd

Note: GY = grain yield, SPP = seed number per pod, PPP = pod per plant PH = plant height, TS = total score, R = rank

Table 4. Farmers' preference criteria, relative score and rank of faba bean varieties int Alicho-Wuriro district during 2015-2017 cropping season

Variety	Selection criteria, relative score and rank of faba bean varieties						
	PH	PPP	SPP	GY	TS	Mean	Rank
Degaga	4.8	5.7	6.6	7.3	24.0	6.0	2nd
Dosha	3.7	8.9	8.4	8.7	29.7	7.4	1st
Walki	3.3	6.2	5.3	6.3	21.2	5.0	3rd

Note: GY = grain yield, SPP = seed number per pod, PPP = pod per plant, PH = plant height, TS = total score, R = rank

Training

Training was provided in two districts for 850 participants (500 male and 350 female) consisting of agronomists, farmers and development agents. The training topics included faba bean production technologies, diseases and weed control practices, minimizing post-harvest loss and introduction of improved storage materials like Purdue Improved Crop Storage (PICS).

Field day

All field management issues, production challenges and future directions were discussed during the field days. A total of 400 farmers (280 men and 120 women), 45 researchers, 30 zonal agricultural and natural resource department and districts experts, 27 development agents, and 6 media experts participated. These field days enhanced awareness, experience sharing and learning during evaluation of the demonstrated faba bean varieties. During the field visit, farmers showed interest to produce high-yielding varieties as sources of income in Gumer and Alicho wuriro sites.

Conclusion and Recommendation

The results of the demonstrations conducted to evaluate yield performance of faba bean varieties under farmers' condition in 2015 to 2017 at Gumer and Alicho-Wuriro concludes have shown that the improved faba bean variety, Dosha, performs higher in yield and farmers preference over Moti and Degaga varieties. Therefore, though the yield differences are not significant, faba bean variety Dosha can be promoted for wider scale production in both districts due to farmer's preferences.

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On-Farm Demonstration and Popularization of Orbanche Tolerant Faba Bean Variety in Southern Tigray

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Broomrape (*Orobanche crenata*) is the most seriously limiting parasitic weed for faba bean production particularly in northern Ethiopia. In Southern Tigray, the history of Orobache weed appearance goes back to 1985 in Ofla district at Adigollo kebele (Teklay *et al.*, 2013a). Recently, its distribution increased from one district to four and from one kebele to thirteen kebeles and its incidence varies from <10% up to 100% in South Tigray (Figure 1). Previous research results indicated that yield losses due to this weed might reach as high as 75-100% in certain parts of the Sudan and Ethiopia (ICARDA, 2008; Teklay *et al.*, 2013b). Similarly, a study in South Tigray indicated that widespread and high infestation of *Orobanche crenata* causes up to total crop loss depending on host susceptibility, level of infestation and environmental conditions (*Tsehaye, 2017*).

Therefore, Alamata Agricultural Research Center in collaboration with ICARDA had been working to identify high-yielding and disease tolerant faba bean varieties. As a result, the center released one Orobanche tolerant faba bean variety called, Hashenge (AARC, 2014). Hence, this study was initiated to boost the production of faba bean through on-farm demonstration and popularization of the Hashenge variety on farmers' fields and subsequently evaluated farmers' perception towards the variety in Ofla district, South Tigray, Ethiopia.

The main objectives of the study are to:

- Demonstrate and popularize the Hashenge variety in Orobanche infested areas
- Evaluate farmers perception towards the variety, Hashenge
- Enhance farmers participation and awareness for adopting improved technologies

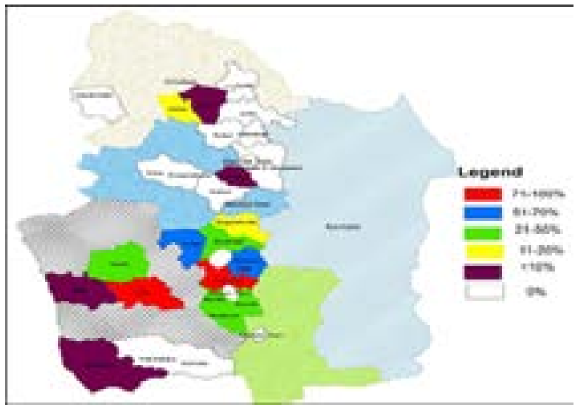

Figure 1. Distribution and incidence of Orobanche weed in Southern Tigray

Research Methodology

Description of the study area

The activity was carried out in Ofla district, South Tigray, Ethiopia, located at 12°31' N latitude and 39°33' E longitude with an elevation of 2490 masl. The annual rainfall of the district varies from 450 to 1200 mm during summer (June to September) and 180-250 mm during winter season (February to May). The mean annual temperature is 22°C with minimum and maximum temperature of 6°C and 30°C, respectively. The major crops grown in the district include wheat, barley and faba bean. Similarly, main soil textural classes are clay, silty, clay loam and sandy (SZDCO, 2016).

Kebeles and farmers selection

Ofla district is one of the Orobanche weed infested areas with higher incidence of 71-100% (Figure 1). In 2015/16 production season, demonstration was conducted in Adigollo kebele, which was highly Orobanche-infested area in the district (Figure 2). In 2016/17 and 2017/18, the activity continued in the Adigollo and Hashenge kebeles (Figure 2). The selection of kebeles and test sites in each kebele was based on the Orobanche infestation history of the farmlands. The adjacent Orobanche infested areas and interested participant farmers were selected in collaboration with development agents of the respective kebeles. Theoretical and practical trainings were provided during the popularization exercise of the improved variety.

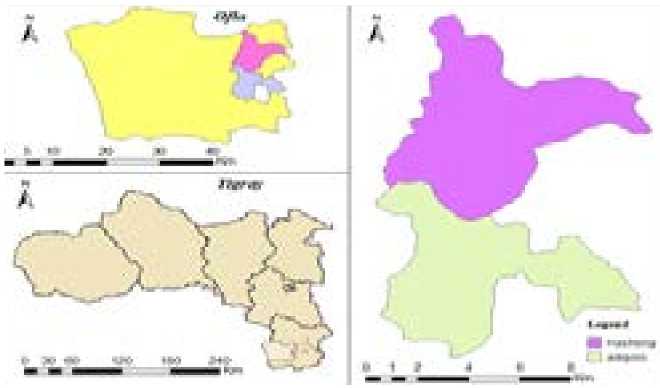

Figure 2. Maps showing the locations of study areas in South Tigray

In the first year (2015/16), the Hashenge variety was demonstrated on 10 interested farmer's fields at Adigollo kebele. Besides, to popularize the variety seed of Hashenge was given to 21 interested farmers in cluster production in Adigolo kebele in 2016/17 production season and 114 farmers in Adigolo and Hashenge kebeles in 2017/18 production season. During the three years, 145 farmers participated, and 33.75 ha land was covered by Hashenge variety. In addition, all participants applied bio-fertilizer in 2017/18 production

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season. During the project period, trainings were provided to participant farmers, experts, and development agents. In addition, filed days were organized at crop maturity to create awareness and promote the variety in three consecutive years.

Data collection and analysis

The data on grain yield of the local and improved faba bean varieties were collected using 1 m by 1 m quadrant. Thus, a total of 5 m^2 area in random sampling was harvested from each farmer's field and threshed manually. Grain yield was weighed using sensitive balance and converted to hectare bases. In addition, to get feedback on farmer's perception of the varieties, a list of attributes was used and a relative score out of 10 values was provided to each attribute for rating the relative preference of the varieties. However, in the first year, the perception level of participant farmers was collected through Likert scale questions for the list of attributes. SPSS version 20 software was used to analyze the collected data. Descriptive statistics like mean, percentage, and standard deviation; and inferential statistics like t-test were used to make comparison between the local and improved Hashenge variety.

Results and Discussion

Capacity building

A total of 118 farmers and 12 kebele and district experts were trained on topics related to agronomic practices, disease and pest management of faba bean (Table 1). In addition, in the third-year, practical training on the application of bio-fertilizer was provided (Photo 1). Photo 2 shows how farmers applied bio-fertilizer and Photo 3 shows how row planting was done to implement the practical training. They used umbrella for shading the bio-fertilizer from direct sunlight, which weakens the rhizobacteria.

Table 1. Training of farmers and experts during 2016/17 and 2017/18 cropping seasons

Years	Farmers		Experts		Total	
	Male	Female	Male	Female	Male	Female
2016/17	17	6	4	2	21	8
2017/18	85	10	5	1	90	11
Total	102	16	9	3	111	19

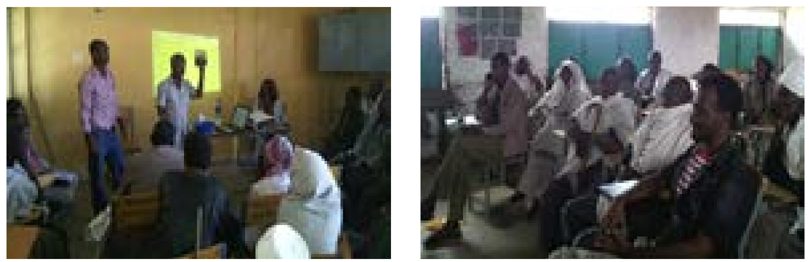

Photo 1. Partial view of participants during practical training on bio-fertilizer application


Photo 2. The farmer mixing the bio-fertilizer with the seed in his filed (left); temporary shed used by farmers to protect bio-fertilizer from direct sun light (right)


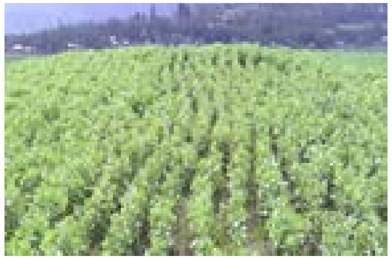

Photo 3. Oxen plowing for row making and covering seed during planting (left); performance of the row planted faba bean at farmers' field (right)

During the field days, 33 stakeholders, 168 researchers and experts, and 337 farmers participated (Table 2). The feedback from the participants was positive. The farmers appreciated the performance of the improved variety, Hashenge, in Orbanche infested areas (Photo 4). Farmers told the field day participants that faba bean production was almost abandoned due to Orobanche weed in the area. They also indicated their interest to plant Orobanche tolerant Hashenge variety on a wider scale for production.

Table 2. Field day participants during the three years

Year	*Farmers*		*Experts and researchers*		*Stakeholders*		*Total*	
	Male	*Female*	*Male*	*Female*	*Male*	*Female*	*Male*	*Female*
2015/16	*100*	*8*	*25*	*2*	*3*	*1*	*128*	*11*
2016/17	*130*	*24*	*67*	*6*	*8*	*2*	*205*	*32*
2017/18	*70*	*5*	*60*	*8*	*16*	*3*	*146*	*16*
Total	***300***	***37***	***152***	***16***	***27***	***6***	***479***	***59***

Photo 4. Partial view of field day participants observing the performance of Hashenge variety

Grain yield

In the first year, 2015/16 production season an average grain yield of 2.13 tons ha^{-1} from Hashenge variety, and 1.5 tons ha^{-1} from local variety was harvested from the demonstration plots (Table 3). Hashenge showed 42% grain yield advantage over the local variety. Similarly, in 2016/17 production season, an average grain yield of 2.01 tons ha^{-1} with a maximum of 3.0 tons ha^{-1} and minimum of 1.2 tons ha^{-1} was harvested from Hashenge variety in Adigollo kebele at farmers' fields (Table 3). This shows that there is an improvement on productivity of the crop compared to the regional average, which is 1.64 tons ha^{-1} (CSA, 2017). However, the performance of the variety showed high yield variation among participant farmers due to the difference in agronomic practices and application of inorganic fertilizer and bio-fertilizer. However, Hashenge variety was highly appreciated by participant farmers for its tolerance to Orobanche weed compared to the local varieties. Nevertheless, the harvested grain yield (Table 3) was low as compared to its potential in research station, which ranges from 3.5-5.0 tons ha^{-1} (AARC, 2014). According to respondent's report, frost problem during the maturity of the crop was the main reason for the low productivity of the variety in 2016/17.

In 2017/18 production season, an average grain yield of 4.53 tons ha^{-1} with a maximum and minimum of 5.03 and 3.53 tons ha^{-1}, respectively, was harvested from Hashenge variety (Table 3). On the other hand, the local variety gave the average grain yield of 1.2 t ha^{-1} with a maximum and minimum of 2.3 and 1.6 tons ha^{-1}, respectively (Table 3). The result showed that there is a highly significant difference between the local and improved variety (t-value=14.79, p value=0.000) (Table 3); participant farmers obtained more than two-fold higher grain yield from Hashenge than the local variety.

Table 3. Grain yield of Hashenge variety compared to local cultivars during 2015/16-2017/18

Production year	Variety	Location	N	Grain yield (t ha^{-1})				t-value	Yield advantage over local (%)
				Mini	Maxi	Mean	SD		
2015/16	Hashenge	Adigollo	1	-	-	2.13	-	-	42.00
	Local	Adigollo	1	-	-	1.50	-	-	
2016/17	Hashenge	Adigolo	10	1.2.	3.00	2.01	0.57		26.89
2017/18	Hashenge	Adigolo & Hashenge	15	3.53	5.03	4.53	0.41	4.79***	186.65
	Local	Adigolo & Hashenge	7	1.2	2.59	1.58	0.49		

*Note: N= number of participant farmers; Mini= minimum; Maxi= maximum; SD= standard deviation; ***= statistically significant at <0.001*

Farmers' preference

In 2016/2017 production season, 110 farmers participated in rating the performance of the tested faba bean varieties against the selected 12 attributes (Table 4). Most of the respondents preferred the improved faba bean variety, Hashenge, based on the rating values for its germination, tillering capacity, disease/insect resistance, pod per plant, seed per pod, grain and biomass yield, marketability and seed color compared to existing local cultivars. About 91% of the participant farmers rated Hashenge from good to very good in germination capacity, tillering capacity, number of pods per plant, number of seeds per pod, seed size, seed color, marketability, grain yield and biomass yield, while the local variety received only 9% of rating for the same attributes. Hashenge also received good to very good rating of about 73% of the participant farmers for its disease/insect resistance. About 55% of the participant farmers rated Hashenge variety as late-maturing as compared to the local cultivars. In terms of rating for food, 36.4% of respondents perceived that the taste of wot from Hashenge is less preferred than the local varieties. On the other hand, the variety was highly preferred by farmers for its local consumption in the form of bokolt (sprouted grain) compared to the local varieties. Consequently, the market price of the variety is higher due to its seed size which is preferred than the local varieties.

Table 4. Farmer's perception and performance rating of faba bean varieties against selected attributes in 2016/17 production season

Attributes	Number of farmers rating each variety									
	Very poor		Poor		Neutral		Good		Very good	
	L	H	L	H	L	H	L	H	L	H
Germination/field establishment	-	-	-		-	-	2	20	8	80
Tillering capacity	-	-	-	-	-	-	3	30	7	70
Earliness in maturity	-	-	6	60	1	10	-	-	3	30
Disease/insect resistance	-	-	1	10	1	10	5	50	3	30
Pod per plant	-	-	-	-	-	-	2	20	8	80
Seed per pod	-	-	-	-	-	-	4	40	6	60
Seed size	-	-	-	-	-	-	1	10	9	90
Grain yield	-	-	-	-	-	-	4	40	6	60
Biomass	-	-	-	-	-	-	3	30	7	70
Food taste	-	-	4	40	-	-	2	20	4	40
Marketability	-	-	-	-	-	-	4	40	6	60
Seed color	-	-	-	-	-	-	2	20	8	80

Note: L= local faba bean variety; H= improved Hashenge variety

Farmers' Perception

During 2017/18 production season, the Hashenge variety was planted in two kebeles of Ofla district for evaluating farmers' perception on its performance. Based on farmers' point of view, nine attributes of the variety were selected for the evaluation. These attributes were plant height, tillering capacity, waterlogging tolerance, earliness to set pods, early maturity, disease/pest resistance, number of pods per plant, number of seeds per pod, and grain yield. The results of the scoring method evaluation by farmers show the mean score [out of ten] for each attribute of the local variety was lower than the improved variety in both locations. Hashenge variety obtained higher scores in eight attributes in Hashenge and Adigollo kebeles compared to the local variety (Table 5). Farmer's perception score showed that the performance of Hashenge variety was higher in plant height, tillering capacity, waterlogging tolerance, disease/pest resistance, number of pods per plant, number of seeds per pod, and grain yield when compared to the local variety in both test locations.

Table 5. Perception of farmers towards Hashenge variety compared to local variety in 2017/18 production season

Attributes	Farmers' score (out of 10)			
	Hashenge kebele		Adigolo kebele	
	Local	Hashenge	Local	Hashenge
Plant height	3	7	2	8
Pod per plant	3	7	3	7
Tillering capacity	4	6	2	8
Waterlogging tolerance	3	7	3	7
Seed per pod	3	7	4	6
Earliness to set pods	4	6	6	4
Early maturity	6	4	6	4
Disease/pest resistance	3	7	3	7
Grain yield	2	8	2	8
Mean	3.44	6.55	3.44	6.55
Standard deviation	1.13	1.13	1.58	1.58
t value	5.45***		4.15***	

Note: *** = significant at 1% probability level

Conclusion and Recommendation

The study concludes that Hashenge variety gave higher grain yield and received higher perception scores in social acceptance compared to the local variety. Hashenge variety had a yield advantage of 26.89 and 186.65% over the local variety, respectively, in the first- and second-year popularization activities. Therefore, Hashenge variety can be promoted for a wider scale of production for its higher yield and tolerance to Orobanche weed, which is expanding and limiting faba bean production in South Tigray.

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On-farm Demonstration of Improved Faba Bean Varieties and Bio-fertilizer Application in Tigray

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In dryland agriculture, like in Tigray region, unpredictable distribution of rainfall coupled with susceptibility to biotic and abiotic factors are the major production constraints. According to the Central Statistics Agency (CSA, 2015), in Tigray region, the total area and production of faba bean were about 12,414 ha and 19,056 tons, respectively.

Research on cropping systems in Ethiopia indicated that the improvements in soil fertility from planting wheat after faba bean rotation can improve grain yield of wheat by more than one ton per hectare and can reduce fertilizer use for cereals in the next season by up to 60% (Amanuel and Daba, 2006). Different research in recent years revealed that inoculation of faba bean with Rhizobium leguminosarum increased yield by 10 to 50% and improved the fertility of the soil (Abere *et al.*, 2009).

However, most of the research works on faba bean inoculants were conducted under controlled conditions in green houses; and farmers have no awareness about the existence of such technology to utilize it. Hence, to address the issues a study was conducted with the objectives to demonstrate the improved faba bean varieties and the effectiveness of bio-fertilizer; and to assess farmers perception on the improved variety and integrated production packages while introducing such a technology package to farmers and pave the way for wider adoption in some parts of Tigray region.

Materials and Methods

Description of the study area

Demonstration of improved faba bean technologies were conducted in 2016 at Atsbi Wenberta and Degua Tembien districts. Atsbi Wonberta district is found in Eastern Zone of Tigray Region, at 13°36"N and 39°36"E (Hailay, 2008). The district has dega (highland, which ranges from 2400 m to 3100 m, and weinadega (mid-altitude highland which ranges from 1800 m to 2400 m) climatic zones. Rainfall is usually intense and short in duration, with an annual average of about 667.8 mm. The average temperature of the area is 18oC. Mixed crop and livestock farming system is the mode of agriculture in the district. The dominant cereal crops that are grown in the area are barley, wheat, teff, maize and sorghum (OoARD, 2010).

Degua Tembien is one of the four rural districts in Southeastern Zone of Tigray region. Its geographical location is between 39°10'E longitudes and 13°38'N latitudes. The district's climatic zones are kola (lowland), weinadega (mid altitude highland) and dega (high altitude highland) covering 26%, 30.5% and 43.5% of the area, respectively. The annual daily average temperature ranges from 18°C to 25°C. The average annual rainfall ranges from 600–800 mm (Ayenew *et al.*, 2011). The area of the district is approximately 112,500 ha with the land use pattern of 19,472 ha of cultivated land, 24,523 ha of forest and 68,508 ha of bush and shrubs. Agricultural activity of the district is rainfed annual mixed crop and livestock production. Pulses and cereals are the major crops (Segers, 2010). From the major cereals, Wheat and hanfets (a mixture of wheat and barley) among major cereals and lentil and faba bean among legumes are the dominant crops grown in the district (OARD, 2011).

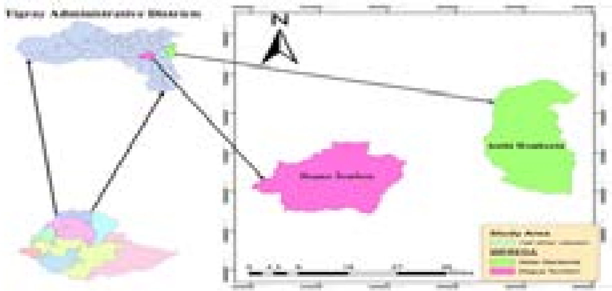

Figure 1. The maps showing the study districts in Tigray Regional State

Treatments and experimental design

A total of 10 volunteer farmers were selected purposively from each district based on their interest towards new technologies, willingness to manage and allocate land for field trial for the activity with collaboration of extension agents and kebele administration leaders.

The improved varieties (Moti for Atsbi Wenberta and Walki for Degua Tembien) and local variety as a check were used for demonstration. A seed rate of 200 kg ha^{-1} was used for both improved and local varieties; and the seed was dressed in 500 g ha^{-1} biofertilizer. In addition, 100 kg ha^{-1} of DAP fertilizer was applied at planting, and Bayleton was used to control fungal diseases. The experiment was laid in single-plot observation having a plot size of 100 m^2 for each treatment with spacing of 10 cm and 40 cm between plants and rows, respectively, for each treatment in each farmer's field. The planting time was in the first week of July 2016. First and second weeding were undertaken equally for all plots at 3-4 and 6-8 weeks after faba bean plant emergence, respectively.

Training was given to 20 beneficiary farmers, six development agencies and four experts of the study area. Field days were conducted to promote the variety before harvesting. The field days were organized at crop maturity at kebele levels. Farmers, researchers, experts, and other stakeholders participated in the field days which include 121 farmers, 14 agricultural experts and seven administrative staff.

Data collection and analysis

Yield data were collected using quadrant sample harvests from both improved and local varieties. Farmers' point of view on the attributes of the variety based on the composite indicators of yield and yield-components was also collected. To generate the information regarding the attitude of farmers towards the improved variety, a five-point Likert scale were used. A checklist was used for interviewing the participants to assess the interest of

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farmers towards technologies for further scaling up and promotion. Besides, production costs were collected to see the profitability of the technology. The data was analyzed with SPSS version-20 computer program using statistical analytical techniques such as descriptive, frequency, and percentage, and CIMMYT (1988) partial budget analysis was used for economic analysis. Therefore, the estimation of the marginal rate of return (MRR) was calculated as follows:

$$\textit{Marginal rate of return (MRR)} = \frac{\textit{The change in net return (NR)}}{\textit{The change in total costs that vary (TCTV)}} *100$$

Results and Discussion

Yield performance of faba bean varieties and biofertilizer

Yield performance of faba bean varieties with biofertilizer and fungicide in each district is presented in Table 1. During demonstration, the improved faba bean variety Moti gave higher yield (3520 kg ha^{-1}) than the local variety (2632 kg ha^{-1}) in Atsbi Wenberta. In Degua Tembien district, the improved variety Walki gave lower yield (2423 kg ha^{-1}) than the local check (3628 kg ha^{-1}). The low productivity of Walki could be due to the disease infestation that occurred in the production season.

Farmers from Atsbi Wenberta and Degua Temben districts obtained an average of 3900 kg ha^{-1} and 3115 kg ha^{-1} from improved variety with bio-fertilizer, respectively. Correspondingly, the local variety with biofertilizer and fungicide gave an average grain yield of 3020 and 4008 kg ha^{-1}. This shows that 10-29% yield increment in faba bean could be obtained using biofertilizer with fungicide in the area. This result agrees with that of Abere *et al*. (2009) who reported that inoculation of faba bean with Rhizobium leguminosarum could increase yield by 10 to 50%. It means that application of biofertilizer significantly improves productivity of faba bean and therefore it can be promoted at a wider scale.

Table 1. Grain yield (kg ha^{-1}) of faba bean varieties with and without bio-fertilizer and fungicide

Districts	Variety	Improved variety (IV)	IV + Biofertilizer and Bayleton fungicide (BF)	Local variety (LV)	LV + Biofertilizer and Bayleton fungicide (BF)
Atsbi Wenberta	Moti	3520	3900	2632	3020
Degua Tembien	Walki	2423	3115	3628	4008

Profitability of biofertilizer and fungicide application

Partial budget analysis results showed that biofertilizer use with fungicide application for faba bean production in Atsbi Wonberta (Table 2). Production of the improved faba bean variety, Moti, with and without bio-fertilizer and fungicide, gave a marginal net benefit of 57,935 and 52,800 Ethiopian Birr (ETB) ha^{-1}, respectively. The local variety with and without bio-fertilizer and fungicide gave a marginal net benefit of 44,600 and 40,980 ETB ha^{-1}, respectively. The MRR of improved faba bean variety Moti and local variety with bio-fertilizer and fungicide was about 734% and 517%, respectively, which is greater than the minimum acceptable rate of return (100%). For every one ETB investment in the treatment of faba bean with bio-fertilizer and fungicide, there was a net return of 7.34 ETB for the improved variety and 5.17 ETB for local variety. This indicates that application of bio-fertilizer to improve soil fertility and fungicide to control diseases could bring additional benefit to faba bean producing farmers.

Table 2. Profitability of faba bean var. Moti with and without biofertilizer and fungicide in Atsbi Wenberta district

Attributes	Improved variety (IV)	IV + Biofertilizer with fungicide (BF)	Local variety (LV)	LV +BF
Grain yield (kg ha^{-1})	3520	3909	2632	3020
Gross income	52800	58635	39480	45300
Cost of Bio-fertilizer	0	500	0	500
Cost of fungicide	0	200	0	200
Total Variable costs	0	700	0	700
Net Benefit (ETB ha^{-1})	52800	57935	40980	44600
Change in variable cost		700		700
Change in Net Benefit		5135		3620
MRR (%)		733.57		517.14

Note: One ETB is equivalent to 0.0368 USD (National Bank of Ethiopia accessed on June 6, 2018)

Similarly, in Degua Tembien district, MRR for the improved faba bean variety, Walki, and the local variety with the application of biofertilizer and fungicide was about 1383% and 714 % although the productivity of the improved variety was significantly lower than that of the local variety (Table 3). This high MMR indicates that there was a net return of 13.83 and 7.14 ETB for every one ETB investment in the treatment of faba bean with bio-fertilizer and fungicide for the improved and local variety, respectively, in Degua Tembein district.

Table 3. Profitability of faba bean var. Walki with and without biofertilizer and fungicide in Degua Tembien district

Attributes	Improved variety (IV)	IV + Biofertilizer with fungicide (BF)	Local variety (LV)	LV +BF
Grain yield (kg ha^{-1})	2423	3115	3628	4008
Gross income	36345	46725	54420	60120
Cost of Bio-fertilizer	0	500	0	500
Cost of fungicide	0	200	0	200
Total variable costs	0	700	0	700
Net Benefit (ETB ha^{-1})	36345	46025	54420	59420
Change in variable cost		700		700
Change in net benefit		9680		5000
MRR (%)		1382.86		714.29

Note: One ETB is equivalent to 0.0368 USD (National Bank of Ethiopia accessed on June 6, 2018) Note: One ETB is equivalent to 0.0368 USD (National Bank of Ethiopia accessed on June 6, 2018)

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Farmers' perception

Farmers' perception on pre- and post-harvest attributes of the high yielding faba bean variety at Atsbi Wenberta district is presented in Table 4. Since the yield performance of the improved Walki variety was significantly lower than that of the local variety in Degua Tembien district, it was not important to evaluate farmers' perception. Pre- and post-harvest attributes for evaluating the perception level of farmers on the performance of the improved faba bean variety, Moti, included early maturity, disease resistance, drought resistance, tiller number, pod size, threshability, seed weight, seed uniformity, seed size, seed color, purity, yield, marketability and taste.

According to the perception assessment on pre- and post-harvest of faba bean variety Moti, about 95% of the sample beneficiaries appreciated the variety and they positively perceived on the indicated attributes. This result calls for wider scale promotion of the variety Moti in Atsbi Wonberta district and similar areas.

Table 5. Farmers' perception on performance of pre- and post-harvest attributes of improved faba bean variety Moti in Atsbi Wenberta district

Attributes	Perception Level				
	Very Poor	Poor	Moderate	Good	Very Good
Early maturity	-	-	-	40	60
Disease resistance	-	-	20	60	20
Drought resistance	-	-	20	60	20
Tiller number	-	-	-	20	80
Pod size	-	-	-	20	80
Threshablity	-	-	-	40	60
Seed weight	-	-	-	60	40
Seed uniformity	-	--	-	40	60
Seed size	-	-	-	60	40
Seed color	-	-	-	40	60
Purity	-	-	-	40	60
Yield	-	-	20	-	80
Marketability	-	-	-	20	80
Taste	-	-	-	20	80

Farmers' satisfaction

Most of the respondent farmers were highly satisfied on the training (85.7%), timeliness of services (67.1%), supply of inputs (78%) and performance of the variety (71.4%) as indicated in Table 5. Whereas 14.3, 21.4 14.3 and 28.6% of the respondents expressed medium level of satisfaction on training, timeliness of services, supply of inputs, and performance of the variety under demonstration, respectively. Besides 11.4 and 7.1%

of the respondents have low satisfaction on timeliness and supply of input. The level of satisfaction with respect to services rendered, linkage with farmers, and technologies demonstrated indicate stronger conviction, physical and mental involvement in the demonstration, which in turn would lead to higher adoption. This finding indicates that farmers were satisfied with existing extension approaches that had been deployed to disseminate the new faba bean varieties and innovations.

Training and field day

The farmers participated in the training performed better land preparation, trial management and evaluation. They allocated the required plot size with borders for isolation. In the planting time, they applied the required inputs and row planting as per the recommendation. They were also active respondents in the data collection and trial evaluation at different stages of the crop.

The participant farmers of the field day indicated that faba bean has been almost out of production due to disease and pest in the area. The disease and pest problems of faba bean production were raised by many participant farmers. Besides, there was no established seed system for sustainable faba bean seed production in the area.

Table 5. Extent of farmers' satisfaction with extension services

Service	Satisfaction level %		
	Low	Medium	High
Training	-	14.3	85.7
Timeliness of input	11.4	21.4	67.1
Supply of input	7.1	14.3	78.6
Performance of technology	-	28.6	71.4

Conclusions and Recommendations

Demonstration of improved faba bean technologies was conducted in 2016 meher season in Atsbi Wenberta and Degua Tembien districts in Eastern and Southeastern Zones of Tigray. The yield and its attributes performance of the improved variety Moti was significantly higher than that of the local variety in Atsbi Wenberta district. In Degua Tembien district the disease and insect incidence caused the improved faba bean variety Walki to perform significantly lower than that of the local variety. However, the treated plots with bio fertilizer and fungicide performed better and gave significantly higher yield advantage and profitability as compared to the untreated ones in both districts.

Therefore, the improved faba bean variety Moti with the application of bio-fertilizer, fungicide and its recommended agronomic practices can be promoted for wider scale production in Atsbi Wenberta district and similar areas. Future research work should focus on the management of faba bean diseases and termites by involving the farmers at appropriate stage of the evaluation of faba bean production where the improved variety Walki was outyielded by the local variety in Degua Tembien district.

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Demonstration of Biofertilizer Application for Improving Productivity of Faba bean in Alicho-Wuriro District in Silte Zone

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Poor soil fertility, especially nitrogen deficiency, is one of the main constraints for faba bean production. Rhizobia species for biological nitrogen fixation in legume production is very important (Bottomley, 1991). Yield increase of faba bean by using bio-fertilizer has been reported (Zeleke *et al*., 2017); the same study reported several benefits of biofertilizer including increased size and plumpness of faba bean seeds resulting in higher sale prices, increased soil fertility and more organic matter.

Varieties released by national agricultural research system require demonstration with biofertilizer to enhance faba bean production and productivity in Southern Nations Nationalities and Peoples Regional State (SNNPRS). Therefore, this study was initiated to demonstrate rhizobia strains used as biofertilizer to the areas where the productivity of faba bean is low.

Materials and Methods

Description of study area

This study was conducted in Alicho-Wuriro district in Siltie zone of SNNPRS of Ethiopia. One of the test sites is located at 7°58'E" latitude and 37°29'N" longitude while the altitude across sites ranges from 2453 to 2984 masl. The average annual rainfall and temperature is 825 mm and 13.26 °C, respectively. The dominant type of soil in the test sites is well-drained loam. Food barley, enset and faba bean are the dominant and staple food crops in the study areas.

Experimental materials and design

The experiment was carried out with one released faba bean variety, Dosha, planted on June 2015 in single plot at Bune-Sakemo kebele where fields of 30 farmers were selected (no replication in each farmer's field). Selection of the kebele was done in participatory way with district agricultural office and experts based on its potential for faba bean production. Similarly, selection of farmers was done in collaboration with agricultural office experts, kebele officials and development agents. After selection, training was organized for farmers, development agents and experts. The seed was planted at the rate of 150 kg ha^{-1} with row spacing of 40 cm and plant spacing of 10 cm on a plot size of 100 m^2 for each treatment.

Biofertilizer (different strains of rhizobia) was obtained from Menagesha Biotech Industry PLC. Seeds of faba bean were coated with inoculum of each rhizobium strain to demonstrate the treatments before planting. Dosha faba bean variety was used and the treatments included: (i) T1= FB1035 rhizobium inoculation; (ii) T2= FB1018 rhizobium inoculation; (iii) T3= FBEAL-110 rhizobium inoculation; and (iv) T4= Control (no biofertilizer).

NPS fertilizer was applied once at the rate of 121 kg NPS ha^{-1} for all plots during planting time. Plots with biofertilizer were fertilized with Urea as enhancement (50 kg ha^{-1}) three weeks after planting. No Urea was applied on control plots. Plowing, weeding and other management practices were done as required. Harvesting was done from the whole plots manually in mid-November and the yield was adjusted to 10% moisture content.

Data collection and analysis

Yield-related data were measured on five randomly selected plants per plot. Grain yield was measured from whole plot harvested at maturity. Collected data were subjected to statistical analysis using SPSS version 20 software.

A group of farmers having thirty members (ten female and twenty male) were randomly selected to participate in the evaluation of the treatments. Farmers evaluated and ranked the treatments at vegetative stages and after harvesting. They used parameters like plant height, pod per plant, seed weight, nodules per plant, and grain yield to evaluate the treatments. These evaluation criteria were identified through group discussions. Farmers' preferences were collected and analyzed by using simple ranking method in accordance with the given value (de Boef and Thijssen, 2007). The equation of ranking method used was specified as:

$$Rank = \sum \frac{N}{n}$$

Where N, is value given by group of farmers for each variety based on the selection criteria and n is number of selection criteria used by farmers.

Results and Discussion

Yield and agronomic performance

Grain yield performance of the four biofertlizer treatments are summarized in Table 1. The four biofertilizer treatments FB-1035, FB-1018, FBEAL-110 and non-inoculated control gave the respective faba bean grain yield of 2.68, 2.53, 1.79 and 1.50 t ha^{-1}. Generally, grain yield of treatments in this experiment was low because of the wide range of environmental factors mainly of high amount of precipitation at planting time. However, the mean grain yield obtained was in line with Goa and Kambata (2017) who reported similar mean yield on faba bean varieties in four locations. Treatment with FB-1035 rhizobium inoculation also gave the highest yield advantage of 78.67% over control. The control (no biofertilizer) significantly gave the lowest plant height, number of seeds per plant, number of pods per plant, number of nodules per plant, and hundred seed weight (Table 2).

Table 1. Grain yield of faba bean with biofertilizer treatments in Alicho-Wuriro district in 2015/16 meher cropping season

Treatments	Grain yield (tons ha^{-1})	Yield difference (tons ha^{-1})	Yield increase over control (%)
FB-1035	2.68	1.18	78.67
FB-1018	2.53	1.03	68.67
FBEAL-110	1.79	0.29	19.33
Control (no- biofertilizer)	1.5	-	-

Table 2. Agronomic traits performance of faba bean as affected by biofertilizer treatments in 2015/16 meher cropping season in Alicho-Wuriro district

Biofertilizer treatments	PH	SNP	PPP	NNP	HSW
FB-1035	96.47ab	18.61a	10.67a	29.5ab	65.66
FB-1018	100.20a	17.89a	11.33a	33.33a	65.03
FBEAL-110	84.07b	16.22ab	8.67ab	18.18b	68.07
Control (no biofertilizer)	60.20c	11.00b	6.33b	15.87b	65.22
Mean	**85.24**	**15.93**	**9.25**	**24.22**	**65.99**

Note: PH = plant height (cm), SNP = seed number per plant, PPP = pods per plant, NNP = nodule number per plant, HSW = hundred seed weight (g)

Correlation coefficients among agronomic traits of the tested treatments are indicated in Table 3. Plant height had positive and significant correlation with grain yield and highly significant correlation with seed number per pod and pod per plant. Seed number per pod had positive and significant correlation with grain yield. Pod per plant also had positive and significant correlation with grain yield and seed number per pod. Nodule number per plant had positive and significant ($p<0.05$) correlation with grain yield and pod per plant. Goa and Kambata (2017) also reported that plant height strongly associated with the major yield components.

Table 3. Pearson correlation coefficients for grain yield and agronomic traits of faba bean in 2015/16 meher cropping season at Alicho-Wuriro district

	GY	SNP	PPP	PH	NNP	HSW
GY	-	0.942*	0.967*	0.952*	0.934*	-0.216
SNP		-	0.953*	0.981**	0.815	0.113
PPP			-	0.991**	0.946*	-0.150
PH				-	0.893	-0.016
NNP					-	**-0.463**
HSW						-

*Note: *, ** significant difference at 0.05 and 0.01 probability level; GY = grain yield; SNP = seed number per pod; PPP = pod per plant; PH = plant height; NNP = nodule number per plant; HSW = hundred seed weight*

Farmers' preference evaluation

Farmers set out the main selection criteria to rank the performance of biofertilizer treatments (Table 4). These criteria include seed number per pod, pod per plant, plant height, nodules per plant and yield. Based on the selection criteria, treatment with FB-1035 rhizobium inoculation was preferred by farmers and other neighboring farmers during field day organized on farmers' training centers. Treatment with FB-1035 received the highest total score of 30 while the control treatment (no biofertilizer) received the lowest score of 12 by farmers in 2015/16 meher cropping season at Alicho-Wuriro district. However, the score for faba bean performance in nodules per plant with FB-1035 and FB-1018 was the same (3.5). Similarly, the performance evaluation score by farmers for FB-1018 and FBEL-110 in nodule per plant was also the same (5.0). In general, FB-1035 biofertilizer treatment got highest score in all parameters and it was selected as first by farmers' evaluation (Table 4).

Table 4. Farmer's preference criteria and scores on the performance of faba bean biofertilizer treatments in 2015/16 meher cropping season at Alicho-Wuriro district

Treatments	PH	PPP	NNP	SNP	GY	Total	Mean	Rank
FB-1018	3.4	8.6	3.5	5	3	23.5	4.7	2nd
FBEAL-110	3	9	3	5	2	22	4.4	3rd
FB-1035	4	9.5	3.5	6	7	30	6	1st
Control (no biofertilizer)	2.5	2	1	3.5	3	12	2.4	4th

Note: Score values are out of 5; PH = plant height; PPP = pod per plant, NNP = nodules per plant; SNP = seed number per pod; GY = Grain yield

Training and field days

Training was provided for a total of 150 participants (80 male and 70 female) consisting of farmers who hosted the demonstration trial and other nearby farmers, agronomists, and development agents. The training covered faba bean production technologies, diseases and weed control, post-harvest loss and application methods of biofertilizer for faba bean production.

Field days were conducted during 2015/16 for participants to observe and evaluate the performance of faba bean biofertilizer treatments. All field management practices, production challenges and future directions were discussed and agreed during field days. A total of 240 farmers (145 men and 95 women), 15 researchers, 10 zonal agricultural and natural resource department and districts experts, nine development agents and three media experts participated. The main purpose was to create awareness and obtain feedback on improved faba bean production technologies with biofertilizer. During the field visit, farmers showed an interest to use faba bean biofertilizer to improve productivity and production.

Conclusions and Recommendations

This experiment was conducted at Alicho-Wuriro district during 2015/16 meher cropping season to demonstrate and promote faba bean biofertilizer. Biofertilizer treatment with FB-1035 outperformed and it was preferred by farmers for higher performance in plant height, pod per plant, nodules per plant, seed number per pod and grain yield. This biofertilizer treatment gave the highest grain yield of 2.68 t ha^{-1} and had yield advantage of 78.67% over the control treatment (no biofertilizer). Therefore, biofertilizer treatment with FB-1035 is recommended for wider scale promotion in Alicho-Wuriro district and areas with similar agroecological conditions to improve faba bean productivity.

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Demonstration of Bayleton Fungicide for Faba Bean Gall Disease Management in North Shewa Zone

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Faba ben gall has become a serious threat to faba bean production and productivity in some parts of the country causing yield losses as high as 100% (Beyene and Wulita, 2012). In Ethiopia, the disease was first reported as a faba bean gall in North Shewa (Degem, Bash area of Menz Mama and Mojana-Wadera districts) in 2011 (Beyene and Wulita, 2012; Dereje *et al*., 2012). This disease was also reported to reach up to 100% severity in Tigray region (Teklay *et al*., 2014). Moreover, according to the survey conducted in 2013, the disease has spread to the highland faba bean-growing areas of Amhara, Tigray, and Oromia regions (Endale *et al*., 2014).

Good field sanitation methods, including weed control practices reduce the pressure of faba bean gall disease. According to earlier experiments conducted, there were some tolerant, but no resistant varieties found to faba bean gall disease in the country. Thus, any attempt of gall disease control requires an integrated approach. Currently, Bayleton was identified as an effective fungicide for seed treatment and foliar spray to reduce the damages of faba bean gall disease (Beyene and Abiro, 2014; SARC, 2014). Hence, the objective of this study was to demonstrate Bayleton fungicide and to create awareness and demand among farmers and broaden the control options of faba bean gall disease.

Materials and Methods

Description of the study area

The demonstration was conducted on the farmer's fields that were considered as "hot-spot" for faba bean gall disease, which is locally known as *Kormid*, at Mush kebele, in Basona-Worana district of North Shewa zone in 2016/17 cropping season. Major crops produced in the area are faba bean, wheat and potato. The site lies at an altitude of 2975 masl, 9°78'N latitude and 39°67'E longitude. The location receives average annual rainfall of 897.8 mm with mean minimum and maximum temperatures of 6.1 and 19.67°C, respectively. The soil of experimental area is brown in color.

Experimental treatments, design and management

The trial was carried out using three treatments: (i) seed treatment (300 g Bayleton with 300 ml of water for 100 kg faba bean) and two times foliar spray (700 g Bayleton with 200 liter of water ha^{-1} after 14 days interval); (ii) three times foliar spray (700 g Bayleton with 200 liter of water ha^{-1}) after 14 days interval; and (iii) untreated control. Plot size of each treatment was 90 m^2, being replicated in three farmer's fields. Planting was done in June 2016 in broadcast with seed rate of 200 kg ha^{-1} on flat bed. DAP fertilizer was applied at a rate of 100 kg ha^{-1} during planting. Foliar application of fungicide was done immediately after the disease appearance and repeated at 14 days interval. The recommended weeding and other agronomic practices were applied uniformly for all plots. Field days were organized twice at seedling and grain-filling stages.

Data on disease incidence and severity were recorded starting from the onset of the disease and repeated at 14 days interval. Harvesting was done in December 2016 from the center of the plot using 1 m by 1 m quadrant (9 quadrant samples per plot). Costs that vary (chemical cost (1120 ETB kg^{-1}), labor cost (for seed dressing and foliar spray) and cost for sprayer were estimated on a hectare base. Partial budget analysis was done (CIMMYT, 1988) to determine the profitability of fungicide treatments for the control of faba bean gall disease.

Results and Discussion

Faba bean gall disease severity

The result of this experiment showed that treatments had differential effect on the observed disease parameters (Figure 1). Disease incidence was observed at initial assessment (seedling stage) on all plots (100%); the lowest severity (4.33%) was recorded on plots treated with seed treatment (300 g Bayleton) and twice-foliar application (700 g Bayleton ha^{-1}) and the highest with 10% for untreated plot. At grain filling stage the highest (90%) severity was recorded on untreated control plots of faba bean, while the lowest (15%) gall severity was recorded on faba bean plots treated with seed treatment and twice-foliar application.

In general, faba bean gall epidemics occurred on all treatments; however, the pressure varied among treatments. The disease rapidly increased on unsprayed control plots when compared to other treatments; nevertheless, none of the treatments completely controlled the disease development. The result of the current study agrees with the finding of DBARC (2015), which reported that application of Bayleton fungicide significantly reduced faba bean gall disease.

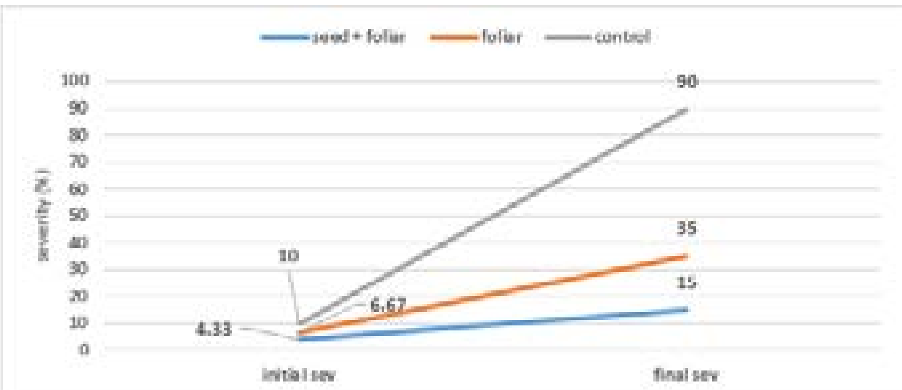

Figure 1. Severity of faba bean gall disease at different crop growth stages in 2016 meher cropping season

Note: Severity: (i) Initial sev = faba bean gall disease severity at seedling stage; (ii) final sev = faba bean gall disease severity at grain filling stage;

Grain yield and related agronomic traits

Faba bean grain yield and yield related parameters varied among treatments (Table 1). The highest plant height of 68 cm, and number of pods per plant of 29.6 were recorded on plots treated with seed treatment and twice foliar application. Untreated control plots gave the lowest plant height of 32.7 cm, and number of pods per plant of 7.7. Consequently, the highest numbers of seeds per pod of 6.98 was recorded on plots with seed treatment and twice-foliar application, while the lowest number of seeds per pod of 1.82 was recorded on untreated control plots.

Likewise, the highest grain yield of 1,964 kg ha^{-1} was obtained from plots with seed treatment and twice-foliar application. The second highest yielding treatment was from three times foliar application which gave 937 kg ha^{-1} grain yield. The lowest grain yield of 128 kg ha^{-1} was obtained from untreated control plots. This finding agrees with that of, DBARC (2016) which reported that lowest grain yield was obtained from unsprayed control plots.

Table 1. Grain yield and yield related parameters of faba bean in 2016/17 meher cropping season

Treatments	*Plant height (cm)*	*Pod per plant*	*Seed per pod*	*Grain yield (kg ha^{-1})*	*Biomass yield (kg ha^{-1})*
Seed dressing + 2 foliar applications	*68.03*	*29.6*	*6.98*	*1964*	*3244*
Three foliar applications	*56.4*	*12.8*	*3.34*	*937*	*1714*
Un sprayed (check)l	*32.7*	*7.7*	*1.82*	*128*	*331*

Partial budget analysis

Partial budget analysis indicated that there was variation in net benefit among treatments (Table 2). The highest net benefit of 17,225.4 ETB was obtained from plots treated with 300 g Bayleton dressing of 100 kg seed and twice-foliar application at 14 days interval. The second highest net benefit of 7,293.95 ETB was obtained from three times foliar application of 700 g ha^{-1} Bayleton at 14-days interval. The lowest net benefit of 1324.8 ETB was obtained from untreated control plots. These treatments also showed similar trend for marginal returns.

Table 2. Summary of partial budget analysis of fungicide application treatments for faba bean gall disease control in 2016/17 meher cropping season

Attributes	*Seed treatment +2 foliar applications*	*Three foliar applications*	*Control*
Adjusted grain yield (kg ha^{-1})	*1767.6*	*843.3*	*115.2*
Grain price (ETB 100 kg^{-1})	*1150*	*1150*	*1150*
Sell revenue (ETB)	*20327.4*	*9697.95*	*1324.8*
Fungicide cost (ETB)	*3102*	*2404*	*0*
Net benefit (ETB)	*17225.4*	*7293.95*	*1324.8*
Marginal benefit	*15900.6*	*5969.5*	
MRR (%)	*512*	*248*	

Note: Adjusted grain yield = obtained yield of faba bean adjusted by 10% downward; MRR = Marginal rate of return

Farmers' perception

During the field evaluation, 62 (12 females) farmers, 24 extension workers and five heads of district offices of agricultural development were involved in the evaluation of the performance of faba bean gall disease management treatments. Their evaluation criteria were disease pressure and yield performances of the treatments. Treatment of 300 g Bayleton dressing 100 kg seed of faba bean followed by twice-foliar application at the rate of 700 g ha^{-1} Bayleton at 14-days interval was rated as best by all participants. Finally, farmers were convinced to use the chemical treatment for the faba bean gall disease management.

Conclusions and Recommendations

The result of our study indicated that application of Bayleton fungicide lowered faba bean gall intensity and increased yield of faba bean when compared to the untreated control. Comparing the Bayleton treated plots showed that treatment of 300 g Bayleton dressing 100 kg seed of faba bean followed by twice-foliar application at the rate of 700 g ha^{-1} Bayleton at 14-days interval gives the highest net benefit and marginal rate of return. Thus, this treatment is recommended for wider scale promotion in faba bean gall disease affected areas.

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On–Farm Demonstration of Fungicides for Control of Faba bean Chocolate Spot in Bale Zone

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Faba bean is grown in several regions of Ethiopia receiving annual rainfall of 700-1000 mm (ICARDA, 2006). However, despite the availability of high-yielding varieties, the average yield of faba bean under smallholder farmers is not more than 1.8 t ha^{-1} (CSA, 2014). This low productivity is attributed to its susceptibility to biotic stresses mainly diseases (Sahile *et al*., 2008a; Mussa *et al*., 2008; Nigussie *et al*., 2008; Berhanu *et al*., 2003). The most important yield-limiting diseases of faba bean are chocolate spot (*Botrytis fabae*), rust (*Uromyces vicia-fabae*), black root-rot (*Fusarium solani*) and Ascochyta blight (*Ascochyta fabae*) (Mussa *et al*., 2008; Ahmed *et al*., 2010).

Different experiments have been conducted on the management of chocolate spot. According to a survey conducted, this disease was prevalent in all the faba bean growing areas of Ethiopia. Despite wide cultivation of faba bean and widespread occurrence of chocolate spot, research efforts concentrated on fungicide applications. But the results have not been communicated and farmers have limited information on the use of fungicide for the control of faba bean disease including chocolate spot. Therefore, this study was conducted to, (i) demonstrate different fungicides for the control of chocolate spot on faba bean, and (ii) create awareness on the use and effectiveness of the fungicide in controlling faba bean chocolate spot.

Materials and Methods

Description of study areas

The demonstration was carried out on farmer's field at one location per district in Goba and Dinsho districts during 2017-2018 cropping seasons. The locations are suitable for regular prevalence of chocolate spot under natural conditions. Goba is located at 1517- 4378 masl receiving mean annual rainfall of 937.3-1342.44 mm and mean annual temperature of 6.53-19.58°C. Dinsho is located at 2444–4250 masl receiving mean annual rainfall of 965.03–1314 mm and mean annual temperature of 7.07-15.33°C (Adamu Zeleke, unpublished survey). Soil type is Pellic Vertisol and Vertisols for Goba and Dinsho, respectively.

Treatments and experimental design

The demonstration was conducted using improved faba bean variety, Moti. Two fungicides Mancozeb 80% WP (2.5 kg ha^{-1}) and Odeon 825 WG (2.5 kg ha^{-1}) were used with two sprays of 8 days interval. The experiment was laid out in non-replication having three treatment plots in each farmer's field: (i) Mancozeb 80% WP sprayed plot; (ii) Odeon 825 WG sprayed plot and (iii) Control (unsprayed) plot. Each plot had a size of 25 m^2 (5 m x 5 m). Recommended agronomic practices were followed from the emergence of the crop. Fungicide application started after the appearances of the disease.

Data collections and analysis

Chocolate spot severity was assessed per plot at a weekly interval from the first time the disease appeared until the crop reached physiological maturity. Disease severity on leaves was rated using 1-9 rating scale (Bernier *et al*.,1993), where (i) 1= no disease symptoms or very small specks; (ii) 3= few small discrete lesions; (iii) 5= some coalesced lesions with some defoliation; (iv) 7= large coalesced sporulating lesions, 50% defoliation and some dead plant; and (v) 9= Extensive lesions on leaves, stems and pods, severe defoliation, heavy sporulation, stem girdling, blackening and death of more than 80% of plants and according to Bernier *et al*.,. (1984), the disease severity scores were converted to percentage severity index (PSI) for analysis using the following equation.

$$PSI = \frac{Snr}{Nps \times Msc} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where:

Snr = sum of numerical ratings
Nps = number of plants scored
Msc = maximum score on the scale

Yield loss was calculated separately for each of the treatments with different levels of disease, as:

$$RL\,(\%) = \frac{(Y1\text{-}Y2)}{Y1} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where,

RL% = percentage of relative loss (reduction of the parameters; i.e. yield, yield component),
Y1 = mean of the respective parameter on protected plots (plots with maximum protection)
Y2 = mean of the respective parameter in unprotected plots (i.e. unsprayed plots or sprayed plots with varying level of disease).

Farmers' selections and evaluations

Farmers participated on the evaluations of fungicide against faba bean chocolate spot. Selection and evaluation were considered on the farmers' interests and motivation toward the new technology.

Results and Discussion

Fungicide treatment and faba bean productivity

Table 1 shows average faba bean diseases severity index at Goba and Dinsho districts in 2017/18 cropping season. The highest mean chocolate spot severity index recorded was 55% on unsprayed plot at Goba district. The minimum mean chocolate spot severity index (27.5%) was recorded on Odeon 825 WG sprayed plot.

At Dinsho, mean chocolate spot severity index was similar before and after spray, indicating that the fungicide application arrested the disease severity progress. The mean chocolate spot severity index was higher at Goba as compared to Dinsho. In addition to chocolate spot severity, there were high severities of rust and Ascochyta blight at both locations, especially at flowering stage.

The fungicides generally reduced the mean chocolate spot severity index by up to 50% as compared to the unsprayed plots. However, the mean severity of chocolate spot was lower during the 2017/18 cropping season as compared to the previous one.

Table 1. Average faba bean diseases severity index at Goba and Dinsho districts in 2017/18 cropping season

Districts	Treatments	Rust		Chocolate spot		Ascochyta blight	
		Before	After	Before	After	Before	After
Goba	Odeon 825 WG	11	11	33	27.5	11	16.5
	Mancozeb 80% WP	11	16.2	38.5	33	11	16.5
	Control	11	22	38.5	55	11	27.5
Dinsho	Odeon 825 WG	11	11	33	33	11	22
	Mancozeb 80% WP	11	11	22	22	11	22
	Control	11	22	22	33	11	22

Note: Before = before fungicide spry; After = after fungicide spray

Productivity of faba bean under different fungicide treatments is given in Table 2. Mancozeb 80% WP sprayed plots gave the highest yield of 2680 and 2490 kg ha^{-1} at Goba and Dinsho, respectively. The unsprayed plots gave the grain yields of 1760 and 1650 kg ha^{-1} at Goba and Dinsho, respectively. The plot treated with Odeon 825 WG spray increased faba bean grain yield over the check by 20.36% and 22.17% at Goba and Dinsho, respectively. While Mancozeb 80% WP spray treated ones gave grain yield advantage of 34.33 and 33.74% over the untreated check at Goba and Dinsho, respectively.

Generally, the yield obtained in 2017/18 cropping season was lower than the production potential of faba bean in on-station experiments and production by farmers in previous years. Earlier experiences show that on average the faba bean yield obtained at research level was more than 5.0 t ha^{-1} and at farmers level more than 3.8 t ha^{-1}. The major reasons for low productivity in 2017/18 cropping season could be attributed to high rainfall, which caused lodging, reduced number of tillering and pods per plant.

Table 2. Productivity of faba bean under different fungicide treatments at Goba and Dinsho in 2017/18 cropping season

Districts	Treatments	Grain yield (kg ha^{-1})	Yield increase over untreated check (%)
Goba	Mancozeb 80% WP	2680	+34.33
	Odeon 825 WG	2210	+20.36
	Control (not sprayed)	1760	
Dinsho	Mancozeb 80% WP	2490	+33.74
	Odeon 825 WG	2120	+22.17
	Control (not sprayed)	1650	

Profitability of fungicide treatments

Profitability of fungicide treatments for faba bean production is presented in Table 3. Mancozeb 80% WP sprayed plots gave the highest gross return of 40,200 and 37,350 ETB ha^{-1} at Goba and Dinsho, respectively. Similarly, Mancozeb 80% WP treated plots had the highest net return of 2156 ETB ha^{-1} and the highest benefit cost ratio of 1.15 at Goba; and the highest net return of 18753 ETB ha^{-1}, and the highest benefit cost ratio of 1.0 at Dinsho. This highest performance of Mancozeb 80% WP in profitability and productivity was followed by Odeon 825 WG treatment while the untreated check was the lowest.

Table 3. Profitability of fungicide spray treatment for the control of faba bean Chocolate spot disease in 2017/18 cropping season at Goba and Dinsho districts

Districts	Fungicide spray treatment	Yield (kg ha^{-1})	Sale price (ETB kg^{-1})	Total variable costs (ETB ha^{-1})	Gross return	Net return (GR-TVC) ha^{-1}	Benefit cost ratio (NR÷TVC)
Goba	Mancozeb 80% WP	2680	15	18,694	40200	21506	1.15
	Odeon 825 WG	2210	15	17,553	33150	15597	0.89
	Control (no spray)	1760	15	16518	26,400	9,882	0.60
Dinsho	Mancozeb 80% WP	2490	15	18,637	37350	18713	1.00
	ODEON 825 WG	2120	15	17,526	31800	14274	0.82
	Untreated control	1650	15	16485	24,750	8,265	0.50

Note: GR = gross return; TVC = total variable cost; NR = net return

Farmer's preference

About 50 farmers participated on the evaluation and selection of fungicides at Goba and 42 farmers participated at Dinsho. At both locations, the farmers selected the plot sprayed by Mancozeb 80%WP and Odeon 825 WG as their first choice. During the evaluation and selections, farmers mostly considered the burned stem and leaf of the crop. Accordingly, they said that the plot with no fungicide applications was more damaged by the disease as compared to the fungicide treated plots. To avoid the biasness during evaluation and selection, farmers were not informed about the spayed and unsprayed plots. They simply observed the status of the plots and compared the level of damage caused by the disease.

Conclusion and Recommendation

The results obtained from the two districts indicated that the fungicides, Mancozeb 80% WP and Odeon 825 WG, were the most effective against the chocolate spot disease on faba bean. The yield and net benefits from fungicides sprayed plots are by far higher than those of the unsprayed plots. Hence, the tested fungicides are effective for the management of faba bean chocolate spot disease and can be promoted for wider scale use in areas where faba bean chocolate spot disease inflicts economical loss.

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On-farm Demonstration of Herbicides for Faba Bean Weed Control in Bale Zone

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Weeds can be controlled by manual, mechanical, and chemical methods. Weed management with herbicides is an effective, quick in action, and time saving practice (Ahmed *et al*., 2005). Bale highland is a wheat production belt where many alternatives of herbicides to control weeds are available. However, hand weeding is the only practice used to control weeds in faba bean fields due to unavailability of pre- and/or post-emergence herbicides.

Dual-Gold 960 E.C is one of the pre-emergence herbicides to kill both grassy and broadleaf weeds at the early and later stage of the crop growth to reduce yield loss. Gallant Super is the post emergence herbicide to kill annual and perennial grass weeds in broad leaf crops at any time. However, demonstration of these herbicides on farmers' fields was not carried out widely to popularize and promote the technology in Bale highland.

Therefore, the objectives of this study were to: (i) demonstrate and validate the effectiveness of Dual Gold and Gallant Super herbicides against faba bean weeds; (ii) create awareness for end users on the effectiveness of these herbicides for the management of weeds in faba bean production; and (iii) evaluate economic profitability of herbicide application in faba bean weed control.

Materials and Methods

Description of the study area

The demonstration was conducted in two districts of Bale zone, Goba and Dinsho, to demonstrate and validate the effectiveness of pre-emergence (Dual Gold 960 EC) and post emergence (Gallant Super) herbicides in 2017/2018 cropping season. The altitude ranges from 1517 – 4378 masl for Goba and 2444 – 4250 for Dinsho; however, the testing sites are in the high-altitude areas called Dega. Average annual rainfall (mm) is 937.3 -1342.44 and 965.03 – 1314 for Goba and Dinsho, respectively. Maximum temperature is 19.58°C for Goba while 15.33°C for Dinsho. Minimum temperature is 6.53°C for Goba and 7.07°C for Dinsho. Soil types are Pellic Vertisols and Chromic Luvisols for Goba district, and Vertisols and Cambisols for Dinsho. Soil PH is 6.01- 6.82 for Dinsho district.

Treatments and experimental design

The demonstration was conducted at four kebeles (2 kebeles per district) in Goba and Dinsho districts. Kebeles were considered as replications, that means the demonstration was replicated on two kebeles per district. Each demonstration field has three plots, Dual Gold sprayed, Gallant Super sprayed, and unsprayed plots laid out in simple-plot design on 25 m^2 (5 m x5 m) plots area. Dual Gold 960 EC pre-emergence herbicide was applied at the rate of 1.5 litres ha^{-1} mixed with 200 litres per hectare of water on the third day of planting for control of broad and grassy weeds before the crop emergence. The post-emergence herbicide, Gallant Super, was used for controlling grassy weeds when target grass weeds are actively growing at the 2-6 leaf stage at the rate of one liter per hectare using 200 liters water per hectare. The faba bean variety, Moti, was planted in the main cropping season for the demonstration purpose. The recommended seed rate of 180 kg ha^{-1}, and fertilizer rate of 100 kg NPS ha^{-1} was uniformly applied for each treatment at planting. No hand weeding was applied to see the effectiveness of the herbicides.

Data collection and analysis

Yield and yield components, percentage of yield increases or losses, production costs and benefits were collected to see the profitability of the different treatments. Yield from the experimental plot was adjusted downward by 10% to reflect the difference between the experimental yield and the yield farmers could expect from the same treatment. Accordingly, the mean grain yields of herbicide sprayed, and unsprayed plots were subjected to a discrete economic analysis using the procedure recommended by CIMMYT (1988). To estimate economic parameters, faba bean yield was valued at average open market price of 13 ETB kg^{-1}, 1000 ETB $litre^{-1}$ Dual Gold, and 800 ETB $litre^{-1}$ of Gallant Super were set during planting time. Labor was valued at 35 ETB per person per day and used to determine the variable costs.

The agronomic data were analyzed using GENSTAT computer software and descriptive statistical techniques. Economic analysis was done using partial budget analysis to determine the economic feasibility of the herbicides.

The cost-benefit analysis conducted was expressed on hectare basis (Table 3). The dominated treatments according to the dominance analysis were eliminated from further economic analysis. To identify treatments with the optimum return to the farmer's investment, marginal analysis was performed on non-dominated treatments.

Results and Discussion

Weed Species observed and productivity of herbicide treatments

Both broad leaved and grass weeds were found in the demonstration fields. The most dominant broad-leaved weed species were Guizotia scabra, Galinsoga parviflora, Chenopodium spp., Galium spurium, Amaranthus hybridus, Commelina benghlensisa and latifolia, solanum nigrum, Euphorbia spp., and Raphanus raphanistrum. The most dominant grass weeds were Cyperus esculentus, Avena fatua, and Bromus pectinatus.

An average of 1796, 1447 and 1200 kg ha^{-1} of grain yield was harvested from the treatments of Dual Gold, Gallant Super, and unsprayed plots, respectively (Table 1). This shows an average yield increase of 50% from pre-emergence (Dual Gold) herbicide, and 21% from the post-emergence herbicide (Gallant Super) when compared to the unsprayed control. This higher yield advantage especially from the pre-emergence herbicide could be due to the contribution of the herbicide in effectively controlling the weeds at the early establishment of the crop that significantly reduces the competition (Figure 1).

The one-way analysis of variance with no blocking also showed significant ($P<0.05$) differences for plant height, pods per plant and grain yield among treatments with Dual

Gold, Gallant Super and unsprayed control. Application of pre-emergence herbicide (Dual Gold) was the best in producing higher pods per plant and grain yield (Table 2).

Table 1. Faba bean grain yield, yield increment and yield loss as affected by herbicide treatments

Districts	Kebeles	Herbicide treatments	Grain yield (kg ha^{-1})	Yield increment (%)	Yield loss (%)
Dinsho	Abakara	Dual Gold	1350	50	33.3
		Gallant Super	1100	22.2	18.2
		Unsprayed	900		
Goba	Sinja	Dual Gold	1840	95.7	49
		Gallant Super	1240	32	24.2
		Unsprayed	940		
Goba	Alloshe	Dual Gold	2200	25	20
		Gallant Super	2000	13.6	12
		Unsprayed	1760		

Figure 1. Pre-emergence herbicide effectiveness (right) compared to unsprayed control (left)

Profitability of herbicide treatments

In the districts, faba bean yield of the dual gold and gallant super treatment were better than the unsprayed plots. Application of dual gold gave the highest net benefit to cost ratio (8.3), followed by gallant super with benefit cost ratio of 7.3, and unsprayed control with net benefit cost ratio of 1.25 (Table 2). This shows that application of dual gold gives the most economic returns.

Table 2. Cost-benefit analysis of herbicide treatments in faba bean production

	Dual Gold	Gallant Super	Unsprayed control
Grain yield (kg ha^{-1})	1796.7	1461.3	1166.7
Adjusted grain yield (kg ha^{-1})	1617	1315.2	1050
Gross income (ETB ha^{-1})	21021	17097.6	13650
Total costs that vary (ETB ha^{-1})	2260	2060	6060
Net benefit (ETB ha^{-1})	18761	15037.6	7590
Benefit (Net benefit/TC that vary)	8.30	7.30	1.25

Conclusion and Recommendation

Both Dual Gold (pre-emergence) and Gallant Super (post-emergence) herbicides were effective in controlling weeds in faba bean plots. They increased faba bean grain yield by 13.6-95.7% over the unsprayed control. The highest yield increment was from the pre-emergence herbicide, Dual Gold. The net benefit from Dual Gold and Gallant Super herbicides were higher than the unsprayed plots. Therefore, farmers in the Bale zone can use both herbicides to control weeds in faba bean farms. Wider scale promotion of these effective herbicides is required to create awareness and enhance availability and access.

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CHAPTER 3

FABA BEAN SEED PRODUCTION

Early Generation Seed Production of Faba Bean at Kulumsa Agricultural Research Center

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The Kulumsa Agricultural Research Center (KARC) is the major source of the EGS for faba bean in Arsi zone and the country at large. The KARC produces the EGS using the main center at Kulumsa and its sub centers (Bekoji and Kofele). Each year KARC provides more than 500 tons of breeder, pre basic and basic seed to the national seed system of different crops, including faba bean. Therefore, the ICARDA-USAID-faba bean project, in collaboration with Ethiopian Institute of Agricultural Research, designed activities to address the following objectives: (i) Improve the capacity of the KARC to produce high-quality EGS; (ii) Improve the linkage of the KARC with seed producers and seed producer cooperatives; and (iii) Produce enough quantity of EGS for newly released faba bean varieties for seed enterprise and SPCs.

Materials and Methods

Description of sites

The EGS production was carried out by Highland Pulse Research Program of KARC at the main center (Kulumsa), and sub-centers (Bekoji and Kofele) for three years (2015/16 to 2017/18); the geographic location and descriptions are presented below (Table 1).

Table 1. Geographic location and description of centers/subcenters in faba bean seed production

Center/ Subcenter	*Latitude N*	*Longitude E*	*Altitude masl*	*Annual total rainfall (mm)*	*Annual average maximum temperature (°C)*	*Annual average minimum temperature (°C)*	*Soil type*
Kulumsa	*8°01'*	*39°09'*	*2200*	*830*	*23.2*	*10*	*Light*
Bekoji	*7°53*	*39°25*	*2780*	*1020*	*20*	*8*	*Light*
Kofele	*07°04'*	*38°48*	*2620*	*1077*	*18.3*	*2.3*	*Vertisols*

Varieties and EGS production

The newly released and/or well-adapted faba bean varieties were included in the project. The varieties included Ashebeka, Dida'a, Dosha, Gabelcho, Gora, Hachalu, Moti, Numan, Tumsa, and Walki. For the EGS seed production, the following procedures were employed.

- **Maintenance breeding:** The breeder selected about 1000 pods from true-to-type plants from each selected varieties and planted each pod in a single row the following year. Then the breeder evaluated each row thoroughly and eliminated not true to type plants to the original population (Lavarack, 1994).
- **Breeder seed production:** The breeder increased the quantity of seed obtained from the maintenance breeding program and at this time similar inspection was also done by the breeder. Those rows with off type were eliminated and the true to type rows were harvested for each variety (van Gastel *et al*., 2002).

- **Pre-basic and basic seed production:** The pre-basic and basic seed production was carried out in collaboration with the KARC farm management department. In this process, the seed research team inspected and approved the seed based on quality standards set by the Ethiopian Standards Authority.

Crop management

The seed production fields at KARC and its sub-centers was selected based on the cropping history of the preceding year. The land used for EGS production of faba bean was the land covered with cereal crops in the previous cropping season.

The farm was prepared using the standard cultivation practices of the center set by the Farm Management Department. Planting was done in mid-June at Kulumsa and Bekoji, whereas planting at Kofele was in mid-August. The seed rate used for faba bean production was 150 kg ha^{-1} in row planting while fertilizer application rate was 100 kg ha^{-1} DAP. Weeding was done solely by manual means.

Results and Discussion

Breeder-seed production

At KARC, during three cropping seasons, 10 faba bean varieties were multiplied on 13.8 ha with the production of 15.89 tons (Table 2). The breeder seed was multiplied at the KARC main station. This seed was distributed mainly to seed enterprises and agricultural research centers (Table 3 and 4). In addition, some portion of the breeder seed was used for pre-basic seed production at KARC. Out of the total faba bean breeder seed produced, Walki, Hachalu and Ashebeka covered about 50% of the total seed produced because they are the most preferred and widely produced varieties by farmers.

Table 2. Breeder seed production by KARC at Kulumsa, Bekoji and Kofele ARS:2015/16-2017/18

Variety	2015/16		2016/17		2017/18		Total	
	Area (ha)	Seed (q)	Area (ha)	Seed (q)	Area (ha)	Seed (q)	Area (ha)	Seed (q)
Hachalu,	0.5	5	1.2	6	0.5	10	2.2	21
Moti	0.25	7	0.5	5	0.25	1.2	1	13.2
Ashebeka	0.25	6	1	8.5	0.75	5.5	2	20
Tumsa	0.5	1.35	0.5	5	0.75	14.7	1.75	21.05
Gora	0.25	3	0.5	4.65	0.5	6	1.25	13.65
Gabelcho	0.125	3	0.3	8	0.5	5.5	0.95	16.5
Dida'a	0.5	8	0.5	7.5	0.75	0	1.75	15.5
Walki	0.75	12	1.2	14.5	0.5	3.8	2.45	30.3
Dosha					0.25	3.7	0.25	3.7
Numan					0.25	4	0.25	4
Total	**3.125**	**45.35**	**5.72**	**59.15**	**5**	**54.4**	**13.8**	**158.9**

Note: 1 quintal is equivalent to 100 kg

Table 3. Faba bean seed delivered (q) to different stakeholders from KARC in 2015/16

Seed class	Variety	Initital stock	BahrDar U	TMSR	GIZ Green	OSE	Areka ARC	SG2000	WRbARC	KARC	HARC-ICARDA	ICARDA	HwARC	AAU	DbARC	Others	Final stock
Breeder	Gebelcho	1.49															1.49
	Hachalu	1.4		1													0.4
	Moti	5.67		2						1							2.67
	Tumsa	2		2													0
	Didea	9		2													7
	Ashebeka	2.34		2													0.34
	Sub-total	21.9		9						1							11.9
Pre-basic	Dosha	96	0.05	20			4	10	0.31	25.3	15	9.41	0.54		2	7.04	2.35
	Hachalu	33.27	0.05	9	3	10						2		0.5	2		6.72
	Sub-total	129.27	0.1	29	3	10	4	10	0.31	25.3	15	11.41	0.54	0.5	4	7.04	9.07
Basic	CS20DK	33															33
	Total	**184.17**	**0.1**	**38**	**3**	**10**	**4**	**10**	**0.31**	**26.3**	**15**	**11.41**	**0.54**	**0.5**	**4**	**7.04**	**53.97**

Note: One quintal is equivalent to 100 kg

Table 4. Faba bean seed delivered (q) to different stakeholders by KARC in 2016/17

Seed class	Variety	Initial stock	Arsi U	Hawassa U	TMSR	KARC	ESE	Areka ARC	ICARDA	GIZ Green	Ambo ARC	Soil KARC	KARC-ICARDA	Jimma U	Gondar U	DbARC	SekARC	Final stock
Breeder	Ashebeka	4.95			3													1.95
	Gora	4.65			4													0.65
	Gebelcho	5.3			3		2										0.1	0.2
	Hachalu	6.49			4						2							0.49
	Walki	11.45		0.2	7		3											1.35
	Moti	5.5		0.2	4			1										0.3
	Didea	6.12			4							1.32						0.8
	Tumsa	5			4													1
	Sub-total	49.46		0.4	33	0	5	1	0	0	2	1.32					0.1	6.74
Pre-basic	Tumsa	4.18			2							0.68						1.5
Basic	Dosha	131	1.8		30	10			6	20		1	40	0.4		10	1.8	10
	Hachalu	70			4					11			33.05	0.95	20			1
	Sub-total	201	1.8		34	10			6	31		1	73.05	1.35	20	10	1.8	11
	Total	**254.64**	**1.8**	**0.4**	**69**	**10**	**5**	**1**	**6**	**31**	**2**	**3**	**73.05**	**1.35**	**20**	**10**	**1.9**	**19.24**

Note: One quintal is equivalent to 100 kg

Pre-basic seed production

During the three cropping seasons, KARC in its main campus and sub-stations produced 20.9 tons of pre-basic seed on 31.1 ha of land (Table 5). In pre-basic seed production, seven faba bean varieties were included although the highest amount produced was for variety, Dosha (9.7 tons) followed by Hachalu (4.1 tons).

Table 5. Pre-basic seed of faba bean produced during 205/16-2017/18 by KARC

Variety	2015/16		2016/17		2017/18		Total	
	Area (ha)	Seed (q)	Area (ha)	Seed (q)	Area (ha)	Seed (q)	Area (ha)	seed (q)
Hachalu	5.5	32			2.5	9.5	8	41.5
Dosha	8.22	97					8.22	97
CS20DK	3.3	30					3.3	30
Dida'a			1	5.25	2		3	5.25
Tumsa			0.6	8	1.5		2.1	8
Moti					2.5		2.5	0
Walki					4	27.2	4	27.2
Total	**17.02**	**159**	**1.6**	**13.25**	**12.5**	**36.7**	**31.1**	**208.95**

Note: q= quintal; and one quintal is equivalent to 100 kg

Basic seed production

Only two of the most prominent faba bean varieties, Dosha and Hachalu, were included for basic seed production (Table 6). This was due to the demand by farmers and other actors. In the three-year project period, the KARC allocated 18.8 ha of land and produced a total of 32.375 tons of faba bean basic seed.

Summary of faba bean seed production

In general, during 2015/16 to 2017/18, the KARC in collaboration with the ICARDA-USAID-project produced about 69.16 tons of breeder, basic, pre basic seed of faba bean on 63.7 ha of land. This indicates the contribution of the KARC and the project in seed system.

The breeder, pre-basic and basic seed produced at KARC was distributed all over the country. Among the recipients are research centers, universities, NGOs, seed producer cooperatives, seed enterprises and others (Tables 2 and 3). Ultimately the seed distributed increased fab bean productivity and production thereby contributing to food and nutrition security of resource poor farmers in the country.

The major reason for the yield variation across years for faba bean EGS production was the lack of appropriate mechanization for harvesting. As a result, the harvesting was sometimes delayed and resulted in yield losses. In addition, in the sub stations, delayed land allocation and land preparation contributed to the low yield. Faba bean gall and Ascochyta blight diseases also contributed to the yield reduction.

Table 6. Basic seed of faba bean produced by KARC during 2016/17 to 2017/18 cropping season

Variety	2016/17		2017/18		Total	
	Area (ha)	Seed produced (t)	Area (ha)	Seed produced (t)	Area (ha)	Seed produced (t)
Dosha	9.8	16.95	5.5	6.574	15.3	23.52
Hachalu	3.5	8.85			3.5	8.85
Total	**13.3**	**25.8**	**5.5**	**6.574**	**18.8**	**32.374**

Challenges

Shortage of land for EGS production in the research centers is a critical challenge. The KARC, which is the sole provider of the EGS of faba bean in the Oromia region, did not have enough land to work at full capacity. Therefore, this issue should be taken seriously so that the KARC can produce the required amount and quality of EGS seed and supply for the seed producers in the country.

Future direction

The responsible agency, especially the office of agriculture at zonal and woreda levels, should facilitate and provide more land for KARC for early generation seed production. The other option, until enough land is obtained, is to work with the Oromia Seed Enterprise for faba bean seed production. The strategic solution requires policy support from the federal and regional governments to keep the existing research lands and to get the new ones if the government wants to improve the productivity of the farmers through access to improved technologies especially quality seed supply.

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Basic and Certified Seed Production of Faba Bean Varieties by Farmer Seed Producer Cooperatives

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In Ethiopia, the gap between demand and supply for faba bean seed is very high. Bishaw and Atlaw (2016) indicated that only 9% of farmers seed demand for faba bean was met from the formal sector. Seed multiplication program by farmers' seed producers' cooperatives (SPCs) has increased hopes in strengthening the country's national seed system (Bishaw *et al*, 2018). In recent years, SPCs closely working with Kulumsa Agricultural Research Center (KARC) have been producing and marketing high-quality seed of newly released faba bean varieties to various stakeholders in different parts of the country. Since 2015/16 cropping season, ICARDA-USAID supported project was launched to strengthen the SPCs in producing the required faba bean varieties both in terms of quality and quantity. Therefore, the objective of this paper is to present the achievements made and the challenges encountered in faba bean seed production by SPCs in Arsi and West Arsi zones of Oromia Regional State.

Materials and Methods

Project target districts

Seven districts (six in Arsi, namely Tiyo, Lemu-Bilbilo, Honkolo-Wabe, Munesa, Arsi-Robe, and Chole) and one in West Arsi (Kore) were involved in faba bean seed production (Table 1; Figure 1). These districts are known for their potential faba bean production; and they are situated from 07°43.645' to 08°11.341' N latitude, and from 03°66.489' to 039°54.592' E longitude. Their altitude ranges from 2453 masl (Belekesa Gado in Arsi-Robe district) to 3084 masl (Moye Gado in Chole district). These areas receive an annual rainfall that ranges from 863.8 mm (Bila-Sokora in Chole district) to 1089.9 mm (Dandi-Boru in Tiyo district). Their minimum and maximum temperatures as well as their major soil types are indicated in Table 1.

Table 1. Descriptions of ICARD-USAID project supported faba bean seed producer cooperatives

SPCs	District	Kebele	N	E	Altitude (m)	RF	Tmax	Tmin	Soil type
Moye-Gado	Chole	Gado	08°14'	039°55'	3084	866	27.1	14.3	Nitosols
Bila-Sokora	Chole	Koro	08°11'	039°54'	2962	864	27.1	14.3	Nitosols
Hundie-Gudina	Munesa	Dobashe	07°31'	038°59'	2778	1026	22.5	10.0	Luvisols
Tuka-Katara	Limu Bilbilo	Dawa-Bursa	07o26'	039°14'	2928	1029	18.1	5.7	Vertisols
Lemu-Dima	Limu Bilbilo	Lemu-Dima	07°34'	039°16'	2893	1050	19.6	8.3	Luvisols
Lemu-Burkitu	Limu Bilbilo	Burkitu	07°36'	039°15'	2734	1050	19.6	8.3	Luvisols
Dheka-Dhera	Limu Bilbilo	Hule Kara	07°26'	039°16'	2981	1029	18.1	5.7	Vertisols
Teji-Burkitu	H/Wabe	Teji-Walkite	07°25'	039°24'	2839	989	23.5	11.2	Vertisols
Balakasa-Gado	Arsi Robe	Balaksa-Gado	07°49'	039°44'	2453	872	25.5	13.0	Vertisols
Beriti	Tiyo	Beriti	07°50'	039°11'	2983	1026	22.5	10.0	Luvisols
Dandi-Boru	Tiyo	Bilalo	07°52'	039°07'	2565	1090	21.8	12.3	Luvisols
Lelisa-Bole*	Kore	Bolehilenso	07°13'	038°56'	2805	1281	20.6	8.4	Nitosols

*Note: * West t Arsi zone; SPC = seed producer cooperative; RF = rainfall (mm); Tmax = maximum temperature (°C); Tmin = minimum temperature (°C)*

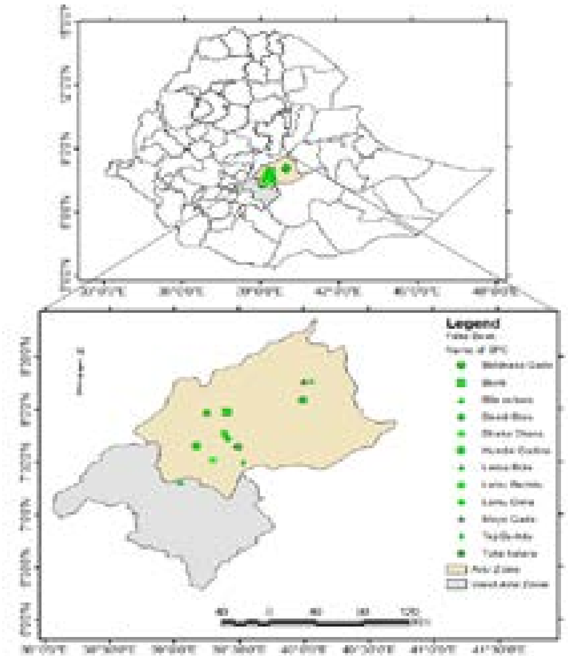

Figure 1. Map showing the relative location of project target SPCs in Arsi and West Arsi zones

Seed producer cooperatives and member farmers

A total of 12 licensed SPCs in seven districts were involved in the faba bean seed production, each cooperative having a minimum of 25 and a maximum of 172 member farmers with a total members of 817 (744 male and 73 female) were involved and the number is increasing over time (Table 2). Farmers that are not members of SPCs but who have farms in proximity to the seed farms of member farmers were also involved in the project activities to cover the land area with the same faba bean variety and avoid cross pollination.

Table 2. Number of member farmers of SPCs involved in faba bean seed production

SPCs	Zone	District	Kebele	Members		
				Male	Female	Total
Lemu-Dimma	Arsi	Lemu Bilbilo	Lemu-Dima	144	28	172
Tuka-katara	Arsi	Lemu Bilbilo	Dawa-Bursa	48	5	53
Deka- Dhera	Arsi	Lemu Bilbilo	Hule-Kara	61	4	65
Lemu-Burkitu	Arsi	Lemu Bilbilo	Lemu-Burkitu	88	1	89
Teji-Burkitu	Arsi	Honkolo Wabe	Teji-Welkite	30	4	34
Hunde-Gudina	Arsi	Munesa	Dobashe	38	3	41
Beriti	Arsi	Tiyo	Waji-Chilalo	40	6	46
Abdi-Boru	Arsi	Tiyo	Haro-Bilalo	32	6	38
Bila-sekora	Arsi	Chole	Bila	35	0	35
Moye-Gado	Arsi	Chole	Gado	22	3	25
Balakasa-Gado	Arsi	Arsi Robe	Habe	95	1	96
Lelisa-Bole	West Arsi	Kore	Bole-Hilensa	111	12	123
Total				**744**	**73**	**817**

Training

Several trainings were organized for farmers, development agents, and agricultural professionals working on the seed production in the districts and localities where SPCs are located. Five major trainings were organized separately depending on the levels of each SPC covering broad range of topics including technical and management issues.

Crop management

The planting time for faba bean in the target districts ranged from early to late June. Majority of the member farmers in the cooperatives row planted their faba bean with seed rates of 150 to 175 kg ha^{-1} for medium seed size faba bean varieties Dosha, Walki and Hachalu; and 200 kg ha^{-1} for large seed-size varieties, Gebelcho, Ashebeka and Gora. They used 75 to 125 kg ha^{-1} NPS and 500 g (four packs each with 125 g) of biofertilizer per hectare to fertilize their faba bean fields. Farmers applied one to two hand weeding with inter-row cultivation to control weeds. Some farmers also applied one liter per hectare Gallant Super post-emergence herbicide to control grass weeds. Other recommended seed production packages like proper land preparation, cropping history, isolation distances, crop management, harvesting, drying and seed cleaning and storage were also applied under the supervision of a team of researchers from KARC and agricultural experts from respective districts of the cooperatives. Depending on the localities, the harvesting time ranged from early November to early December.

Seed quality control and certification

Assela seed quality control and certification laboratory inspected the quality of the faba bean seeds produced by each cooperative. Apart from seed quality control, the laboratory participated in providing trainings to the members of the cooperatives and development agents to develop skills for improving seed production.

Field days

KARC, in collaboration with the SPCs and other stakeholders, organized various field days each year to demonstrate the new varieties and promote the seed production of the SPCs to create market linkages. Various governmental and non-governmental organizations, and farmers participated in the field days.

Data collection

Data collection included the amount and classes of seeds and faba bean varieties distributed to the cooperatives, area covered by each variety and seed class, quantity of seeds produced in each seed class and variety, seed marketing by the cooperatives and individual member farmers, seed fields inspected and the results of the inspection.

Results and Discussion

Seed supply

Each year, with the joint support of ICARDA-USAID project and KARC, significant amounts of initial seed of faba bean varieties were provided to the SPCs. At the start of the project, in 2015/16 cropping season, all the cooperatives linked to the project and other individual farmers who were not member of cooperatives, used 21.2 tons seed to cover 106 ha of land. From the seeds provided, KARC contributed 4.1 tons of pre-basic seeds of five varieties (Dosha, Gabelcho, Hachalu, Tumsa, and Gora). The project purchased 9.1 tons basic seed of Walki variety from Oromia Seed Enterprise, and 8.0 tons basic seed of Gabelcho variety from Lemu-Dima and Tuka-Ketar Seed Producers' Cooperatives.

In 2016/17 cropping season, with the support of the project, KARC has delivered 25.6 tons seed of three varieties (Dosha, Gabelcho and Walki) to eight SPCs and other farmers to cover 128 ha of land. Sources of purchased seed in 2016/2017 include 15.9 tons seed from KARC and four cooperatives (Lemu-Dima, Tuka-Ketar, Hunde-Gudina, and Balakasa-Gado). The remaining 9.7 tons seed was revolving seed from previous cropping season.

Similarly, in the 2017/18 cropping season, with the same support, 30.48 ton seed of different classes of seeds of five varieties were delivered to 12 SPCs to cover 152.4 ha. Out of this amount, only 0.48 tons of the seed was pre-basic seed of the two varieties (Gabelcho and Ashebeka), which was supplied by KARC. About 17.35 tons (56.92%) of the seed was basic seed of three varieties, namely Dosha, Gabelcho and Hachalu purchased from KARC and three SPCs (Tuka Ketar, Hunde-Gudina and Teji-Burkitu). The remaining 12.65 tons (41.5%) of seed was either basic or certified seed 1 of three varieties (Gabelcho, Dosha and Walki) from revolving seed from the previous cropping season.

Basic and certified seed production

KARC, with the support of ICARDA-USAID project, promoted basic and certified seed production by the SPCs from 2015/16 to 2017/18. A total of 175.4 tons of basic seeds of six varieties were produced from 86.4 ha of land during the three years (Table 3). The large proportion of seed produced was for Gabelcho variety contributing 88.05 tons (50.2%) of the total basic seed production, followed by Dosha variety that had a share of 76.95 tons (43.8%) of the total produce. The remaining seed production was from four varieties that contributed only 13.91 tons (7.93%) of the produce. In producing these basic seeds 192 member farmers (186 male and 6 female) were actively involved.

Table 3. Faba bean basic seed production by SPCs during 2015/16 to 2017/18 meher cropping season

Variety	2015/16		2016/17		2017/18		Total		Producer farmers		
	Area (ha)	Yield (t)	Area (ha)	Yield (t)	Area (ha)	Yield (t)	Area (ha)	Yield (t)	Male	Female	Total
Dosha	7.5	11.7	30	65.25			37.5	76.95	69	5	74
Gabelcho	8.5	9.85	35	76.4	0.65	1.8	44.2	88.05	100	1	101
Gora	2.5	6.40					2.5	6.40	8	0	8
Tumsa	0.75	1.20					0.75	1.20	2	0	2
Hachalu	1.5	2.80					1.5	2.80	2	0	2
Ashebeka					1.75	3.51	1.75	3.51	5	0	5
Total	**20.75**	**31.95**	**65**	**141.7**	**2.4**	**5.31**	**86.4**	**175.4**	**186**	**6**	**192**

Note: t= ton and 0.1 ton is equivalent to 100 kg; M = male; F = female

The SPCs also played quite significant role in producing large quantity of certified seed of four varieties of faba bean during the three years. Their production increased from 149.4 tons in 2015/16 to 260.54 tons in 2017/18 with total production of 532.8 tons on 298 ha of land (Table 4). The highest production was for Walki variety, which is suitable for Vertisols areas of the country, contributing 218.7 tons (41.05%) of the total production. For Gabelcho and Dosha about 169.3 tons (31.77%) and 110.4 t (20.72%) of seed produced, respectively. The overall productivity of Gabelcho and Dosha was relatively low due to moisture stress and high aphid infestation in the early crop growth stage in the 2015/16 cropping season, and frost damage in 2017/18 cropping season in some areas. For certified seed production, a total of 553 member farmers (515 male and 38 female) participated.

Table 4. Faba bean certified seed production by SPCs during 2015/16-2017/18 meher cropping season

Variety	2015/15		2016/17		2017/18		Total		Producer farmers		
	Area (ha)	Seed (tons)	Area (ha)	Seed (tons)	Area (ha)	Seed (tons)	Area (ha)	Seed (tons)	Male	Female	Total
Dosha					65	110.39	65	110.39	130	5	135
Gabelcho	40	30.6	26	57.2	50	81.45	116	169.25	185	13	198
Walki	45.5	118.8	37	65.7	19	34.2	101	218.70	162	19	181
Hachalu					16	34.5	16	34.50	38	1	39
Total	**85.5**	**149.4**	**63**	**122.9**	**150**	**260.54**	**298**	**532.8**	**515**	**38**	**553**

Seed certification

The seed quality control and certification of faba bean seed for all SPCs were carried out by Asela Seed Quality and Certification Center (ASQCC) up on the request from KARC in 2016/17. In 2017/18 cropping season, the seed fields of Tuka-Ketar, Deka-Dera, Teji-Burkitu, and Lemu-Dima SPCs was linked to Galema Union, and Belekesa-Gado SPC was linked to Hitosa Union and the field inspection was conducted based on the request from the respective unions. The seed fields of other cooperatives such as Hunde-Gudina were not inspected since either they did not have certificate of competence, or they were not linked to any of the unions that have the certificate of competence. In 2016/17, about 39.06 ha of land was inspected, out of which 35.86 ha (91.81%) was accepted and the remaining 3.2 ha (8.19%) was rejected (Table 5). In terms of seed production, 81.19 tons (91.76%) was accepted while the remaining 7.3 tons (8.24%) was rejected.

Similarly, in 2017/18 cropping season, 55.4 ha of seed production fields of four varieties of faba bean were inspected by ASQCC (Table 6). Out of the total inspected fields, 54.15 ha (97.74%) with seed yield of 129.72 tons (98.77%) was accepted while only 1.25 ha (2.26%) with seed production of 0.16 tons (1.23%) was rejected (Table 6).

Table 5. Faba bean seed production and certification by ASQCC in Arsi zone in 2016/17 meher cropping season

SPC	Variety	Seed class	Area (ha)				Seed produced (tons)	
			Planted	Evaluated	Accepted	Rejected	Accepted	Rejected
Tuka-Ketara	Gabelcho	Basic	8.16	4.06	1.86	2.2	6.362	6.366
	Gora	CS1	1.75	1.5	1.25	0.25	3.2	0.7
Bekoji-Negeso	Gabelcho	CS1	5	3.5	3.5	0	8.525	0
Hunde-Gudina	Dosha	Basic	7.5	5	4.25	0.75	12.55	0.225
Teji-Burkitu	Dosha	Basic	5	2	2	0	2.4	0
Balakasa-Gado	Walki	CS1	25	23	23	0	48.15	0
	Total		52.41	39.06	35.86	3.2	81.187	7.291

Note: SPC = seed producer cooperatives; CS1= certified seed 1

Table 6. Faba bean seed production and certification by ASQCC in Arsi zone in 2017/18 meher cropping season

SPC	Variety	Seed class	Area (ha)				Seed produced (tons)	
			Planted	Evaluated	Accepted	Rejected	Accepted	Rejected
Lemu-Dima	Dosha	CS1	2.5	2.5	2.5	0	6.4	0
Tuka-Ketara	Gabelcho	Basic	0.65	0.65	0.65	0	1.8	0
	Gabelcho	CS1	12	12	12	0	32.0	0
	Dosha	CS1	5	5	5	0	10.5	0
Deka-Dera	Gabelcho	CS1	5	5	4.25	0.75	12.17	0.7
	Dosha	CS2	4.25	4.25	3.75	0.5	9.315	0.92
Teji-Burkitu	Gabelcho	CS1	5	5	5	0	13.3	0
	Dosha	CS1	2	2	2	0	62.2	0
Balakasa-Gado	Hachalu	CS1	16	16	16	0	34.5	0
	Ashebeka	Basic	3	3	3	0	3.51	0
	Total		**55.4**	**55.4**	**54.15**	**1.25**	**129.715**	**1.62**

Note: SPC = seed producer cooperative; CS1 and CS2 are certified seed 1 and certified seed 2

Seed marketing and farmer seed exchange

The aim of establishing SPCs is to avail quality seed of farmers' desired varieties within their close vicinities. The SPCs working on faba bean particularly played significant role in achieving the objectives with the ICARDA-USAID supported project. They were not only marketing seed to their neighboring farmers but also to farmers beyond kebeles in their districts and to farmers from other districts. They were also marketing seed to various governmental and non-governmental organizations that distributed seed in various regions of the country. Data on seed marketing and distribution at the beginning of the project (2015/16) was not properly collected and the seed produced during the final year of the project (2017/18 from January 2017 to December 2018) were not totally accounted for since the distribution took place after harvest in 2019. Therefore, this report includes the seed marketing report in 2016/17 cropping season, based on data collected from six SPCs (Table 7).

The seed marketing and exchange data collected indicate a total of 143.28 tons of seed of three faba bean varieties sold/bartered either by individual farmers by themselves or through their respective cooperatives (Table 7). A total of 54.25 tons (37.86%) of seed was sold through the cooperatives to various customers including farmers. These cooperatives sold their seeds to research centers such as Holeta, Debre Birhan, Sekota, Gondar, Mekele, Alamata, and Kulumsa; non-governmental organizations (NGOs) such as Self-help Africa, GIZ Green Innovation and ICARDA-Africa Rising; other SPCs, cooperatives' unions, and individual farmers. The seeds sold to various research centers, NGOs and unions were distributed to farmers and seed producer groups in their respective regions/districts where they operate.

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SPC member farmers sold (34.86 tons) or bartered (1.13 tons) collectively about 35.99 tons (25.12%) of the seed to 392 male and 26 female farmers in 57 kebeles of 14 districts. From the remaining seed, 20.6 tons (14.38%) was used for farmers' own seed source for the next cropping season, while 32.44 tons (22.64%), which is a significant amount, was either consumed at home or sold as grain due to poor seed market linkages.

The seed price ranged from 950 to 2000 ETB per 100 kg seed, the lowest price being when the seed was sold during harvesting period and the highest price was when the seed was sold during planting time. The price was variable when sold individually, but it was fixed when sold through the cooperatives. Some farmers exchanged their faba bean seed through bartering mainly with either teff or wheat and the exchange ratio was one-to-one for teff, and 1.5: 1 for wheat to faba bean.

Table 7. Faba bean seed marketing, exchange and use by SPCs in 2016/17

SPCs	Variety	Seed sold by SPCs		Direct farmer exchange/sale (t)			Beneficiary farmers from local exchange				Own seed use (t)	Grain use (t)	
		Amount (t)	Price (0.1 t)	Bartered	Sold	Price (0.1 t)	M	F	Districts	Kebeles		Consumed	Sold
Hunde-Gudina	Dosha	13	1868-2000	0.15	4	1100-2000	40	2	2	9	1.7	3.905	2.74
Lemu-Dima	Dosha	8.5	1868-2000								0.5		
	Gabelcho	4.9	1868-2000										
Teji-Burkitu	Gabelcho	0.65	1200-1600	0.05	1.375	1200-1600	15	0	2	5	1.25	0.425	
	Dosha	4.75	1250	0	3.15	1000-1800	28	0	2	7	1.2	1.125	0.345
Beleksa-Gado	Walki	0.7	1450	0.93	21.485	950-1800	266	24	5	26	8.42	6.515	10.735
Deka-Dera	Gabelcho	5.5	1860	0	1.1	1450-1860	12	0	1	1	2	1.1	2.05
Tuka-Ketar	Gabelcho	13.5	1860	0	3.45	1450-1860	28	0	1	7	4.5	1.4	1.6
	Dosha	2.75	1860	0	0.3	1450-1861	3	0	1	2	1	0.2	0.3
Total		**54.25**		**1.13**	**34.86**		**392**	**26**	**14**	**57**	**20.57**	**14.67**	**17.77**

Note: t=tons and 0.1 ton is equivalent to 100 kg; seed price is in ETB 100 kg^{-1}; M = male; F = female

Trainings and field days

Various trainings and field days were organized with support from the ICARDA-USAID project. The themes of the trainings were:

- Seed production and management of faba bean to make farmers aware of the necessary requirements and develop the knowledge and technical skills of quality seed production; Moreover, the importance and application of biofertilizer for faba bean production is also included;
- Practical training on management of seed production fields. Visits will be made to most seed fields (cluster-fields) and farmers present the management used on his/her seed fields. This is followed by question-and-answer sessions, open discussions and suggestion on way forward;
- Post-harvest management for maintaining seed quality such as seed cleaning and storage conditions; and
- Seed business and entrepreneurship skills for executive committee members of the cooperatives, district level cooperative officers and auditors that are working

with the SPCs. The aim of the entrepreneurship training was to strengthen the organizational structures for effective technical and financial management of the cooperatives and ensure their sustainability.

In general, 1832 participants were involved in all the trainings delivered during the three years from 2015/16 to 2017/18. Among the trainees 1448 (1320 male and 128 female) were farmers and the rest 384 (332 male and 52 female) were zone and district level experts, kebele development agents, researchers and others from relevant stakeholders (Table 8).

Table 8. Summary of training course participants during 2015/16-2017/18

Participants	2015/16			2016/17			2017/18		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Farmers	302	35	337	580	88	668	573	39	612
Experts and DAs	77	1	78	106	18	124	70	8	78
Researchers				40	2	42	49	11	60
Others				72	7	79	43	6	49
Total	**379**	**36**	**415**	**798**	**115**	**913**	**735**	**64**	**799**

Note: DAs= development agents

The field days contributed a great deal in creating a better image of the SPCs in the presence of potential customers and authorities, such as the Bureau of Agriculture and Cooperative Promotion Agency. Experience sharing and knowledge transfer among farmers were also important part of the field days. In total, about 2127 participants participated in the field days organized during the three years period from 2015/16 to 2017/18 meher cropping seasons. Among participants, 1617 (1455 male and 162 female) were farmers and the rest 510 (457 male and 53 female) participants were from different partners and stakeholder organizations; including researchers (Table 9).

Table 9. Summary of number of participants of field days organized during 2015/16-2017/18

Participants	2015/16			2016/17			2017/18		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Farmers	82	6	88	844	99	943	394	23	417
Experts and DAs	34	11	45	128	24	152	56	11	67
Researchers				38	1	39	36	4	40
Others				40	1	41			
Total	**116**	**17**	**133**	**1050**	**125**	**1175**	**486**	**36**	**522**

Note: DAs=development agents

Challenges

The major challenges of the seed producer cooperatives in faba bean seed production includes:

i. Shortage of initial seeds: There is critical shortage of early generation seed particularly of recently released faba bean varieties. As a result, cooperatives could not regularly access the initial seed required for varieties in sufficient quantities and are forced to use later generation seed (certified seed 1 and below) for their seed production.

ii. Clustering fields: There were many fields of non-member farmers amidst the fields of SPC member farmers that made the field clustering difficult. Since faba bean is a partially cross-pollinated crop there is a need for proper isolation of the variety during seed multiplication. However, there is no legal enforcement to forbid a near-by farmer not to sow a different faba bean variety. Lack of isolation increases the chances of cross-pollination leading to increased rejection rate of the seed produced.

iii. Lack of consensus among SPC members seed production as business: There is no common understanding among member farmers and across cooperatives in considering seed production as business and not giving due considerations in developing their cooperatives. Some farmers individually sold their seed with lower prices not only for seed purpose but also as grain and hence not able to get the right benefit for themselves or for their cooperatives undermining the collective effort. Besides, most of the cooperatives are not appropriately promoting themselves as seed producers and not able to search for the right market for their produced seed and rather depend on other stakeholders to search market for them.

iv. Weak capacity: Most of the cooperatives have limited financial and physical capacity that hinders them to collect, process and store the produced seed by member farmers and market it collectively.

Recommendations

- Strategies must be designed along the faba bean seed value chain to solve the bottlenecks of each actor to sustainably supply the seeds of the required varieties.
- The cooperatives need to persuade their neighboring farmers to join their cooperatives; they also need to be supported by responsible public agencies, particularly by cooperative development offices in their respective districts in this regard.
- More concerted efforts are required for improving the awareness of farmers on local seed business so that all the seeds produced to be solely used for seed purpose.
- Financial institutions need to be involved and design strategies in availing creditss for the cooperatives to develop their physical and financial capacity.
- Sustainability of SPCs should be given emphasis in the future since the cooperatives active participation in seed production is associated with project support and are not standing by themselves. The cooperative development offices in each district should strongly support them to guarantee their sustainability as seed producers.

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Profitability of Faba Bean Seed Producer Cooperatives in Arsi Zone

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The Kulumsa Agricultural Research Center (KARC), with the support of ICARDA-USAID faba bean-malt barley seed production and scaling project and other collaborative organizations, established 12 local seed producer cooperatives (SPCs) in Arsi zone to enhance malt barley and faba bean seed production and supply in the national seed system. Experiences elsewhere on the community-based bean seed production enterprises in Ethiopia showed a gross margin profitability of US$ 792 ha^{-1}, besides its easy accessibility to the farmers (Tebeka *et al*., 2017). Similarly, the results from the wheat contractual seed production in Amhara region showed a profitability value of US$ 514 ha^{-1} which is reasonably encouraging (Tsegaye, 2012). Therefore, this study was focused to assess the profitability of faba bean seed production in Arsi zone.

Materials and Methods

Seed producer cooperatives

The study was conducted during 2015/16-2017/18 cropping seasons on four seed producer cooperatives established by KARC in Arsi Zone, Oromia Regional State. The geographic location and farming system descriptions of the seed producer cooperatives participated in the study are presented below (Table 1). Although the SPCs were established and involved in seed production of other crops, this study focused on the faba bean seed production.

Table 1. The geographic location and descriptions of SPCs participated in the study

Seed Producer Cooperative	Latitude N	Longitude E	Altitude masl	Annual total rainfall (mm)	Annual average maximum temperature (°C)	Annual average minimum temperature (°C)	Soil type
Lemu Dima	7°34.572'	39°16.536'	2893	1049.6	19.6	8.3	Luvisols
Hundie Gudina	7°31.494'	38°59.696'	2778	1025.7	22.5	10.0	Luvisols
Tuka Katara	7°26.774'	39°14.936'	2928	1028.5	18.1	5.7	Vertisols
Teji Burkitu	7°25.301'	39°24.491'	2839	989.2	23.5	11.2	Vertisols

Data collection and analysis

Data on the number of member farmers of each SPC were collected. To estimate the profitability (net benefit) of each SPC, the following data were recorded.

1. The total land occupied by each faba bean variety in the respective SPC.
2. The average farm-gate price of the seed and straw produced; however, price of faba bean straw was not obtained since it had no established market.

3. All associated costs incurred to produce the faba bean seed in each SPC.
4. Total revenue was estimated by multiplying the average farm-gate price with the total seed and straw production.
5. The net benefit was estimated by subtracting the total cost incurred from the total revenue.

Results and Discussion

Seed producer cooperatives

The year of establishment and gender disaggregated membership of target SPCs are presented in Table 2. Although Teji-Burkitu SPC was established earlier than the other SPCs, its member farmers are the lowest with 34 farmers (4 female), while Lemu-Dima SPC which was established in 2011 has the highest number of member farmers of 172 (28 female). The number of member farmers may have effect on scale and total net benefit (Tables 2 & 3) since land holding size of the SPC is directly associated with the number of member farmers who have individual right for direct access to landholding. With the support of ICARDA-USAID faba bean-malt barley seed production and scaling project in 2015/16—2017/18, the four SPCs produced malt barley and faba bean seeds in rotation to maintain soil fertility and health in the highlands of Arsi Zone where the two are major crops.

Table 2. The number of member farmers and target seed producer cooperatives during 2015/16—2017/18 cropping seasons

SPCs	Districts	Year established	Member farmers		
			Male	Female	Total
Lemu Dima	Lemu Bilbilo	2011	144	28	172
Hunde Gudina	Munisa	2012	38	3	41
Tuka Ketara	Lemu Bilbilo	2012	48	5	53
Teji Burkitu	Honkolo Wabe	2010	30	4	34

Profitability

Summary of the faba bean seed produced, productivity and profitability is presented in Table 3. Total production area of faba bean varieties across the four SPCs for the three years was 17.31 and 12.29 ha of land for Dosha and Gabelcho, respectively. Tuka-Ketara SPC had the highest land area of 11.34 ha for faba bean seed production, but the productivity was the lowest, being about 2.56 tons ha^{-1} while productivity of Hunde-Gudina SPC having the second largest land area of 8.22 ha was the highest, being 3.10 tons ha^{-1}. The respective productivity of faba bean in Lemu-Dima and Teji-Burkitu SPCs was 2.66 and 2.98 tons ha^{-1} on the corresponding land area of 5.23 and 4.81 ha. Even though seed price was not the same among SPCs (12.50—19.34 ETB kg^{-1} seed), profitability was the highest for the SPC having the highest productivity. The lowest profitability was in Teji-Burkitu due to the combined effect of the lowest seed price (12.50—14.00 ETB kg^{-1} seed) and the lower productivity (2.98 tons ha^{-1}). Thus, Hunde-Gudina, Teji-Burkitu, Lemu-Dima, and Tuka-Ketara, with the respective productivity of 3.10, 2.98, 2.66 and 2.56 tons ha^{-1} obtained the corresponding net

benefit of 41,415.12, 21,366.13, 35,428.09 and 28,461.86 ETB ha^{-1}. Hunde-Gudina, with the combined effect of higher seed price (19.34 ETB kg^{-1} seed) and the second largest planted land area of 8.22 ha, obtained the highest total net benefit of 340,432.27 ETB, followed by 322,757.52 ETB of Tuka-Ketara with the largest planted land area of 11.34 ha and the lowest productivity of 2.56 tons ha^{-1}.

In faba bean, both productivity and price influenced profitability since a wide range of price and productivity gaps among SPCs were observed. Seed price gap between the lowest and the highest was 54.72% while productivity gap was 21.09%. That is why Teji-Burkitu with the lowest seed price and the second-best productivity became the least in profitability, 21,366.12 ETB ha^{-1}. Regardless of price variations among SPCs, the widely produced faba bean variety, Dosha, on a total of 17.31 ha had the highest profitability of 33,264.97 ETB ha^{-1} because of its highest productivity of 2.87 t ha^{-1} as compared to Gabelcho variety, which gave a profitability of 30,547.85 ETB ha^{-1} on 12.29 ha of land with the average productivity of 2.69 t ha^{-1}. Therefore, along with the selection of productive faba bean variety, farmers are required to apply all the necessary agronomic practices according to the recommendation of agricultural production packages to increase productivity for improving profitability per unit area. It was also an learning experience to know that Teji-Burkitu was weak in bargaining power to fix price because of its small size in scale and therefore obtained the lowest profitability because of its lowest seed price regardless of its second-best productivity.

Table 3. Summary of profitability analysis of faba bean seed production by SPCs during 2015/16—2017/18 in Arsi Zone of Oromia Regional State

Cooperative	Variety	Planted area (ha)	Total seed produced (t)	Total cost (ETB)	Total revenue (ETB)	Total net benefit (ETB)	Profitability (net benefit ETB ha^{-1})
Hunde Gudina	Dosha	8.22	25.50	152641.03	493073.30	340432.27	41394.00
Total		**8.22**	**25.50**	**152641.03**	**493073.30**	**340432.27**	**41394.00**
Lemu Dima	Dosha	3.52	9.00	56165.63	174060.00	117894.38	33534.40
	Gabelcho	1.71	4.90	27371.47	94766.00	67394.53	39336.40
Total		**5.23**	**13.90**	**83537.09**	**268826.00**	**185288.91**	**36435.40**
Teji Burkitu	Gabelcho	1.41	3.75	23998.31	52500.00	28501.69	20217.20
	Dosha	3.40	10.57	57855.63	132125.00	74269.37	21852.20
Total		**4.81**	**14.32**	**81853.93**	**184625.00**	**102771.07**	**21034.70**
Tuka Ketara	Dosha	2.17	4.55	41409.33	84630.00	43220.67	19948.00
	Gabelcho	9.17	24.45	175233.15	454770.00	279536.85	30488.00
Total		**11.34**	**29.00**	**216642.48**	**539400.00**	**322757.52**	**25218.00**

Note: Average farm gate price of faba bean seed was 19.34, 19.34, 12.50-14.00 and 18.60 ETB kg^{-1} at Hunde-Gudina, Lemu-Dima, Teji-Burkitu and Tuka-Ketara SPCs, respectively. One USD was equivalent to 28.00 ETB in the official market during the study.

Conclusions and Recommendations

This study confirmed that seed production as a business by seed producer cooperatives in Arsi zone is profitable. Profitability for faba bean seed production ranged from 21,366.12 to 41,415.12 ETB ha^{-1} among the study target of four SPCs during 2015/16—2017/18. Both productivity and seed price affected profitability. Further, the study suggests that improving productivity of varieties and crop management practices may increase profitability of SPCs. The size of SPCs is also important to increase the scale of production based on land area (since member farmers own land), which largely influences price bargaining power and eventually the profitability.

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Community-based Faba Bean Seed Production and Marketing in North Shewa Zone

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The farmer-based seed production (FBSP) entails the organization and establishment of a group of farmers to operate seed business at local level (Seth *et al*., 2015). Several entities are involved in farmer-based faba bean seed and grain production and marketing systems in North Shewa Zone. These include government development institutions, public seed enterprises, farmers' cooperatives unions, cooperatives, seed producer farmers, and grain producers. In the process, there is flow of inputs and products as well as many activities and actors involved. This study was conducted to evaluate the contribution and profitability of farm-level faba bean seed production and marketing activities in the North Shewa Zone of Amhara Regional State.

Approaches

Study area descriptions

The activity was implemented with two seed producer and marketing cooperatives in North Shewa zone of Amhara region. Gudoberet kebele in Basona-Worana district, and Mangudo kebele in Moretina-Jiru district were the targeted study areas.

Profitability analysis

For this specific study, 54 ha of land was clustered to produce the seed of improved faba bean varieties; Dagim and Dosha varieties were planted on 23 and 31 ha, respectively. The faba bean seed business was conducted for three years (2015-2017) while the cost-benefit analysis was done only for the latter two years (2016-2017) because of data collection problems in 2015. The profitability of faba bean seed production and marketing was evaluated using the cost-benefit analysis technique. In this technique, all costs and benefits of seed production were identified. All the items of costs incurred related to seed production and marketing activities from the field to market destinations were listed and all benefits gained related to seed production and marketing outcomes were also registered. The data were collected at immediate harvest to minimize the lag price variabilities and market distortions. The team used different profitability analysis techniques:

Net Benefit (NB) sometimes called cost-benefit analysis was calculated by deducting the total production costs incurred from the total field benefits gained from the activity by using equation 1 below.

$$NB = \text{Gross field benefit} - \text{Production costs} \quad \text{.............................} \quad (1)$$

Gross Margin (GM) is the difference between the Gross Return (GR) and the Total Variable Cost (TVC). It is a useful planning tool in situations where fixed capital is a negligible portion of the farming enterprise in the case of small-scale subsistence agriculture (Olukosi and Erhabor, 1988). GM is calculated by using equation 2 below.

$$GM = GR - TVC \quad (2)$$

Benefit-Cost Ratio (BCR) is given by the percentages Total Variable Cost to the Gross Return by using equation 3 below.

$$BCR = \frac{GR}{TVC} \quad (3)$$

Where GR= faba bean seed production (kg) multiplied by price (ETB); and TVC= summation of costs of all variable inputs (ETB). If the ratio is less than one, then the costs exceed the benefit; and the ratio of more than one indicates the benefits exceed the costs (Gittenger, 1982; Jehanzeb, 1999).

Break-even Analysis is the point where gross margin and total variable cost (TVC) are the same or when the sales of a farm outputs are enough to cover the expenses (variable costs) of the farm. The goal of calculating a break-even price is to find out at what price a product would have to be sold in the marketplace to pay for its production. Break-even yield also shows at what production potential (yield per unit area) a product is economically feasible given the variable cost and price. Accordingly, breakeven analysis can be calculated as follows:

$$Breakeven\ Yield = \frac{TVC}{Sale\ Price} \quad (4)$$

$$Breakeven\ Price = \frac{TVC}{Total\ Production} \quad (5)$$

Results and Discussion

Benefits of organized approaches

To support the faba bean seed system, each year CBSP fields were inspected by regulatory agency from the Dessie Seed Inspection and Certification Center. Amhara Seed Enterprise, Tegulet and Wodera Unions, and individual farmers purchased the seed each year for selling to farmers. However, most of the produced seed was used in the informal seed system where more than 500 tons of seed was used at local level through farmer-to-farmer exchange. The district offices of agriculture linked the producer farmers to non-participant farmers across the kebeles. From 2014 to 2016, about 20 tons of Dosha and 25 tons of Dagim seed was produced in cluster farms and sold to different organizations directly from the farmers' cooperatives and used in formal sector.

In 2017, the new seed business model was established, and market linkages were created with the Unions; and convinced farmers to use the improved seed produced locally instead of buying it from external sources. This intervention helped farmers to

access quality seed of different faba bean varieties in required amount and at the right time with the relatively low market price. Farmers get seed through direct purchase or exchange from the producers.

The seed produced was brought to formal seed system through farmers' cooperatives; and was used by Amhara Seed Enterprise, Tegulet Union, and Debre Birhan Agricultural Research Center. This approach benefited the host farmers to access new varieties, better market opportunities, and acquire skill in seed production and marketing. However, for sustainability of the seed production and marketing, there is a need to further refine the processes and the institutional arrangements.

Technical performance of CBSP

The community seed producers used cluster farming for seed production. A total of 9,420 kg of seed estimated to cost ETB 219,640 was used (Table 1). All the seeds produced by farmers were approved during inspection and was disseminated to faba bean producer farmers.

Table 1. Area allocated and seed requirement for community based faba bean seed production

Variety	Area allocated (ha)	Seed rate (kg ha^{-1})	Total seed used (kg)	Seed cost (ETB kg^{-1})	Total seed cost (ETB)
Dosha	31	200	6200	24	148,800
Dagim	23	140	3220	22	70,840

A total of 54 ha of land was inspected and approved by the regulatory agency and produced 183.8 tons of seed (Table 2). This confirmed the technical feasibility of seed production by the communities that met the seed quality standards. Farmers sold the seed produced by the community to the cooperative for further market linkages. Most of the produced seed was transferred to the formal sector through Tegulet Union for cleaning, packing, marketing and distribution.

Table 2. Summary of faba bean seed production

Variety	Area planted (ha)	Area inspected (ha)	Area approved (ha)	Seed yield (t ha^{-1})	Straw yield (Bundle ha^{-1})	Total seed production (tons)	Straw production (Bundles)
Dosha	31	31	31	2.8	6	86.8	246
Dagim	23	23	23	3.0	5	69.0	115

Profitability analysis of faba bean seed production

The community sold the seed to the cooperatives with an additional 20% margin over the farm gate prices. Farmers sold the seed with 18 and 17 ETB kg^{-1} for Dosha and Dagim varieties, respectively. The straw value was estimated at 80 ETB bundle^{-1}. The community-generated net revenue of ETB 2,356,438 from seed and straw sales (Table 3). The net benefit per hectare was 2,010.39 USD (Table 4).

Table 3. Field benefit of faba bean seed production and marketing activities

Variety	*Total cost incurred (ETB)*	*Total seed produced (tons)*	*Revenue from seed (ETB)*	*Total straw produced (bundle)*	*Revenue from straw (ETB)*	*Total Revenue (ETB)*	*Net revenue (ETB)*
Dosha	*276,282*	*86.8*	*1,562,400*	*246*	*19680*	*1,582,080*	*1,305,798*
Dagim	*131,560*	*69.0*	*1,173,000*	*115*	*9200*	*1,182,200*	*1,050,640*
Total	*407,842*	*183.8*	*2,735,400*	*361*	*28,880*	*2,764,280*	*2,356,438*

Note: Planted area was 31 ha for Dosha and 23 ha for Dagim

Table 4. Summary of cost-benefit analysis of faba bean seed production and marketing

Cost benefit descriptions	*Values*
Total seed production (tons)	*184*
Total straw production (bundle)	*361*
Average price of cleaned seed (USD ton^{-1})	*667*
Average price of straw (USD bundle^{-1})	*3*
Income from sale of seed (USD)	*122,594.60*
Income from sale of straw (USD)	*1,083.00*
Total gross income (USD)	*123,667.60*
Total variable cost (USD)	*11,621.15*
Total fixed costs (USD)	*3,486.33*
Total production cost (USD)	*15,107.48*
Total net Income (USD)	*108,560.12*
Net income (USD ha^{-1})	*2,010.39*

The average BCR calculated for seed production was estimated as 10.6, which is very safe to invest more, and increase production volumes. The BCR per variety showed 9.76 for Dagim and 6.74 for Dosha varieties. Dagim variety generated more net benefit because of the low seed rate and higher yield than Dosha.

The breakeven analysis was done only for seed production. It could be more profitable when straw is considered. The average breakeven seed yield was 17.42 tons for 54 ha, and 0.32 ton for one hectare. The breakeven seed price was 63.16 USD t^{-1}. All the breakeven analyses showed that it is profitable to produce faba bean seed.

Another informal seed supply system through which the technology spread out in potential faba bean production areas was through a farmer-to-farmer seed exchange. The team tracked the seed exchange trends from the primary host farmers. Therefore, during the implementation years of the intervention areas, more than 1,250 ha of land was covered with improved varieties of faba bean seed through farmer-to-farmer seed exchange systems and, in 2017, about 5,000 indirect beneficiary farmers (750 female) received seeds through informal exchange.

Opportunities and Challenges

The opportunities are

- Farmers' experience to produce faba bean and high seed demand
- Local government attention and support to community-based seed production and cluster farming
- Farmers and other stakeholders' have shown positive attitudinal changes on faba bean production technologies and productivity improvement
- Improved seed access and more local demand for seed market
- More number of seed experts at zone and district levels, and other actors

The challenges are:

- Lack of brand and packaging, labeling, and other postharvest mechanisms
- Proper seed storage problems and quality deteriorations
- Grower farmers did not fully supply the produced seed instead they used some portion for consumption
- Lack of agrochemical supply to control faba bean gall disease
- Capacity and budget constraint to strengthen seed-producing cooperatives with full facilities (seed cleaning machines, seed testing laboratories) and
- Frost affected the quality of seed in some areas

Recommendations

The issues that need attention for strengthening the community-based seed multiplication are:

- Clustering farmers into seed producers and linking them with markets;
- Continuous commitment of the local government (zone, district, and kebele) to linking unaddressed and interested farmers with cooperatives and producer farmers;
- Implementing formal seed certification system to maintain the seed producers farmers and farmers' groups/associations; and
- Promoting the success stories of community-based seed production.

Conclusion

The involvement of many stakeholders including the local government and the interest of farmers in faba bean seed production and marketing activities enhanced access to local seed supply and demand for sustainable production. The provision of training for interested farmers and farmer groups improved the skills of the participant farmers and created the chances of easy management of disease, pest, and other production challenges as well as inspection to produce quality seed.

The important benefit to farmers is market opportunity for their produces. Since our CBSP activities improved the interests of seed suppliers and buyers, participant farmers and cooperatives got high income from the produced seed, and they considered seed as a business.

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Promotion of Improved Faba Bean Technologies Through Community-Based Seed Producers in Bale zone

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Bale Zone is characterized by mixed crop livestock farming systems. Most of the crop areas are under cereal production. Faba bean is used as food and cash crop, and it is the best break crop (crop rotation) for cereal production in the Zone. It has been reported that bread wheat grown after faba bean gives a yield advantage of 15% (Sinana ARC Profile, 2014). Cognizant of this, since 2015, ICARDA-USAID project has implemented faba bean production as a break crop for malt barley production in the Zone. Therefore, promotion, popularization, and dissemination of improved faba bean technologies was initiated by the project. The objectives were to improve farmers' knowledge, skill, and attitude through multidisciplinary participatory training on production and management packages, strengthen stakeholders' linkage, and break the mono-cropping practice to increase faba bean productivity and production in Bale area.

Methodology

Description of study area

Promotion of improved faba bean technologies was carried out in Dinsho and Goba districts of Bale zone (Figure 1) in southeastern, Ethiopia. The districts were selected purposively based on their potential for faba bean production. Dinsho district lies between 2444 m–4250 masl, receives 965.03–1314 mm annual rainfall with the minimum and maximum temperature of 7.07°C and 15.33°C, respectively. The dominant soil types are Nitosols and Cambisols. The altitude of Goba district is 1517 m–4378 masl, it receives 937.3 -1342.44 mm annual rainfall with the minimum and maximum temperature of 6.53°C and 19.58°C, respectively. However, the altitude of the test sites is most commonly in the range of 2600-2800 masl. The dominant soil type is Pellic Vertisols (Sinja area) and Chromic Luvisols (Adamu, 2018). Farming system of the districts is crop-livestock mixed farming. The major crops grown in the districts are wheat (bread, durum, and emmer), barley (food and malt), maize, field pea, faba bean, linseed, garlic, onion, and potato.

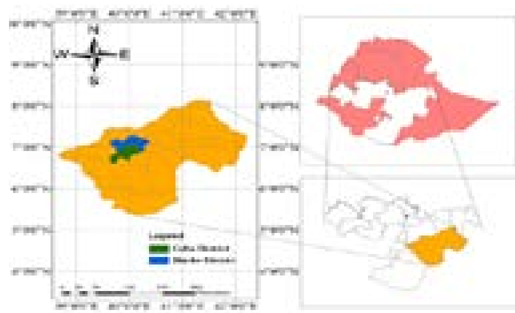

Figure 1. The relative position of the test districts in Bale zone

Stakeholder analysis (SA), and roles and responsibilities

In enhancing faba bean technologies dissemination, the Sinana Agricultural Research Center (SnARC) conducted frequent consultation with its stakeholders and partners. The roles, duties and responsibilities of each actor were clearly stated and shared for implementing the activity (Table 1).

Table 1. Stakeholder roles and responsibilities in implementing activities in 2016 and 2017

SPC	*District*
Sinana Agricultural Research Center (SARC)	• Coordination and facilitation • Provision of faba bean varieties (Walki and Gabelcho) • Provision of training • Technical backstopping • Organize field days • Supervision and joint monitoring and evaluation with zone and district agricultural development offices • Follow up the revolving seed
ICARDA project	• Purchasing of faba bean (Walki and Gabelcho) technologies • Purchasing of inorganic fertilizer (NPS and Bio-fertilizer) • Organize training of trainers • Monitoring and evaluation • Organize annual review and planning workshops
Agriculture Development Office (at zone, district and kebele level)	• Assist in selection of site and participant farmers • Follow up daily activities from zone to kebele level • Assist in providing training • Facilitate seed distribution • Jointly organize and participate on field days
Individual farmer (faba bean growers) and farmer groups	• Allocate land and perform required agronomic practices and share production costs • Actively participate in training for strengthening capacity (knowledge, skill and attitude) • Jointly organize and participate on field days • Share skills and experiences to neighboring farmers • Sell and diffuse produced seed to surrounding farmers • Sell produced seed to cooperatives, unions and seed enterprises
Cooperatives/Unions OSE Bale Branch Office	• Agricultural input supply • Facilitate seed marketing

Site and farmer selection

Pre-scaling up of improved faba bean technologies were undertaken in the main season for two years (2016 and 2017). Two potential faba bean growing kebeles, namely, Abakara and Mi'o from Dinsho district and Walta'i Kubsa and Fasil Angaso/Walta'i Azira kebles from Goba districts were selected for the activity.

Selection of farmers was carried out in collaboration with crop extension experts from agriculture and natural resource offices of the districts, and development agents from target kebeles. Farmers were selected based on land ownership, suitability for land clustering, their interest and motivation in carrying out the recommended management practices, and their commitment to deliver/share the technologies to other farmers. Gender disaggregation and other socio-economic variables were also considered. Groups of farmers were formed for community-based seed production under clustering approach.

Materials and field design

Two recently released improved faba bean varieties, Walki and Gabelcho, were selected since these varieties have been preferred by farmers during the demonstration phase. The varieties were treated with the full recommended faba bean production and management packages. Row planting method and other crop management practices were employed during the field work. The spacing of 40cm between rows was used. Seed rate of 180 kg ha^{-1} was used by drilling in the prepared rows. Fertilizer rate of 100 kg ha^{-1} of NPS was applied during planting time. Two hand weeding were done: the first with cultivation one month after sowing and the second two months after sowing. All farm operations including land preparation, planting, first and second weeding, cultivation, agro-chemical spray (fungicide for chocolate spot), harvesting, threshing was carried out by farmers with close supervision of researchers and district agricultural experts. Planting time was end of July to early August and the harvesting time was end December to early January.

Training

Training was given to farmers, development agents, supervisors, and agricultural experts. Training includes experts from zone and district agriculture development office, zone and district agricultural inputs regulations and quarantine experts, primary cooperatives, unions, private service providers, Arsi-Bale Plant Health Clinic. A multidisciplinary team from SARC delivered the training.

Field days

Field days were organized at each site to involve key stakeholders and enhance better linkage among relevant actors. Discussion session and result communication forums were organized. Field visit was arranged to create awareness and experience and knowledge sharing. Regular joint monitoring and evaluation (follow up actions) and provision of technical advice were undertaken at different crop growth stages.

Data collection and analysis

Amount of input distributed, harvested yield, total number of farmers participated on training, field visits and field days were recorded by gender composition. Farmers' perceptions towards the performance of the technologies) were identified which could be a feedback for breeders and other researchers. The data collection method employed were field observation and focus group discussion with experts, host farmers and group of farmers. Descriptive statistics was used to analyze and interpret the yield data.

Results and Discussion

Input distribution and yield

Table 2 shows the quantity of seed distributed to farmers, planted land area, and harvested yield. The distributed initial seed was used as revolving seed where farmers return the seed in kind to office of agriculture which can be used to reach other farmers in the area in the subsequent years. This approach is relatively low-cost that can ensure availability of sufficient quantity and adequate quality seed and access at right time, place, and reasonable price of the kind of seed at satisfactory level to neighboring farmers. The planted seed class was basic seed, which produced certified seed in the first year. The seed inspection and certification were done properly for formally organized primary cooperatives.

Table 2. Quantity of seed distributed and produced in 2016 and 2017

Cropping season	Location	Variety	Seed distributed (t)	Farmers	Area planted (ha)	Seed produced (t)	Remarks
2016*	Dinsho	Walki	2.5	40	14	21.25	5.5 ha lost due to frost
	Goba	Walki	2.5	39	14	22.5	4.4 ha lost due to frost
2017		Walki	3	60	16.7	60.12	Revolved seed scheme
2017*	Dinsho	Gabelcho	6.9	93	38.3	98.75	
	Goba	Gabelcho	6.6	102	36.7	95.75	

*Note: *In 2016 about 520 packets each with 125 g biofertilizer were purchased for seed producers; **In 2017 about 800 packets each with 125 g biofertilizer were purchased for seed producers.*

Economic return

The scaling up/out process of Walki and Gabelcho varieties through CBSM has shown change in the improvement of the annual income of hosting farmers in the target areas. The economic gain obtained because of using the technology was calculated on hectare base and summarized in Table 3.

Table 3. The economic return obtained by participant farmers from a hectare of land

Variety	Seed yield obtained (q ha^{-1})	Market price (ETB q^{-1})	Total revenue or TR (total output x unit price in ETB ha^{-1})	Total variable cost or TVC (ETB ha^{-1})	Gross Marginal Profit or GMP (TR-TVC)
Walkii	36	1800.00	64,800.00	18,970.00	45,830.00
Gabelcho	33	1800.00	59,400.00	18,970.00	40,430.00

Note: q= quintal; one quintal is equivalent to 100 kg; seed price is the prevailing price obtained from study areas

The gross income/benefit obtained because of using the improved varieties of faba bean, Walki and Gabelcho, was 64,800.00 and 59,400.00 ETB ha^{-1}, respectively. The corresponding gross marginal profit was 45,830.00 and 40,430.00 ETB ha^{-1}. The production cost per hectare (total variable cost) calculated for faba bean production included costs of seed, fertilizer, ploughing, two times weeding and cultivation, Mancozeb 80% WP fungicide, labor for spraying the fungicide, harvesting, threshing, transporting and storage bags.

Training

In 2016 and 2017, 800 participants (772 farmers, 16 development agents and supervisors, 12 agricultural experts and 8 researchers) participated in the trainings, out of which 30% was women farmers. The training covered available improved pulse technologies and their use, faba bean production and management packages, concept of grain value chain, major diseases and their control measures, use of agro-chemicals (type, time, rate) and safety measures, the importance of crop rotation in cereal-based mono-cropping practices through pulse crops integration. Moreover, the training covered the techniques of seed production and the importance of CBSM, their establishment, operation and management of seed business.

Field days

Field days were organized at each district at physiological maturity stage of the crop in which 382 participants (350 farmers, 12 development agents, 4 supervisors, 12 agricultural experts and cooperative leaders, and 4 researchers) participated. Participants shared their experiences especially how to maintain the quality of faba bean seed (manual harvesting, seed cleaning, separate storage). In addition, participant farmers shared information and experience on the local informal seed exchange and the available improved faba bean varieties and ways to exchange and keep them. Finally, fruitful discussions were undertaken among farmers and researchers especially on cereal-based mono-cropping practices and faba bean disease problems in the areas.

Feedbacks

The indeterminate nature of both faba bean varieties led to more vegetative growth with low pod-setting because of the high rainfall in 2017 production season. Walki variety performed better on Vertisols than Gabelcho. All participant farmers were interested with the stands of Walki and Gabelcho especially on their tillering capacity, pods per plant, seeds per pod, seeds per plant, stem strength - resistance to lodging and good for nutrients translocation, good plant height, disease tolerance, relative yield advantage, seed size and color for attractive market price. Furthermore, faba bean has ecological and economic importance in improving soil fertility, income source and attractive market price for improving food security.

FGDs feedback showed that the problem of pulse crop production in the study areas is lack of machinery that ease the burden (labor intensive) and difficulty of faba bean harvesting and threshing. Good awareness and confidence were created among stakeholders about Walki and Gabelcho varieties (demand-pull). Farmers expressed their commitment to expand the production of faba bean because of its importance for crop rotation practices, food security and income generation if they get access to agricultural mechanization and well-developed value chain for the crop.

Challenges

The main challenges observed:

- During CBSM, commitments of some participant stakeholders to accept their roles and discharge their duties and responsibilities effectively were minimal.
- In revolving seed scheme, some farmers were not willing to return the initial seed obtained though the mechanism was well designed, and the agreement was reached from the outset.

Conclusions and Recommendations

Walki and Gabelcho faba bean varieties popularized and transferred to the producers since 2015. The average yield of the two varieties was 3.6 and 3.3 tons ha^{-1}, respectively. Capacity of farmers and agriculture experts (development agents and subject matter specialists) has been built through trainings, awareness creation and field days. The activity requires concerted efforts of different stakeholders (multi-stakeholder approach) including analysis of existing situation. Our farmers should not only be seed receivers but could also be seed producers. Thus, the community-based seed production and marketing can be one of the viable seed business models if it is linked to formal institutions and supported with close supervision of development agents, supervisors, agricultural experts and researchers.

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Faba Bean Community-Based Seed Production and Supply in North Gondar Zone

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The use of certified seed has not yet been adopted in faba bean producing areas of North Gondar Zone. Access to certified seed for faba bean growers will undoubtedly boost productivity and production and will be more effective if supported with soil fertility management (Agegnehu and Fessehaie, 2006; El-Metwally and Abdelhamid, 2008) and crop protection (Bitew and Tigabie, 2016; Ali *et al*., 2014) practices. With this understanding, faba bean seed production with the provision of improved production package through community-based seed production (CBSP) scheme was implemented for three years (2015 to 2017) at Debark and Dabat districts with the support of ICARDA-USAID project. Gondar Agricultural Research Center (GARC) conducted faba bean variety adaptation trials in 2012 and 2013 at Debark and Dabat. Hachalu and Dosha varieties were recommended for their superior yield and better resistance to chocolate spot disease. Therefore, seed production and supply of these improved faba bean varieties was conducted from 2015 to 2017.

Methodology

Area description

Faba bean seed production was executed at three districts, Wogera, Dabat and Debark in North Gondar Zone. These districts are the major faba bean growing areas. In terms of area, the dominant crops produced in descending order were wheat, sorghum, tef, malt barley, maize, and faba bean. In 2016, faba bean covered more than 6,000 ha of land in the three districts. Farmers produce faba bean in the main production season either in sole or mixed inter-cropping with field pea. Faba bean and field pea serve as major rotation crops for barley and wheat.

There are two research stations where most of the early generation seed were multiplied. Debark station is located at 13.13166N and 37.899121E where the altitude is 2885 masl. with annual average rainfall of 974 mm, most of which is falling between April and September having peaks in July and August. The temperature ranges from 8.6°C to 19.8°C and the soil type is Cambisols. Dabat station is located at 12.93178N and 37.74412E where the altitude is 2628 masl with annual average rainfall of 758 mm, most of which is falling between April and September having peaks in July and August. Average temperature is 16.6°C and the soil type is Cambisols.

Approaches

Early generation seed multiplication

It was difficult for GARC to manage the highly outcrossing faba bean crop and multiply EGS due to very small land size of the agricultural research stations at Debark (1.96 ha) and Dabat (2.85 ha). To manage the problem either one variety should be multiplied per station, or a mesh cloth covered screen house should be used to minimize out-crossing to produce seed of the two varieties side by side in one station. Thus, breeder and pre-basic seed of Dosha and varieties were multiplied at the two separate stations at Debark and Dabat during 2015 to 2017 main cropping seasons to deliver source seed for further multiplication by farmers.

Community-based Seed Multiplication

Hachalu and Dosha varieties were multiplied on farmers' fields at Wogera, Dabat and Debark districts using a cluster approach. Source seed was provided either by GARC from its EGS multiplication or from seed brought from other research centers. Volunteer farmers who were registered for seed production received the seed of improved faba bean varieties from GARC based on their agreement to return the amount of the source seed they used for multiplication.

Prior to communication with farmers, we discussed the activities with office of agriculture at Debark, Dabat and Wogera districts. Once awareness was created about seed multiplication activities, we shared responsibilities among the research and development partners. The cluster of seed production fields was selected based on accessibility to road for close follow up by the agricultural experts, development agents and researchers. Farmers willing to multiply seed were identified and selected by the development agents and agricultural experts of respective kebeles based on availability of farmland in the selected cluster, farmer's willingness, capacity to use all recommended production packages and membership of seed producer cooperatives.

Training and field days

The selected seed producer farmers and others in the cluster were invited to participate in the training of faba been seed production. The training covered techniques and procedures of faba bean seed production and marketing as well as agronomic practcies such as faba bean pest management, fertility management and rhizobium inoculation.

Field days on faba been seed production and management were organized every year by inviting different stakeholders including farmers, cooperatives, agricultural experts at zonal and woreda level, and researchers.

Crop management

Land preparation and planting according to the production packages, and management of the seed production fields were carried out by close follow up of GARC and development agents of the respective kebeles. Planting was done in early- to mid-June at a seed rate of 200 kg ha^{-1}. Before planting, seeds were inoculated with biological nitrogen fixing inoculant (strain EAL-110) at a rate of 125 g package for a quarter of a hectare. The harvesting time varied based on the soil type and the agro-ecology of the specific area but generally, the seed multiplication fields were harvested from early- to mid-November.

I FABA BEAN: Chapter 3: Faba Bean Seed Production

Seed certification

Seed quality monitoring, inspection and certification was done by Seed Quality Control and Quarantine Branch Office at Gondar.

Achievements

Seed and bio-fertilizer distribution

In 2016 and 2017 cropping seasons, 3.6 tons seed of Dosha and Hachalu varieties were distributed to 115 male and 14 female farmers covering 18 ha of land (Table 1). About 5107 packs of biofertilizer was distributed to 2721 (98 female) participant farmers and covered 1156 ha of land to improve productivity of faba bean.

Table 1. Seed distribution for seed producer farmers in Wogera, Dabat and Debark districts

Year	Variety	Seed class	Amount (ton)	Area covered (ha)	Participant farmers	
					Male	female
2016	Dosha	Pre-basic	1	5	65	9
2017	Dosha	Basic	0.6	3	15	-
2017	Hachalu	Basic	2	10	40	3
Total			**3.6**	**18**	**115**	**14**

Early generation and community-based seed production

Early generation seed including breeder and pre basic seeds were multiplied during 2015–2017. A total of 0.51 ton of breeder seed, and 2.67 tons of pre-basic seeds of Dosha and Hachalu faba bean varieties were produced by GARC during the three years (Table 2).

Table 2. Early generation seed production of faba bean during 2015 to 2017 main cropping season

Seed class	Variety	2015		2016		2017	
		Area (ha)	Seed produced (ton)	Area (ha)	Seed produced (ton)	Area (ha)	Seed produced (ton)
Breeder seed	Hachalu	0.0992	0.1984	0.02	0	0	0
	Dosha	0.1178	0.2356	0.01	0	0.05	0.077
Total		0.217	0.434	0.03	0	0.05	0.077
Pre-basic seed	Hachalu	0.29	0.725	0	0	0	0
	Dosha	0.1072	0.268	0.48	1.055	0.31	0.623
Total		0.3972	0.993	0.48	1.055	0.31	0.623

From source seed provided to farmers a total of 33.31 tons cleaned seed of Hachalu and Dosha varieties was multiplied by farmers on 19 ha in 2015 and 2016 main cropping season (Table 3).

Table 3. Community based faba bean seed productions during 2015 to 2017 main cropping season

Variety	Seed class	2015		2016		2017	
		Area (ha)	Seed produced (ton)	Area (ha)	Seed produced (ton)	Area (ha)	Seed produced (ton)
Hachalu	Basic	0	0	0	0	10	17.4
Dosha	Basic	1	1.7	5	9.35	3	4.86
Total		1	1.7	5	9.35	13	22.26

Farmer-to-farmer seed exchange was the predominant informal seed distribution in the area. A total of 142 male and 18 female farmers exchanged about 6.68 tons of faba bean seed (Table 4). Seed production and distribution to other districts is restricted due to the presence of the invasive weed in the area.

Table 4. Farmer to farmer seed exchange at Dabat, Debark and Wogera districts

Variety	Amount exchanged (t)	Farmers who received seed	
		Male	Female
Hachalu	0.048	10	1
Dosha	6.632	132	17
Total	**6.68**	**142**	**18**

Trainings and field days

All farmers (115 male and 14 female) who received seed and participated in community-based seed multiplication were trained. Moreover, farmers who received the rhizobium packs (2363 male and 98 female) were also trained by the development agents on how to inoculate the seeds with rhizobium while taking the sachets.

Field days to demonstrate the seed multiplication activities as well as the performance of the varieties were organized for 604 male and 63 female participants from different stakeholders, including farmers (Table 5). Experiences were shared on seed production using a clustered approach and crop management activities. Discussions were also held on how to utilize the produced seed. Participants discussed the challenges and opportunities of faba bean seed production from previous experiences and suggested way forward to establish sustainable seed production and marketing system. The main request from farmers was how to establish regular delivery system of quality source seed instead of the ad hoc arrangement through the offices of agriculture.

Table 5. Field day participants for faba bean seed production in Wogera, Dabat, and Debark districts

Field day participants	2015		2016		2017	
	Male	Female	Male	Female	Male	Female
Farmers	312	22	49	4	160	15
Zonal and district experts and development agents	19	5	9	2	22	13
Researchers	15	0	5	0	13	2
Total	**346**	**27**	**63**	**6**	**195**	**30**

Field days

Monitoring and certification

Seed quality monitoring, inspection and certification was carried out by Seed Quality Control and Quarantine branch office at Gondar. The seed produced at Wogera was certified since the district was free of the invasive weed, locally known as Boren (Chrysanthemum segatum). No certification was obtained for seed produced in Dabat and Debark districts because of the Boren infestation and the seed were used only within the districts. This invasive weed is a big challenge for the development of viable seed production system in the area.

Challenges

- Shortage of EGS (breeder and pre-basic seed) supply was a big challenge for promoting farmers' seed production.
- The SPCs have very limited capacity to purchase seed and the farmers multiplying seed are subsistent. As a result, farmers usually sell the seeds they produced as grain. GARC had to buy the seeds from farmers to avail the seed at the time of planting. However, the effort was not sufficient since enough budget was not allocated timely.
- The invasive weed Boren (Chrysanthemum segatum) is the major problem for faba bean seed certification and marketing.
- Severe infestation and damage of faba bean gall disease (Olpidium viciae) has caused higher yield reduction.
- Weed management in some seed production fields were not executed as per the recommendations thus reduced overall production and productivity of seed production.

Recommendations

- Research centers in general and GARC in particular, need capacity building in terms of enough land, budget, and facilities for breeder and pre-basic seed production.
- Credit services must be provided for farmers and seed producer cooperatives to strengthen their capacity not only to produce but purchase and store seed at harvesting for sale later.
- All actors and stakeholders in faba bean value chain should support the seed producer cooperatives to strengthen faba bean seed system.

- The bottleneck of seed production in the area, the existence of invasive weed, needs special attention. Research centers, office of agriculture and development partners should devise effective control measure before it spreads throughout the country.

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CHAPTER 4

FABA BEAN TECHNOLOGY MULTIPLICATION AND SCALING

Popularization and Pre-scaling up of Improved Faba Bean Technologies in Western Amhara Region

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In Amhara region, faba bean is produced from mid- to high altitudes both in light and heavy soils. However, the productivity of faba bean is still far below its potential due to several factors such as lack of improved varieties; lack of properly designed seed system; occurrence of disease and pests (chocolate spot and faba bean gall); and soil acidity in the highlands. To alleviate these problems, Adet Agricultural Research Center (AdARC) in collaboration with the national research system has made efforts and developed improved faba bean technologies like improved varieties, improved agronomic practices including application of bio-fertilizers and improved crop management options (disease control options). Moreover, demonstration of these improved faba bean technologies had been conducted in Yilmana-Densa and Farta districts and demand was created for the technologies. From the results of the demonstrations, the pre-scaling up activity was initiated in the two districts in western Amhara region. The specific objectives were to:

- Create wider demand of the improved faba bean technologies,
- Create and strengthen linkage among the possible actors through CBSM scheme, and
- Enhance technology multiplication and dissemination system

Materials and Methods

Faba bean pre-scaling up activity was carried out for two consecutive years (2016/17 and 2017/18 meher cropping season) at Yilmana Densa (Goshiye kebele) and Farta (Tsegur, Abaregay and Awuzet kebeles) districts in western Amhara Region, Ethiopia (Figure 1).

In Farta district, the most widely grown annual crops are barley, potato, tef, wheat, triticale, faba bean and field pea while maize, linseed, chickpea, and finger millet are produced in small amount. Faba bean production is declining due to lack of improved technologies (variety, seeds, agronomy, pest control), soil acidity and occurrence of the new faba bean gall disease. For Yilmana-Densa district the major crops grown are teff, bread wheat, maize, barley, potato, faba bean, field pea, and finger millet.

Table 1. Description of Enemay, Yilmana-Densa and Enarj Enawuga distircts

Description	*Farta*	*Yilmana-Densa*
Geographic location	*South Gondar*	*West Gojam*
Geogrpahic coordinates	*11°51′ N and 38°1′E*	*11°6′N and 38°29′E*
Altitude (masl)	*2700*	*1800-3200*
Annual rainfall (mm)	*1599-1250*	*1051.8-1488.2*
Rainfall pattern	*Unimodal; June to October*	*Unimodal; June to September*
Temperature (^{0}C)	*9-25*	*8.8-25.2*
Soil type	*Nitosol (predominant)*	*65% red, 20% black and 15%*

Source: FWOA, 2016; YDWOA, 2016;

Figure 1. Map of faba bean pre-scaling up districts in Amhara Region, 2017/18

Farmer selection and clustering fields

Selection of host farmers and land clustering was done in close collaboration and discussion with agricultural extension agents and the farmers themselves. A total of 741 voluntary host farmers were selected based on their willingness and interest to participate in the pre-scaling up activity. These farmers were selected after awareness had been created by agricultural experts and researchers. Almost all host farmers clustered their fields which is good for seed production, field inspection, monitoring and evaluation, exchange of feedbacks, and to show impact on large scale. Farmers who have 0.05 to 0.25 hectares of land and are willing to participate in the pre-scaling up activity clustered their fields and to maintain the isolation distance. Isolation distance of up to 200-400 m was kept between the Walki variety and any other farmers' faba bean to avoid cross contamination.

Crop management practices

An improved faba bean variety, Walki, was used for the pre-scaling up in all locations. A seed rate of 200 kg ha^{-1} with fertilizer rate of 100 kg ha^{-1} DAP (Di-ammonium Phosphate) or NPS (Nitrogen-Phosphorous-Sulfur) were used and all DAP or NPS was applied during planting. A bio-fertilizer inoculant (FB-EAL-110 strain) was sued at the rate of 500 g (4 sachets each of 125 g) per hectare bought from Menagesha BioTech PLC. Row planting with spacing of 40 cm between rows and 10 cm between plants was used. Ridomil Gold and/or Mancozeb at the rate of 2 to 3 kg ha^{-1} with 400 to 600 liter water for chocolate spot control with one time spray, and 0.7 kg ha^{-1} Bayleton for faba bean gall disease control with 3 times spray at 10 days interval were applied.

Technology dissemination approaches

The technology dissemination and promotion approaches used, and the procedures followed for faba bean pre-scaling up included: establishment of innovation platforms (IPs); strengthening capacity (training); partnership arrangement and sharing responsibilities; joint planning, implementation and monitoring and evaluation; enhancing community-based seed production system; and creation of market linkage with cooperatives (unions). Generally, participatory joint planning, implementation, and monitoring, evaluation and learning approach of agricultural research for development was followed throughout the implementation of pre-scaling up activity.

Multidisciplinary team of researcher establishment: A multidisciplinary team of researchers that consisted of economists, research-extensionist, seed experts, breeders, agronomists and crop protectionists was established from the implementing research center that was involved in providing training, field monitoring and evaluation, feedback collection, and technical assistance for farmers and experts as the need arises.

Innovation platforms and linkages: IPs comprising research center, office of agriculture from region to kebele level, farmers' primary cooperatives and unions, and seed agencies was established and made functional from planning, implementing, and evaluating the whole process of the activity through regular meetings, field days and workshops. The platform members discussed on achievements, plans, problems encountered and provide advice for future directions. With this approach, it was anticipated to create linkages among partners for sustainability in production and marketing of faba bean.

Partnership arrangement

The role and responsibility of different stakeholders in technology pre-scaling up and modality for partnership was properly designed and agreed before the implementation of the activity. Memorandum of Understanding (MoU) on the main roles and responsibilities of each actor was signed among research, office of agriculture and farmers' cooperatives union. Focal persons from offices of agriculture were assigned in each intervention sites at district and kebele level for data collection, easy communication, and smooth implementation of the activities.

Adet Agricultural Research Center (AdARC): AdARC was responsible for coordination and facilitation of all activities; delivery of initial seed of improved variety; provision of training and organizing field days and IPs meetings/workshops; and arranging and facilitating joint monitoring and evaluation events with stakeholders. These roles helped AdARC to build effective and efficient coordination and collaboration among stakeholders to ensure a smooth flow of information and knowledge about the technologies among stakeholders for future wider dissemination and sustainability.

Farmers: The major role of farmers was providing their own labor and land for the implementation of the activity on the ground. Moreover, they participated in planning, implementation and evaluation of activities with researchers, experts and officials.

Office of agriculture (regional, zonal, district, and kebele): The office of agriculture is the main responsible government organization for technology dissemination and transfer. The offices were facilitating site selection (host farmers) and mobilizing farmers for training, technology evaluation, and field day events. The agricultural office also participated in the joint monitoring and evaluation events, and regularly following up the implementation with farmers.

Farmers' cooperatives union: The main role of farmers' cooperatives union is to bring inputs (seed, inorganic fertilizer, and agro-chemicals) for farmers and facilitating faba bean seed and grain marketing through agreements reached and signed between farmers and the cooperatives union.

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ICARDA-USAID project: ICARDA as an implementing agency was responsible to provide overall guidance and coordination of the project and provide financial support, delivery of initial technologies (seeds, inoculants), capacity building including training-of-trainers, and participate in the joint monitoring and evaluation events including organizing workshops and meetings for annual reporting.

Training

Multidisciplinary team of researchers from AdARC gave theoretical and practical trainings for farmers and experts (zone, district, and kebele level agricultural experts and cooperative experts) on faba bean production (agronomy, fertilizer, bio-fertilizer); control of diseases (chocolate spot and faba bean gall disease) and pests; seed production, storage, and marketing; and extension tools (land clustering, monitoring and follow up, and data collection). Power point presentations in Amharic language, leaflets, posters, and audio visuals were used as a training material.

Field days

Field days were organized towards the maturity stage of the crop by inviting farmers, agricultural experts and officials/administrators, and other stakeholders (seed agencies, universities, and quarantine offices) to have their reflection and feedbacks about the faba bean technologies promoted and popularized (Figure 2). Amhara Mass Media broadcasted the field day event on its television and radio programs.

Figure 2. Performance evaluation and field day event on faba bean pre-scaling up, 2016-2017

Joint planning, imlementation, and monitoring and evaluation (M & E)

There were forums for joint planning and reviewing achievements/progress to design the next season interventions. During M & E, application of agronomic packages and seed production techniques (isolation distance and roguing) by farmers and any technical challenges and constraints were assessed and solutions were suggested. A team of researchers, regional, zonal and district level experts, kebele agricultural development agents, farmers' cooperative/union experts, and farmers jointly monitored and evaluated the implementation of the planned faba bean pre-scaling up activities at least twice per production season each year.

Communication

Mass-media coverage: The faba bean pre-scaling up activity was broadcasted by Amhara television and radio programs for wider awareness and demand creation for the community within and outside the intervention areas.

Technology promotion materials: Technology promotion materials such as banners, posters, leaflets, and production manuals about faba bean were used during training and field day events for wider technology adoption and dissemination enhancement.

Community-based seed producer schemes

The pre-scaling up activity was linked to local seed production to make available seed for own use and/or for sell to surrounding farmers or any development organization interested in faba bean seed. Faba bean pre-scaling up activity was carried on the fields of farmers who were members of farmer seed producers and marketing cooperatives organized by cooperative agency for local seed business, especially for seed marketing. Faba been seed was produced, inspected, approved, and sold mostly to surrounding farmers at the intervention sites.

Seed quality control: AdARC worked with quarantine offices for seed quality control and certification for pre-scaling up activities and CBSP. The research center wrote a formal letter to the Plant Quarantine offices of each zone of Amhara Region that contains information such as the planted area under the variety, seed class, number of hosting farmers and request the experts of the offices evaluate the variety based on their own seed inspection criteria. After the final stage of evaluation, they notified results by writing formal letter to the research center and farmers.

Tracking farmer-to-farmer seed exchange: Farmer-to-farmer seed exchange was recorded by development agents in each kebele each year to use it for next season production planning and to assess farmers' technology demand, and dissemination for future research for development efforts.

Data collection and analysis

Yield data was collected after harvest by taking quadrant plot sampling technique and surveys by preparing checklists. Farmers' preference and overall performance of the technology were collected by checklist-guided discussion with host famers who

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implemented the pre-scaling up activity. Sex disaggregated data on number of farmers participated in the trainings, field visits and field days were collected. The quantity of seed distributed, and number of farmers benefited in farmer-to-farmer seed exchange system were recorded. Social data like role of farmers and other stakeholders in technology promotion, change in level of knowledge and skill of farmers, and farmers' and experts' opinion/perception/feedbacks on the promoted technology were collected during M and E, experience sharing and field day events as well as during innovation platform and joint planning meetings. Direct field observation; individual host farmers' interview using checklists; focused group discussion (FGD) and key informant interview (KII) were some of the methods of data collection in pre-scaling up activity.

Quantitative data were collected and analyzed using simple descriptive statistics, and social data (farmers' and experts' opinion/feedbacks) were simply qualitatively described and classified by themes and contents.

Results and Discussion

Early generation and initial seed source

Early generation seed (EGS) produced was used for maintenance and further multiplication as well as for pre-scaling up activity. A total of 17.6 t of seed (0.587 t of breeder, 5.0.5 t of pre-basic and 12.0 t of basic seed) of improved faba bean varieties was produced on 8.17 ha of land on-station under close supervision of researchers and used for breeding and pre-scaling up throughout the project period (Table 1).

Table 1. Early generation seed production of faba bean at AdARC during 2015-2017

Seed class	Varieties	Area (ha)				Produced seed (t)			
		2015	2016	2017	Total	2015	2016	2017	Total
Breeder	Walki, Dosha, Tumsa, Lalo & Adet-Hana	0.16	0.13	0.03	0.32	0.28	0.232	0.075	0.587
Pre-basic	Walki & Adet-Hana	0.2	0.25	1.4	1.85	0.6	0.7	3.75	5.05
Basic	Walki	0	6	0	6.00		12.0	0	12.0
Total		0.36	6.38	1.43	8.17	0.88	12.932	3.825	17.637

Note: Basic seed was produced on fields of cooperative union member farmers under close supervision of research and office of agriculture.

Training and sensitization workshop

Awareness was created about the improved faba bean technologies and farmers' and experts' knowledge, skill and attitude was enhanced through capacity building (training) and technical support through continuous monitoring and evaluation events. This had positive impact on the sustainability and adoption of the technology under pre-scaling up. Hence, theoretical, and practical trainings were given to a total of 484 farmers (65 female) and 131 experts (18 female) to bridge their gaps on knowledge, skill, and attitude for the better accomplishment of the pre-scaling up activities (Table 2). Simple evaluation of the training event using check list showed that the training was rated good in methodology, contents, and logistics, respectively by 85%, 90% and 75% of the participants. The positive effect of the training was also observed on farmers' fields performance during monitoring and evaluation trip, which revealed that famers and experts tried to implement the pre-scaling up activity according to the training.

Table 2. Training for faba bean pre-scaling up at Farta and Yilmana-Densa districts, 2016- 2017

Years	Districts	Farmers			Experts*			Total		
		Male	Female	Total	Male	Female	Total	Male	Female	Total
2016	Yilmana-Densa	64	3	67	67	3	70	131	6	137
	Farta	135	15	150	6	4	10	141	19	160
2017	Farta	210	47	257	40	11	51	250	58	308
Total		**409**	**65**	**474**	**113**	**18**	**131**	**522**	**83**	**605**

*Note: *Experts include development agents; agricultural experts at district and zone level who work on extension, input delivery, agronomy and crop protection; experts from cooperative offices and seed agencies/enterprises.*

Input delivery and beneficiary farmers

Improved faba bean variety seed, inorganic fertilizer (DAP), bio-fertilizer (inoculants) and agro-chemicals were some of the major inputs used in the faba bean pre-scaling up activity.

Seed of improved variety: About 5.6 t of pre-basic, basic and/or certified seed of the improved faba bean variety, Walki, was delivered to 218 smallholder farmers, who planted it on 28 ha of land during the project period from 2015 to 2017 cropping season at Yilmana-Densa and Farta districts (Table 3). The seed produced used by farmers themselves, sold to other farmers or mostly used through farmer-to-farmer seed exchange scheme. Based on the agreement reached, the seed provided to the farmers were collected by kebele and district agriculture offices in consultation with the research center during harvest for re-distribution to other farmers in the next production season as a revolving seed scheme.

Table 3. Faba bean seed production in Yilmana-Densa and Farta districts during 2015/16 – 2017/18

Year	Area planted (ha)	Seed provided (tons)	Number of direct beneficiary farmers	Quantity of seed produced (tons)
2015	2	0.4	10	3.974
2016	12	2.4	48	26.645
2017	14	2.8	160	24.885
Total	**28**	**5.6**	**218**	**55.50**

Bio-fertilizers/Inoculants: Farmers were advised to use bio-fertilizers at a rate of 500 g ha^{-1} (4 sachets each of 125 g), in addition to DAP fertilizer. About 5178 sachets of rhizobial bacteria inoculant were provided to 2169 direct beneficiary farmers (Table 4). To popularize the bio-fertilizers/inoculants among growers, it was also provided to non-participant farmers in the pre-scaling up activity to inoculate local faba bean varieties. Farmers revealed that inoculants make faba bean plants vigorous, relatively tolerant to disease (chocolate spot and faba bean gall) and high yielder.

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Table 4. Number of rhizobial bacteria inoculant distributed for beneficiary farmers in Yilmana-Densa and Farta districts during 2015/16-2017/18

2015/16			2016/17			2017/18			Total			
Sachets	No. of farmers		Sachets	No. of farmers		Sachets	No. of farmers		Sachets	No. of farmers		
	M	F		M	F		M	F		M	F	Total
1960	1200	35	1948	614	8	1250	290	22	5158	2104	65	2169

Note: M= Male and F= Female farmers

Field days

About 10 field days were organized in collaboration with district and kebele agriculture offices and representative participant farmers to share experience and create wider demand for the technology. Accordingly, 486 farmers (90 female) and 296 experts (39 female) attended the field day events in the target districts (Table 5). The field day events were broadcasted by Amhara Television and Radio programs. Large audience was reached for awareness and demand creation especially on the performance of the improved Walki faba bean variety, bio-fertilizer/inoculants and agrochemicals.

Table 5. Field days organized and number of participants on pre-scaling up of faba bean technologies in target districts during 2016 -2017

Year	Districts	Participants								
		Farmers			Experts			Total		
		Male	Female	Total	Male	Female	Total	Male	Female	Total
2016	Yilmana-Densa	156	50	206	72	11	83	228	61	289
	Farta	40	15	55	2	1	3	42	16	58
2017	Yilmana-Densa	25	0	25	175	25	200	200	25	225
	Farta	175	25	200	8	2	10	183	27	210
Total		396	90	486	257	39	296	653	129	782

Performance of variety

Walki performed very well and gave a mean grain yield of 2.073 and 2.03 tons ha^{-1} at Yilmana-Densa and Farta districts, respectively, on farmers' fields and management over the two years. The faba bean yield at Yilmana-Densa and Farta districts were relatively higher than the national (1.983 tons ha^{-1}) and regional (1.809 tons ha^{-1}) average yields. The average grain yield in both districts were by far better than that of South Gondar Zone of 1.644 tons ha^{-1} (Table 6 and 7). However, according to personal communication with farmers and experts, and practical field observation, productivity of Walki in the pre-scaling up activity is by far higher than the yield of farmers' own local variety, which was reported to yield 1.0 tons ha^{-1}. At present, farmers allocate small portion of their total cultivated land around homestead, usually less than a quarter of a hectare for faba bean production. Therefore, pre-scaling up of improved faba bean technologies is an important contribution to expand faba bean production in the target districts and similar areas.

Table 6. Mean grain yield of Walki variety on farmers' fields during 2016 – 2017

Districts	Yield (tons ha^{-1}) in each year										Mean
	2016					2017					
	Min	Max	Mean	Range	STD	Min	Max	Mean	Range	STD	
Yilmana-Densa	1.712	2.225	1.977	0.513	0.156	1.420	2.60	2.17	1.18	0.376	2.073
Farta	1.500	2.650	2.046	1.150	0.364	1.35	2.68	2.01	1.33	0.44	2.030

Note: STD= Standard deviation; Min= Minimum; Max=Maximum

Table 7. Average productivity of faba bean (tons ha^{-1}) during 2015/16 – 2016/17

Year	Ethiopia	Amhara region	West Gojam zone	South Gondar zone
2015/16	1.912	1.747	1.735	1.640
2016/17	2.053	1.871	2.052	1.648
Mean	**19.83**	**1.809**	**1.894**	**1.644**

Source: CSA, 2015 and 2016

Farmer-to-farmer seed exchange

The faba bean grain produced in the pre-scaling up activity was consumed, marketed, and exchanged among farmers mostly on cash basis. The faba bean seed produced mostly transferred to surrounding farmers through farmer-to-farmer seed exchange and the data was recorded to track the destination, technology diffusion and adoption. The data collected and researchers own observation revealed that, there was high seed transfer from seed producer farmers to non-participant farmers. This is one of the best advantages of community-based seed production scheme that made seed locally available with relatively low cost and enabled farmers to take the seed with full confidence. Accordingly, a total of about 15.9 tons seed of Walki variety was revolved and exchanged in farmer-to-farmer seed exchange scheme, benefiting about 364 farmers dueing the last three years in the target districts (Table 8).

Table 5. Field days organized and number of participants on pre-scaling up of faba bean technologies in target districts during 2016 -2017

Method of seed dissemination	Area (ha)				Seed (tons)				Farmers benefitted			
	2015	2016	2017	Total	2015	2016	2017	Total	2015	2016	2017	Total
Revolving seed scheme	0	4	19	23	0	0.875	3.8	4.675	0	35	173	208
Farmer to farmer exchange	-	-	-	-	0	7.2	4.0	11.200	0	76	80	156
Total	**0**	**4**	**19**	**23**	**0**	**8.075**	**7.8**	**15.875**	**0**	**111**	**253**	**364**

Feedback on improved technologies

Farmers and experts actively participated during field days and raised important questions about improved faba bean variety and inputs (bio-fertilzer/inoculants and agro-chemicals) during discussions.

Farmers: Farmers said that due to different problems (mainly disease), they are forced to abandon faba bean production. The result of the farmers' needs assessment shows that Walki is highly preferred for its vigor, good pod setting and tillering potential than the local variety. Farmers also indicated that Walki variety is relatively disease tolerant than the local ones. Moreover, farmers also appreciated the importance of bio-fertilizers/inoculants in making the faba bean plant greener, more vigorous, and tolerant to disease and insects. Farmers agreed that they can allocate more land for faba bean production if they get quality seed and full agronomic packages especially for disease control options.

Experts: Concerned about faba bean disease control options particularly the threat of newly emerged faba bean gall disease. Linkage among stakeholders and strengthening input deliveries of faba bean particularly the seed producer farmers' groups for sustainability. Experts and officials reiterated the need for technical and material support (capacity building, introduction of new varieties, inputs) from the AdARC to make the activity sustainable.

Awareness and trust development

Researchers' practical field observations, and farmers' and experts' feedbacks revealed that the area coverage of faba bean is declining over time due to diseases (chocolate spot and faba bean gall) and soil acidity in the highlands of the target areas. Farmers complain that they are abandoning faba bean production although it is their main food item for protein source and cash crop for market. The pre-scaling up activity of faba bean improved technologies revealed increased faba bean production by creating awareness and trust of new technologies in the target areas. Farmers developed trust in allocating land and growing faba bean due to the intervention.

Farmers' awareness of local seed business

Farmers' awareness on seed production as a business was enhanced due to the intervention of faba bean pre-scaling up activity through community-based seed production at Yilmana-Densa and Farta districts. Farmers were able to grow quality seed of faba bean and sell it to the organizations for higher price than the grain.

Facilitation of institutional linkages

It is believed and confirmed from the whole process of the pre-scaling up activity that there was significant improvement in institutional linkages through joint planning, implementation and evaluation events, training, field days, experience sharing, and sensitization workshops for faba bean production and marketing aspects.

Challenges

- Shortage of initial seed that emanates from the cross-pollination nature of faba bean making it difficult to produce and maintain seed even by research institutions.
- Difficulty in clustering land for the pre-scaling up activity since farmers lost confidence in faba bean production prior to the intervention; high cost of running the innovation platforms; and relatively prior weak linkage among stakeholders were some of the challenges in conducting the pre-scaling up activity.
- Occurrence of severe disease infection on faba bean (new disease called faba bean gall (*Kormid/Kortim in Amharic*) especially in Farta district.

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- Unavailability of agro-chemicals (Bayleton) on market and lack of fungicide supplier for the management of faba bean gall disease.
- Maintaining the sustainability of community-based seed production schemes and technical constraints in ensuring pure seed production due to out crossing from local varieties and small land size.

Recommendations

- Walki variety with full package including biofertilzer and agrochemicals should be popularized on a wider scale to reach more farmers (vertical and horizontal scaling out) by office of agriculture in collaboration with farmers cooperatives, unions and/ or universities
- Training, package development (revised) and regular seed renewal of faba bean in collaboration with office of agriculture at least every 3 years;
- Evaluation and promotion of disease management options especially of faba bean gall disease which needs due attention of research;
- Improving CBSP scheme calls for establishing and/or strengthening community-based seed producer cooperatives/ associations through capacity development and technology supply;
- Biofertilizer production, supply and quality control system in Ethiopia needs further research and development because there are still non-responsive soils in faba bean production areas.

Conclusions

The improved faba bean variety, Walki, with full production package widely accepted by farmers for its better performance than the local variety under farmers' management practices. The pre-scaling up of the improved technologies and CBSP demands concerted efforts of different stakeholders across the value chain. Capacity of farmers and agriculture experts has been improved through trainings, awareness creation, monitoring and evaluations, stakeholder meetings and field day events, but further effort is required.

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Popularization of Waterlogging-Tolerant Faba Bean Variety in Southern Tigray

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Waterlogging is one of the causes for low productivity of faba bean in the potential production areas of Southern Tigray. A study by Getachew *et al*. (2003) indicated that high moisture level limits the production of faba bean in the Vertisols due to waterlogging. Birhanu (2016) also reported that Vertisols in Southern Tigray are still underutilized due to waterlogging problem. Therefore, boosting productivity and production of faba bean through popularization of the waterlogging tolerant variety and evaluation of farmers' perception of improved varieties is an important initial step and focus of the study for management of the Vertisols in Southern Tigray.

Materials and Methods

Description of study area

The activity was carried out at Ayba, Atsela and Embahasti kebeles in Endamehoni and Emba-Alaje districts (Figure 1). The study areas were selected based on their potential for faba bean production and the presence of Vertisols with waterlogging condition.

Endamehoni district is located between 12.36-12.7°N latitude and 39.18– 39.57°E longitude. The mean annual rainfall is 700 mm with the range of 600 to 800 mm while the temporal rainfall of the district shows bimodal event. The average temperature is 10°C with the range of 8 to 12°C. The major crop commodities grown in Endamehoni include wheat, barley and faba bean. The dominant soil classes are clay, silt, clay loam and sand (EoARD, 2016).

Emba-Alaje district is located between 14.22-14.39°N latitude and 53.05-56.01°E longitude and lies at an average altitude of 2350 masl. The mean annual rainfall of the district is 912 mm with a mean daily temperature between 9 and 23°C. The important crops grown in the district include wheat, barley and faba bean (Tesfay *et al*., 2014).

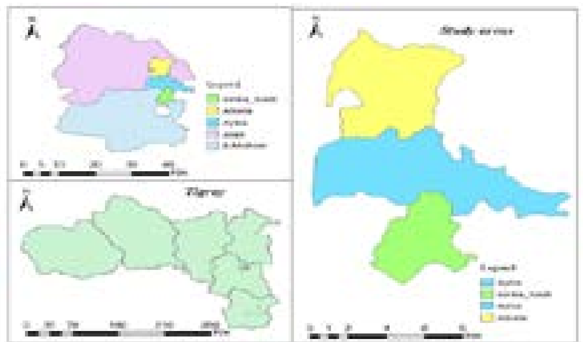

Figure 1. The relative position of study areas in Southern Tigray

Selection of kebeles and farmers

Kebeles were selected based on their potential for faba bean production on Vertisols with waterlogging problem. For clustering fields, the adjacent waterlogging areas and interested participant farmers were selected in collaboration with development agents of the respective kebeles. During the three years project activities (2015/16-2017/18), 211 participant farmers in the two districts planted seed of the improved faba bean variety Walki on 52.75 ha of land. In the second year, participant farmers received biofertilizer in addition to seed of Walki variety. Practical and theoretical trainings were provided to farmers, development agents and experts during the first-year popularization of the improved variety with its production package.

Data collection and analysis

Grain yield data of the local and improved faba bean varieties were collected. Five random samples, each with 1 m^2 quadrant, were taken from each farmer's field to estimate grain yield on hectare basis. Data of the local variety were also collected the same way from nearby farmers' fields for comparison with the improved faba bean variety, Walki. In addition, to get farmers' perception on the varieties, a list of attributes was used for farmers to score each attribute by comparing Walki and the farmers' local varieties.

SPSS version 20 software was used to analyze the collected data. Descriptive statistics like minimum, maximum, mean and standard deviation as well as inferential statistics like t-test was used to make comparison among the local and improved Walki variety.

Results and Discussion

Capacity building

A total of 128 farmers, five kebele and four district experts were trained on topics covering improved faba bean varieties, agronomic practices, and disease and pest management including biofertilizer (Table 1).

Table 1. Training participants in 2016/17 production season

Participants	Gender of participants		Total
	Male	Female	
Beneficiary farmers	109	19	128
District experts	3	1	4
Development agents	3	2	5
Grand total	115	22	137

Filed days were also conducted to promote the variety before harvesting while it was in the field in both years. During the field days, a total of 33 stakeholders, 168 researchers and experts, and 337 farmers participated (Table 2). The feedback of the participants was positive, and they highly appreciated the better performance of Walki variety under waterlogged condition than the local varieties.

Table 2. Field day participants during three years of the project implementation

Year	Farmers		Experts and researchers		Stakeholders		Total	
	M	F	M	F	M	F	M	F
2015/16	100	8	25	2	3	1	128	11
2016/17	130	24	67	6	8	2	205	32
2017/18	70	5	60	8	16	3	146	16
Total	**300**	**37**	**152**	**16**	**27**	**6**	**479**	**59**

Note: M= Female; F= Female

Grain yield

The result of the study indicated that an average grain yield of 2.787 t ha^{-1} was recorded by the variety Walki while the local one gave 1.208 t ha^{-1} (Table 3). Walki gave lower grain yield at Emba Alaje (Ayba kebele) compared to Endamehoni (Embahatsi kebele). In addition, the grain yield variation of the variety among participant farmers was higher in Emba-Alaje than in Endamehoni districts. The variation might be due to the difference in agronomic and disease management, and other inputs like inorganic fertilizer and biofertilizer application by individual farmers. Generally, the harvested grain yield was low, compared to its potential reported in research station, which is 4.366 t ha^{-1} in Ayba kebele (Birhanu, 2016). Another report also showed that Walki gave an average grain yield of 2.7 t ha^{-1} on farmers' fields in the highland areas of Guji zone (Basha and Dembi, 2017). In our study, Walki showed an average yield advantage of 130% over the local variety at both locations (Table 3). The result of the t-test showed that grain yield difference between the two varieties is statistically significant ($p<0.05$) in both locations (Table 3). This implies the possibility of boosting the production of faba bean using improved varieties in both districts.

Table 3. Mean performance of faba bean varieties at Endamehoni and Emba Alaje districts in 2017/18 production season

Districts	N	Variety	Grain yield q ha^{-1}				t value	Yield advantage over local (%)
			Min	Max	Mean	SD		
Emba Alaje	8	Walki	16.54	37.92	25.54	8.16	2.83**	119.04
	3	Local	10.00	13.00	11.66	1.53		
Endamehoni	6	Walki	28.04	37.28	30.98	3.47	8.61***	147.84
	3	Local	11	14	12.50	1.50		
Average	14	Walki	16.54	37.92	27.87	6.94	5.44***	130.72
	6	Local	10.00	14.00	12.08	1.43		

*Note: Q= 1 quintal is equivalent to 100 kg; N=number of sampled farmers' fields; Min = minimum; Max = maximum; SD = standard deviation; **, *** indicates the respective statistical significance at 5 and 1% probability level*

Farmer's perceptions

Farmers' perception about Walki variety was evaluated using prepared list of 10 varietal attributes taken from farmers' viewpoint. Accordingly, plant height, waterlogging tolerance/resistance, pod per plant, tillering capacity, number of seed per pod, earliness to set pods, early maturity, disease/pest tolerance/resistance, and grain yield were the parameters set by farmers to compare the varieties. The result showed that the mean score of the local variety was lower than the improved variety in both locations. Walki variety got higher scores in eight parameters in each of Ayba kebele of Emba-Alaje district and in Embahasti kebele of Endamehoni district than the local variety. Farmers perceived that the improved Walki variety is late in maturity and pod setting as compared to the local variety in both kebeles. The result showed there is a highly significant ($p<0.01$) difference in perception scores between the local and the improved Walki variety (Table 4).

Table 4. Perception of beneficiary farmers of improved Walki and local varieties in 2017/2018 production season

Variety attributes	*Score out of 10*			
	Emba Alaje district		*Endamehoni district*	
	Local	*Walki*	*Local*	*Walki*
Disease tolerance/resistance	3	7	3	7
Plant height	1	9	1	9
Waterlogging tolerance/resistance	2	8	1	9
Pod per plant	4	6	3	7
Earliness to set pods	6	4	7	3
Grain yield	2	8	2	8
Seed size	2	8	2	8
Seed per pod	3	7	3	7
Tillering capacity	4	6	4	6
Early maturity	6	4	7	3
Mean	3.3	6.70	3.30	6.70
Standard deviation	1.70	1.70	2.16	2.16
t value	4.46***		3.52***	

*Note: *** indicate statistical significance at 1% probability level*

Conclusions and Recommendations

The study shows that the improved faba bean variety, Walki, gave higher grain yield and received higher perception score than the local cultivar. The yield advantage of Walki was 131%, when averaged over the test locations in Ebma Alaje and Endamehoni districts. Thus, it can be concluded that Walki variety is currently the better option than local cultivars to boost production and productivity of faba bean in the high rainfall and waterlogging areas of South Tigray. Hence, Walki should be scaled out in areas which receive high rainfall and experience waterlogging on Vertisols in South Tigray. It is critical to create continuous and consistent seed multiplication scheme through organized seed producer cooperatives or farmers' groups to ensure sustainability of quality seed supply.

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Scaling-up of Improved Faba bean Technologies and Seed Production on Light Soils of North Shewa Zone

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Many factors contribute to the low productivity and adoption of faba bean by smallholder farmers (Mussa *et al*., 2008). These include inherently low yield potential of local cultivars, susceptibility to abiotic stresses such as waterlogging, and soil acidity; and biotic stresses, particularly diseases such as chocolate spot (*Botrytis fabae*), rust (*Uromyces vicia fabae*), faba bean gall (locally called Qormed), and black root rot (*Fusarium solani*); and limited access to improved faba bean varieties and seed supply.

Scaling up of high yielding and diseases resistant varieties on light soil in highlands of North Shewa zone of Amhara region is crucial for smallholder farmers to sustain production and ensure food and nutrition security; and introduce crop rotation to maintain productive and sustainable crop production system. The major objectives of the present study were to create wider demand and improved dissemination of improved faba bean technologies and strengthen the research-farmer linkages.

Approach

Descriptions of the study areas

The activities were conducted in high-potential areas of Basona-Worana and Tarmaber districts of North Shewa Zone of Amhara Region during 2015-2018. The study areas are highlands of above 2600 masl. The soil type is light brown with well drained topography having high rainfall distribution, with the average annual temperature of 15°C while the respective minimum and maximum temperature of 5 and 20°C. The dominant crops are barley, wheat and faba bean.

Partners and responsibilities

First, zonal consultative workshop was organized by inviting experts of zonal and district agricultural development offices, administrative bodies, representatives of NGOs, University and Unions to discuss the planned activities and share responsibilities. Memorandum of Understanding (MoU) was signed between each district and Debre Birhan Agricultural Research Center (DBARC) through facilitation by head of zonal agricultural development office. Zonal workshop was held each year to evaluate the progress and share of responsibilities among farmers, extension workers, cooperatives, and research center.

Sites and farmers selection

Based on the MoU, site and farmers selections and seed dissemination schedules were planned during the zonal workshop. Farmers and site selection, and land preparation was done by kebele agricultural development agents using GPS based on a clustered field. The selected cluster was confirmed by researchers of DBARC based on the history of selected sites such as crop rotation, soil fertility, soil drainage and topography, accessibility, and representativeness for typical faba bean production.

Training and field days

Training was provided by researchers from DBARC to farmers, development agents and experts of district agricultural development offices about the overall agronomic practice of the new faba bean technologies, seed production and disease management options.

Field days were organized together with stakeholders, and host and follower farmers just before crop maturity. Field days targeted discussions on observations and feedback, experience sharing, further dissemination of the improved technologies and enhance linkage and farmer to farmer seed exchange.

Crop management

Farmers used farmyard manure for the improvement of soil fertility and hand weeding for weed control. They also applied biofertilizer and NPS based on soil fertility status as determined by their observations. Most farmers planted faba bean after mid of June. The seed rate used was 200 kg ha^{-1} since the improved varieties are large seeded compared to local varieties. Farmers also applied Bayleton fungicide for seed dressing complimented with 1-2 spraying starting from the early symptoms of gall disease appearance.

Input delivery

Seed of improved faba bean varieties, Walki and Dosha, were provided to the interested farmers for in kind repayment as part of revolving seed for other farmers in subsequent years. Inoculants of faba bean rhizobium FB-EAL-110 strain were also provided free of charge for farmers together with the seed as a package. Farmers were convinced to implement proper crop management practices and applied the recommended rate of phosphorus fertilizer (NPS). Fungicide was supplied by DBARC during the first year and farmers applied twice since faba bean gall diseases appeared during the early flowering stage. For the subsequent years, farmers purchased and applied the fungicide for faba bean production.

Results and Discussion

Training

Trainings were organized in for 765 (125 female) farmers and agricultural experts. The trainings mainly focused on agronomic practcies such as land preparation, planting (row planting), seed rate, inorganic fertilizer and rhizobium application, pest (particularly gall disease) management options and postharvest management. Since rhizobium inoculants were new for the producer farmers, the training also focused on the importance of faba bean inoculants and its application methods. The training focused on integrated faba bean gall disease management option using improved varieties and fungicide applications.

Field days

Several field days were organized in each site where 378 (85 female) participants attended. The participants included farmers, heads and experts of zonal and district agricultural development offices, zonal and district administration authorities, kebele administration and development agents, mass media, and other stakeholders from international organizations (ICARDA, and ILRI as project implementing partners), and Wodera and Tegulet farmers' cooperative unions.

Discussions were held on the the transfer of technology and sustainability of the seed system. Future directions were set by decision-making authorities and responsibilities were shared among different stakeholders. The stakeholders agreed to create wider demand and popularize Walki and Dosha varieties with the improved management practices.

In addition, the two intervention districts also organized field days at various times and invited farmers, development agents and kebele administrative bodies from all kebeles in each district. During the field days more than 476 (77 female) farmers and 30 (6 female) development agents and experts participated. The field days program included field visit, and experience sharing and detailed discussion on the seed marketing and exchange issues.

Different local media were used to create awareness of farmers the possibility of improving faba bean production by controlling the gall disease. Amhara and Fana FM radios, zonal and district communication media were used during the field days of pre-scaling up and seed production activities. Amhara and Fana FM Radios made about 20 minutes broadcast on the improved faba bean varieties and faba bean gall disease management by researchers from DBARC, administrative authorities, and seed union managers each year. During the field days radio broadcast, farmers and stakeholders gave eyewitness accounts on the performance of the improved faba bean technologies. ICARDA project also prepared a documentary film by interviewing faba bean producer farmers, implementing researchers, development agents, and experts of agricultural development offices.

Faba bean gall disease management

The newly emerging faba bean gall disease has different local names in Amharic, which includes Qormid (*kormid*) in North Shewa and South Wollo, Kolsim or Kortim in North Gondar, Chimid or Kurnchit in South Gondar and Aqorfid in East Gojam. In many places, it is known by the name Qormid. The disease was aggressively expanding in the northern and central part of the country (Hailu *et al*., 2014). Therefore, promotion of gall disease management options was one of the targets in the scaling up of improved faba bean technologies and seed production activities. Thus, 67 kg of Bayleton fungicide was sprayed during two intervention years in each faba bean production cluster for creating awareness on the application and demand for its usage. The recommended spraying frequency is 1-2 times depending on the earliness of the disease infection; frequency of spray increases when it appears at early growth stage of the crop. As a result of scaling up intervention, most farmers especially at Mush cluster purchased the fungicide and applied by themselves during the last year of the intervention. Market access to the fungicide for interested farmers was facilitated through cooperatives and individual farmers.

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Seed dissemination and production

Two improved faba bean varieties, Walki and Dosha, were distributed to the selected sites in Basona-Worana and Tarmaber districts based on their adaptability and farmers' interest. A total of 16.9 tons of seed was distributed and planted on 80 ha of land in which 320 (40 female) smallholder farmers participated. These farmers produced 240 tons of faba bean seed, which shows an average productivity of 3.0 tons ha^{-1}. The production and productivity of faba bean had been significantly reduced due to faba bean gall diseases, lack of improved varieties and access to quality seed. Therefore, the current achievement of 3.0 t ha^{-1} productivity through the scaling up of the improved varieties with improved agronomics and integrated diseases management practices is a significant achievement. The average productivities of the improved faba bean varieties compared to the local cultivar is presented in Table 1.

Table 1. The average productivity of improved and local faba bean varieties at scaling up sites

Improved varieties	*Maximum yield (tons ha^{-1})*	*Average yield (tons ha^{-1})*	*Average yield (tons ha^{-1}) of local variety*
Walki	*3.8*	*2.5*	*1.95*
Dosha	*4.5*	*3.6*	

Some of the faba bean seed production was used for seed purpose by informal (farmers to farmers seed exchange) and formal (Amhara Seed Enterprise, Wodera offices of agriculture for further scaling, Tegulet union, seed cooperatives, NGOs, and agricultural research centers) seed systems. The quantity of seed purchased by the formal seed system from the 2017 meher season harvest was 35 tons for planting in 2018 meher season. Part of the produce was also used for home consumption and export.

Conclusions and Recommendations

The scaling up of the improved faba bean varieties with integration of faba bean gall disease management option significantly increased productivity and production during the four years implementation period (2015-2018). This scaling up also significantly increased seed production and improved access to seed by smallholder farmers in the intervention districts.

Since faba bean is the major product and cash crop in the highlands of North Shewa, scaling out improved varieties with integration of faba bean gall disease management options through capacity building supports such as training, experience sharing, extension folders, and leaflets should be future priority interventions. Strengthening the established farmer's seed production and marketing cooperatives by improving their human, financial and physical capacities would help to access quality seed and sustain the production and productivity of faba bean.

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Scaling-up Improved Faba Bean Technologies and Seed Production on Vertisols of North Shewa Zone

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One of the abiotic stresses on Vertisols is its waterlogging nature that reduces productivity of faba bean (Debele and Deressa, 2016). Therefore, scaling up of high-yielding and waterlogging-tolerant faba bean varieties on Vertisols in the highlands of North Shewa zone, Amhara region, is very important for smallholder farmers to sustain production and food security. Wider scale promotion of these waterlogging tolerant faba bean varieties in the Vertisols areas would be an important breakthrough to solve the lack of productive crop rotation in the crop production system where monocropping of wheat is dominant. The major objective of this activity is creation of demand for the improved faba bean technologies particularly waterlogging tolerant varieties, improve the wider disseminations of faba bean technologies and strengthen the research-farmers linkage.

Approach

Descriptions of study areas

The activities were conducted in Ensaro, Moretina-Jiru, and Siyadebrinawayu districts of North Shewa zone, during 2015-2017. The districts have similar agroecology with the altitude ranging from 2600 to 2700 masl and have an annual rainfall distribution of 1600 to 2400 mm with the respective minimum and maximum temperature of 15 and 26^{o}C. The project target highland areas are heavy Vertisols where faba bean is most likely highly infected by root rot disease. Root rot is the major problem for faba bean production on waterlogging Vertisols.

Institutional roles and responsibilities

First, zonal consultative workshop was organized by inviting experts of zonal and district agricultural development offices, administrative bodies, representatives of NGOs, University and Unions to brief the planned activities and share responsibilities. Memorandum of Understanding (MoU) was signed between each district and Debre Birhan Agricultural Research Center through the facilitation by head of the zonal agricultural development office. Zonal workshop was held each year during the project period to evaluate the progress and share responsibility among farmers, extension workers, cooperatives, and research center.

Sites and farmers' selection

Based on the MoU, site and farmers' selections and seed dissemination schedules were planned during the zonal workshop. Farmers and sites selection, and land preparation was done by kebele agricultural development agents using GPS based on a clustered farm. DBARC researchers confirmed the selected history of clustered fields of selected sites' such as crop rotation, soil fertility, land topography to facilitate drainage, accessibility, and representativeness for typical faba bean production on Vertisols.

Training and field days

Training was provided by researchers from DBARC to farmers, development agents and experts of district agricultural development offices about the overall agronomic practice of the new faba bean technologies, seed production and disease management options. Field days were organized together with stakeholders, and host and follower farmers just before maturity of the faba bean crop.

Crop management

Farmers applied the recommended rate of NPS fertilizer. The farmers are experienced in Vertisols management using indigenous knowledge of making broad beds and furrows to drain excess water from the field. The planting time was in the first weeks of July every year with seed rate of 140 kg ha^{-1}. Farmers agreed to manage the weed and other pests based on their experiences and the information shared during the training. The harvesting time was mostly after the last week of October to November.

Input provision

Seed of improved varieties of faba bean, Lalo and Dagim, was provided to the interested farmers for in kind seed repayment for use as revolving seed in subsequent years to other farmers, with the agreement and collaboration of seed exchange to other farmers. Inoculants of faba bean rhizobium FB-EAL-110 strain were also delivered free of charge to producer farmers together with the seed as a package. Seed producer and farmers cooperatives in Moretina-Jiru and Siyadebrina-Wayu participated in seed and seed marketing activities.

Results and Discussion

Training

Trainings were organized in each implementation sites; and 415 (55 female) farmers and agricultural extension workers participated. The trainings mainly focused on agronomic practices such as land preparation, method of planting, seed rate, inorganic fertilizer and rhizobium inoculants application, pest management options and postharvest managements. Integration of waterlogging tolerant varieties with use of broad beds and furrows is an important agronomic management for early planting and achieving better productivity.

Field days

Field days were organized to build trust of non-host farmers through experience sharing with the host farmers, and direct observation on the field performance of the improved technologies. Awareness creation and enhancing seed exchange among farmers, and marketing and stakeholders' linkage were also important focuses of the field days. A total of 220 (70 female) participants were involved including heads and experts of zonal and district agricultural offices, zonal and district administration, kebele administration and development agents, mass media, and other stakeholders from international organizations

(ICARDA and ILRI as project implementing partners), and Wodera and Tegulet Farmers' Cooperative Unions.

Discussions about the sustainability of the seed system and the transfer of technology were made and directions were set by decision-making authorities on shared responsibilities among stakeholders. After the discussions, stakeholders agreed to create demand and popularizing Dagim variety in Moretina-Jiru and Siyadebirna-Wayu districts, and Lalo variety in Ensaro district.

In addition, field days were also organized by each district for farmers, development agents and kebele administration at different growth stages of the crop. In the three districts, a total of 476 (77 female) farmers and 30 (6 female) development agents and experts participated. The field days focused on practical experience sharing through field visits and detail presentation by experts and host farmers on the implementation practices and background of the improved technologies, and discussions on the seed exchange and marketing. Participant farmers at the project implementations areas said that faba bean production in our locality was almost abandoned due to root rot disease that is associated with waterlogging problems. They expressed their interest to produce these same faba bean varieties in the future if they maintained their tolerance/resistance to the prevalent root rot disease on Vertisols. Experts and administration authorities also appreciated the performance of the improved faba bean varieties that are tolerant to waterlogging and root rot disease and promised to do their best in organizing and leading the concerted effort in output marketing.

Different local media were used to create awareness for farmers of the possibility of increasing faba bean production by using these waterlogging tolerant faba bean varieties. Radio and TV media play an important role in creating awareness and demand for enhancing the dissemination of the improved technologies. Amhara and Fana FM radios, zonal and district communication media were used during the field days of pre scaling up and seed production activities. Amhara and Fana FM Radios made about 20 minutes broadcast each for 13 days on the performance of improved waterlogging tolerant faba bean varieties and encourage farmers to adopt and increase production of faba bean for improving their food and nutrition security. During these broadcast events, farmers, researchers from DBARC, administrative authorities, and managers of farmers' cooperatives unions participated in expressing their views and witnessing on the performance of the improved faba bean varieties on Vertisols.

Seed dissemination and production

During the project period, a total of 6.8 tons seed of the two improved faba bean varieties (Lalo and Dagim) was disseminated and planted on 50 ha of land with the participation of 250 (30 female) smallholder farmers. The seeds of the improved faba bean varieties were exchanged through bartering, selling and through the formal seed system by different actors. In 2017, more than 15 tons seed of Dagim variety was purchased by Amhara Seed Enterprise, Tegulet Union and seed producer and marketing cooperatives as formal seed to sale to interested farmers for planting in 2018 meher cropping season. DBARC, through the financial support of ICARDA-UASID project, also purchased five tons seed of Dagim variety for further scaling out.

Farmers who adopted the new faba bean technologies, whether the full package or individual components, obtained significantly higher yields. Elsewhere experiences in Ethiopia show that simply replacing traditional varieties with improved ones led to gains of 42% yield improvement (ICARDA, 2008). The concerted efforts of the scaling up and seed production during 2015-2017 produced about 254 tons seed of the Dagim variety, which was utilized as seed or home consumption. The introduction of the improved varieties (which are tolerant to waterlogging and root rot disease on Vertisols) significantly improved productivity of faba bean production in the area since the respective average productivity of the improved Dagim and Lalo varieties was 3.2 and 2.5 t ha^{-1} compared with the local variety that gave grain yield of 1.95 t ha^{-1} (Table 1).

Table 1. Productivity of improved varieties on Vertisols at the intervention districts

Improved varieties	Maximum grain yield (tons ha^{-1})	Average grain yield (tons ha^{-1})	Average grain yield of local variety (tons ha^{-1})
Dagim	3.5	3.2	1.95
Lalo	2.8	2.5	

Although it was not possible to get the full picture of seed exchange during the project implementation period, the production of improved faba bean varieties on Vertisols areas was expanding through informal seed exchange. For example, about 600 farmers in Moretinjiru district accessed the seed from the host famers through farmer-to-farmer seed exchange system. Office of agriculture linked the intervention kebeles to others as a seed source. The produce was used for seed purpose by informal (farmers to farmers seed exchange) and formal seed exchange system (Amhara Seed Enterprise, district offices of agriculture and Tegulet unions seed cooperatives, NGOs, Wollo University and DBARC). Farmers benefited from the seed business since they sold seed of the improved varieties with 22 ETB kg^{-1} seed, while seed price of the local variety was 14 ETB kg^{-1} seed.

Conclusions and Recommendations

The introduction of waterlogging and root rot tolerant faba bean varieties improved faba bean production and productivity in the intervention districts. Farmers who participated in scaling up of the improved faba bean varieties and seed production benefited from improved market access and crop-rotation options on Vertisols areas, which consequently improves food and nutrition security. The intervention created awareness and demand on the high-yielding improved faba bean varieties, which are tolerant to waterlogging and root rot disease on Vertisols in the highlands of North Shewa.

There should be a concerted effort to match the initiated and future seed demand of these improved faba bean varieties for further scaling out for production on Vertisols. Supporting the scaling out effort of the improved faba bean varieties with training, experience sharing, extension folders and leaflets will improve the capacity of producer farmers. Strengthening the physical and skill capacity of the established farmers' seed production and marketing cooperatives further improves sustainability of the seed system.

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Pre-scaling up Improved Faba Bean Technologies in North Gondar

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North Gondar has about 20,232.77 ha of land covered with faba bean in 2016 crop production season with a productivity of 1.7 tons ha^{-1} (CSA, 2017). This productivity is by far below the yield obtained on research station due to the biological limitations of traditional varieties and poor management practices of farmers (Agegnehu *et al*., 2008). To overcome such low productivity of the crop, different solutions were suggested by different research centers. Gondar Agricultural Research Centre (GARC) had diagnosis study on the effectiveness of rhizobial inoculation on faba bean varieties in the highland areas of North Gondar zone. Rhizobia inoculated seed of improved faba bean variety Dosha planted with additional 50 kg ha^{-1} DAP application gave higher grain yield than without inoculation (GARC SWC report, 2014). Therefore, this pre-scaling up study was designed to popularize improved faba bean variety (Dosha), biofertilizer and other improved agronomic practices for faba bean growers and other stakeholders in the target areas.

Materials and Methods

Study area

The pre-scaling up of improved faba bean technologies was conducted in Wogera district. The altitude of Wogera district ranges from 1500 m to 3040 m. The minimum and maximum temperature of the district is 18^{o}C and 24^{o}C, respectively. On average, the district has annual rainfall distribution ranges from 400 mm-1000 mm. The rainy months extend from June until the end of September. However, most of the rainfall is received during the months of July and August. The soil type is mainly Cambisols. Barley, faba bean, field pea and wheat are major crops grown in these districts.

Approach

Pre-season workshop was made to introduce the planned activities with potential stakeholders. Farmers' selection criteria were developed together with office of agriculture to identify participants. Cluster approach was used to promote the technologies and use the produced grain as a seed for the next cropping season. The activity was done for three consecutive years in 2015-2017.

The improved faba bean technology package in this pre-scaling up included improved faba bean variety, Dosha, bio-fertilizer (500 g ha^{-1} rhizobial inoculant), 50 kg ha^{-1} NPS fertilizer, and 200 kg ha^{-1} seed rate. Planting, in 40 cm and 20 cm spacing between rows and plants, respectively, was done from the second to the third week of June every year. Rhizobial inoculant and NPS fertilizer were all applied at planting. Weeding is not a common practice for faba bean production in the test locations. First, the Boren weed commonly seen in the faba bean field is used for feed for dairy cows and farmers believe that it increases milk production. Second, weeding faba bean during the rainy season increases root rot disease. However, farmers agreed to weed at least once after discussion. The crop was harvested after 140-150 days of planting.

In some fields, gall disease occurred and Redomil fungicide was applied to control the incidence of the disease. Certified seed and bio-fertilizer were purchased and distributed to the beneficiaries with the agreements on in-kind loan after harvest. Field days and media events were organized for wider scale promotion of the technology. In addition, leaflets were prepared and distributed at the time of training and field day events.

Data collection and analysis

Feedbacks and opinions from different stockholders were collected for further improve the technology. Sample yield was taken by using 2 m by 2 m quadrants from 10% of beneficiary farmers plots. Sampled farmers were selected randomly from the total lists of beneficiary farmers. Three quadrant samples were taken from one beneficiary farmer's field and the average yield was estimated per hectare. Simple descriptive statistics was used to analyze and interpret the data.

Achievements

Identifying potential stakeholders and developing partnership

A one-day pre-season workshop was organized in 2015 at Gondar city. The main objective was to sensitize the different stakeholders on improved faba bean production in the selected districts. In attendance were 20 participants who represented different organizations: Gondar Agricultural research Center (GARC) and North Gondar zone office of agriculture facilitated the workshop. During the workshop, faba bean production and its opportunities, available faba bean technologies, the pre-scaling up plan, and monitoring and evaluation mechanisms were discussed. Finally, an agreement was reached on the roles and responsibilities of each stakeholder. Focal persons for each district were selected; and districts prepared their own action plan and follow-up activities.

Selection of farmers and farmland clustering

Experts from the three district offices of agriculture and development agents of the respective kebeles selected participant farmers' and facilitated clustering of farmlands. Six clusters with a total farmland area of 40.5 ha were identified and the respective 152 farmers (10 women) implemented scaling up of faba bean improved technologies.

After reaching consensus and jointly preparing farmers' role and detailed plan of activities, training on production and management of faba bean was organized for farmers and development agents. Four different training sessions were organized, and the training topics include improved faba bean agronomic practices, bio-fertilizer inoculation, disease and pest management, quality seed production and faba bean utilization. During the three years period from 2015 to 2017, about 475 trainees participated of which 351 were farmers (Table 1).

Table 1. Training participants on faba bean technologies from 2015-2017

Training participants	2015		2016		2017		Total	
	Male	Female	Male	Female	Male	Female	Male	Female
Farmers	37	6	125	8	160	15	322	29
District level experts and DAs	14	5	28	10	21	13	63	28
Researchers (excluding trainers)	4	0	14	0	13	2	31	2
Total	55	11	167	18	194	30	416	59

Note: DAs= development agents

Field days and media coverage

Three field days were organized at the crop maturity stages: one field day each year (2015-2017). Participants in the field days included farmers, experts and heads of different organization, primary cooperative and their board members, and managers of Debark farmers' cooperatives union. About 667 farmers (63 female) and 70 stakeholders participated (Table 2). During the field day events, there were discussions on improved faba bean varieties, agronomic practices, inoculation techniques, and linkages with export markets.

To promote the technology for wider scale, media agencies (Amhara mass media agency and Fana radio broadcast agency) broadcasted the field day events.

Table 2. Summary of field day participants during 2015-2017

Field day participants	2015		2016		2017		Total	
	Male	Female	Male	Female	Male	Female	Male	Female
Farmers	312	22	49	4	160	15	521	41
Zonal and district level experts and DAs	19	5	9	2	22	13	50	20
Researchers (excluding trainers)	15	0	5	0	13	2	33	2
Total	**346**	**27**	**63**	**6**	**195**	**30**	**604**	**63**

Note: DAs= development agents

Feedbacks

The feedbacks collected from the direct beneficiary farmers showed that inoculated Dosha faba bean variety is highly appreciated by its seed size. Though hailstorm, which occurred during the month of August, highly damaged all faba bean fields in the area, the improved variety tolerated better and recovered sooner. Weeding and row planting for faba bean production were not practiced for the reasons justified by farmers in the planning stage of the scaling up activity.

Field day participant farmers also appreciated the improved faba bean variety, Dosha, for its large tolerance of gall and chocolate spot diseases. Market actors such as unions, primary cooperatives and legume processors also appreciated the large seed size of Dosha variety. They said the seed size of Dosha variety meets export standard and suggested that it should be produced in bulk to satisfy demand of exporters. The effort made to link producers through cooperatives to faba bean grain cleaners and exporters is also appreciated, and the participants suggested further discussion with important value chain actors to strengthen such platforms.

Grain yield

The highest grain yield of 3,405 kg ha^{-1} was recorded in Site-1 in 2015 cropping season while the lowest yield of 1,550 kg ha^{-1} was in site-2 in 2016 (Table 3). The overall mean yield obtained for the two districts for the two years was 2,445 kg ha^{-1}. The sites with low yield were due to faba bean gall disease and damage by hailstorm. The total grain yield obtained from 40.5 ha land was about 99 tons. The average yield obtained in this scaling up of the improved faba bean technologies, regardless of the observed stress, was higher than the reported average yield of 1.7 ton ha^{-1} in North Gondar zone (CSA, 2017), where our test locations are located. However, due to Boren weed infestation in the test locations, faba bean seed produced in the scaling up clusters was not certified to enter the formal seed system.

Table 3. Mean grain yield (kg ha^{-1}) of Dosha faba bean variety in Wogera district during 2015-2016

Sites	2015	2016	Average
Site1	3405	2400	2903
Site2	1745	1550	1648
Site3	3035	1725	2380
Site4	2650	2550	2600
Site5	1705	1875	1790
Site6	2580	2550	2565
Site7	2395	2550	2473
Site8	3200	-	3200
Mean	**2584**	**2108**	**2445**

Exit strategy

The Amhara Seed Enterprise purchases the seed produced after certification by Gondar seed laboratory in areas free from Boren weed infestation. GARC and agricultural development offices of Wogera, Dabat and Debark districts will follow up the scaling on wider scale and enhance farmers-to-farmer seed exchange in areas infested by Boren.

Lessons

- Public-Private Partnership approach brought important partners on board, eliminates duplication of effort, created coalition of partners with strong voice, and found to be cost effective since the partners share costs and save time for joint events such as field day, training which is a very good lesson
- Faba bean production needs intensive care since it is susceptible to biotic and abiotic stresses, mainly waterlogging associated with root rot, gall disease and Boren weed infestation.
- Market linkages needs proactive planning and intensive discussion with partners and market actors in faba bean value chain.

Conclusions and Recommendation

Our scaling up of improved faba bean technologies significantly increased crop productivity by using the Dosha variety, rhizobia inoculation, and disease management practices. The multi-stakeholders process in technology dissemination approaches such as workshops, training, and field days are important interventions in terms of creating trust, building capacity, promotion of improved faba bean technologies, and collecting farmers' feedback. Hence, the improved faba bean variety, Dosha with its production package should be scaled out in the test locations to enhance faba bean productivity and production.

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Popularization of Improved Faba Bean Variety and Bio-fertilizer Application in Eastern Tigray

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Research on cropping systems in Ethiopia indicated that the improvements in soil fertility from planting wheat after faba bean can improve grain yield of wheat by more than one ton per hectare and can reduce fertilizer usage for cereals in the next season by up to 60% (Amanuel and Daba, 2006). Different research works made in recent years revealed that inoculation of faba bean with Rhizobium leguminosarum increases yield by 10 to 50% and improves the fertility of the soil (Abere *et al*., 2009). However, most of the research works on faba bean with inoculants were conducted in in green houses; and farmers are not aware of their existence, use and benefits. To overcome this problem, Mekelle Agricultural Research Center (MARC) tested and demonstrated an improved variety with bio-fertilizer application. The result showed that a variety with inoculants improves productivity. Therefore, this activity was initiated to popularize the improved faba bean variety, Moti, with rhizobium inoculants in major faba bean production areas in Eastern Tigray zone.

Materials and Methods

Description of the study area

Atsbi-Wemberta district is found in Eastern zone of Tigray Region (Figure 1) located at 13° 36"N and 39° 36"E northeast of Mekelle covering an area of 122,300 ha (Hailay, 2008). The altitude ranges from 2400 m to 3100 masl. Rainfall is usually intense and short in duration, with an annual average of 667.8 mm. The average temperature of the area is 18oC.

Mixed crop-livestock farming system is the common agricultural practice in the district. The average household landholding of the area is 0.5 ha, of which about one third of the land area is covered by pulse crops; faba bean, field peas and chickpea are most important marketable pulse crops. The dominant cereal crops that are grown are barley, wheat, teff, and maize (OoARD, 2010).

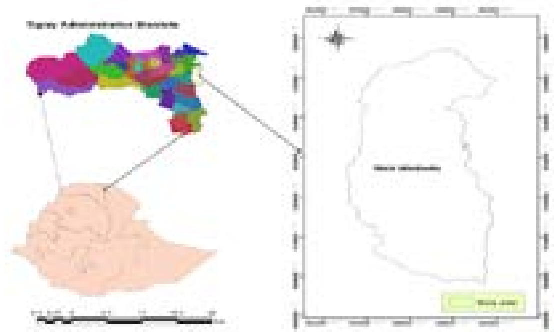

Figure 1. Map showing the relative position of the study area in Tigray

Selection of sites and farmers

The activity was conducted in Habes kebele in Atsbi-Wenberta district. In collaboration with extension agents and leaders of kebele administration, 30 volunteer farmers were purposively selected based on their interest for the technologies, and willingness to manage and allocate their fields for the activity. Training was provided to the selected farmers, district experts, and development agents at target kebeles. The improved faba bean variety, Moti, was planted at the seed rate of 200 kg ha^{-1} in the first week of July. Biofertilizer (FB EAL-110 strain) at the rate of 500 g ha^{-1} was applied for inoculating the seed at planting. Plot size of the improved technology in each farmer's field was 0.25 ha.

Data collection and analysis

Sample yield data was collected using quadrant samples in each plot. Checklist was used for interviewing the participants to assess the real interest of farmers for the improved technologies for further scaling up and promotion. Farmers' point of view on the attributes of the improved variety on the composite indicators of yield and yield components were also collected using Likert scale method, a format that is used by Derrick and White (2017). Coding and entering the data into computer were done for the analysis. The data was analyzed using SPSS version 20 computer program. Statistical analytical techniques such as descriptive, frequency, and percentages were calculated. Besides, different parameters as suggested by Yadav *et al.* (2004) were used for calculating technology gap analysis. Technology gap, extension gap, and technology index were calculated using the following formula:

$$\textit{Technology gap} = \textit{Potential yield} - \textit{Demonstration yied} \quad \text{(1)}$$

$$\textit{Extension gap} = \textit{Demsontration yield} - \textit{yield under farmers practice} \quad \text{(2)}$$

$$\textit{Technology index (\%)} = \frac{\textit{(Potentisal yield-Demonstration yield)}}{\textit{Potential yield}} \quad \text{(3)}$$

Results and Discussion

Training

Training on farmers research group approach, value chain, and good agricultural practices to increase faba bean production (crop diversification such as crop rotations, use of new agronomic practices, integrated weed management, application of bio-fertilizer) were given to development agents, experts and beneficiary farmers (Table 1; Figure 2).

Table 1. Number of participants during the training

Farmers		Development agents		Experts		Total
Male	Female	Male	Female	Male	Female	
21	9	2	2	2	-	36

Figure 2. Training sessions with farmers, development agents and technical staff

Yield advantage

The results of popularization showed that the improved variety, Moti, had higher productivity and yield advantage over the local practices (Table 2 and 3). An average grain yield of 3083 with maximum of 3900 kg ha^{-1} was harvested from Moti, while the local variety gave an average grain yield of 1675 with maximum of 2100 kg ha^{-1}. Thus, the use of improved variety resulted in 84% of yield advantage over the local variety. The t-test result also showed that there is statistically significant mean difference between the two varieties at less than 5% probability level. This would imply that the improved technology could play significant roles in enhancing the productivity of faba bean as well as improving the food security status of smallholder farmers.

The actual and potential yield of the improved technologies was determined and compared to estimate the yield gaps and then further categorized into technology index. The average technology gap was 1017 kg ha^{-1} (Table 2). The observed yield gap of the improved technologies (the improved variety and the applied biofertilizer) could be attributed to variations in soil fertility and salinity levels, erratic rainfall, and other extraneous variables. Hence, to narrow down the gap between the yields of different varieties, location specific recommendation appears to be necessary. Technology index shows the feasibility of the technology at the farmer's field; the lower the value of technology index the more is the feasibility. The technology index of 24.8% that was recorded in our study (Table 2) is in line with the findings of Sawardekar *et al.* (2003), and Hiremath and Nagaraju (2009).

Table 2. Yield, technology gap and technology index of popularization

Practices	Grain yield (kg ha^{-1})	Yield increment (%)	Technology gap (kg ha^{-1})	Technology Index (%)
Improved	3083	84	1017	24.8
Local	1675	-		

The independent sample t-test on grain yield data revealed significant (p=0.01) differences between the improved variety with improved management and local variety with farmers' production practices (Table 3).

Table 3. Independent sample t-test comparison of grain yield

Variety	N	Mean grain yield (kg ha^{-1})	t	SEM	df	P-value
Improved	10	3083	4.56	2.72	38	0.01
Local	10	1675		1.45		

Note: SEM = Standard error of mean difference

Farmers' perception

The attributes that were used to measure the farmers' perception on pre- and post-harvest of the varieties were grouped in to 15 attributes (Table 4). More than 90% of farmers agreed that Moti was the better variety in all parameters compared to the local variety. However, some of the beneficiaries perceived negatively on resistance to disease as compared to the local cultivar (Table 4).

Table 4. Farmers' perception of key traits of faba bean improved variety Moti

Attributes	Perception Level (%)				
	Very Poor	Poor	Moderate	Good	Very good
Early maturity	-	-	-	33.3	66.6
Insect resistance	-	11.1	11.1	55.6	22.2
Disease resistance	-	33.4	-	33.3	33.3
Drought resistance	-	-	-	55.6	44.4
Tiller number	-	-	22.2	33.3	44.4
Pod zone	-	-	11.1	44.4	44.4
Pod size	-	-	11.1	33.3	55.6
Threshability	-	-	-	44.4	55.6
Seed weight	-		22.2	22.2	55.6
Seed uniformity	-	-	22.2	22.2	55.6
Seed size	-	-	-	11.1	88.9
Seed color	-	-	-	22.2	77.8
Purity	-	-	-	33.3	66.7
Yield	-	-	33.3	22.2	44.4
Marketability	-	-	-	11.1	88.9

In general, most of the beneficiaries reported that they are satisfied with the overall performance of the new variety, Moti, and expressed interest to continue using the technology for the next production season.

Conclusion and Recommendation

According to the result from sampled yield and perception of farmers, the Moti variety with bio-fertilizer had given higher yield advantage over the local and it had good acceptance by most of the farmers in the study area. Therefore, it is recommended that Moti, with the improved management practices, further be promoted at wider scale.

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Managing Faba Bean Gall Disease in North Wollo Zone

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In recent years, faba bean is suffering from a new gall forming disease known as faba bean gall (FBG) locally known as *Kormid*, which in severe infections causes complete crop failure over wide areas within short period of time (Wulita, 2014; Bogale *et al*., 2014). Most of faba bean growing areas of North Wollo zone are significantly affected by this new disease resulting to a decline in faba bean production.

Chemical treatments have shown promising results in controlling gall disease elsewhere (Sahile *et al*., 2008). Treating faba bean with fungicides (like Carbendazim, Thiram and Bayleton) were also recommended and practiced in China (Lang *et al*., 1993). According to Sirinka Agricultural Research Center (SrARC) experimental result, Bayleton as a seed dressing fungicide was effective in reducing incidence and severity of the disease (SrARC unpublished data). Therefore, this activity was initiated to promote and create awareness of the recommended Bayleton fungicide for the control of faba bean gall disease and thereby improve productivity and production in North Wollo.

Approaches

Description of study area

The study was conducted at Meket district, North Wollo zone, Amhara region. The location, albeit a food insecure area, represents the major faba bean growing and moisture deficit areas of North Wollo. Field pea and lentil from cool-season pulses, and wheat, tef and barley from cereal crops also have a good coverage and production in the district. Meket district is located between 380 40 16' E and 110492'N at the 2890 masl. Annual rainfall is 1200 mm with minimum and maximum temperatures of 14 and 240C, respectively.

Description of the variety

The faba bean variety, Dosha, was released in 2009 by Holeta Agricultural Research Center. The variety matures between 120-130 day and recommended for an altitude range of 1900-2800 masl. The average productivity ranges from 1.6 to 3.3 tons ha^{-1} on-research station and 1.0 to 2.4 tons ha^{-1} on farmers' fields. SrARC evaluated the variety adaptability, in 2014, through participatory variety selection, and recommended its cultivation in North Wollo areas (Awol *et al*., 2014).

Selection of farmers and capacity building

SrARC researchers in collaboration with district experts and kebele development agents, selected 34 (5 females) voluntary farmers with combined land of 10 ha for promotion activities. Trainings were organized for capacity building and field days conducted for promotion of the technology.

Crop management

Farmers implemented most of the farm activities with technical guidance from researchers and extension agents. Faba bean was planted in mid-June in 2016 and 2017 meher cropping season. According to Bogale *et al*., (2014), Bayleton as seed treatment (300 g Bayleton with 300 ml water for 100 kg faba bean seed) and/or as foliar spray (700 g Bayleton with 200-liter water for one hectare) is recommended for the management of gall disease. Based on this, 1.75 tons of seed was treated by 0.53 kg of Bayleton. The seed was direct purchase (1.3 t) and revolving from previous cropping season (0.45t). Host farmers agreed to give seed through sale or barter at least to five farmers that have interest but missed to participate in this activity. All agronomic practices such as row planting, recommended seed rate, and weeding were applied by the farmers under the supervision of researchers and development agents.

Achievements

Seed produced and farmer exchange

The 35 participant farmers, who planted Dosha, produced 20 tons of yield, with the average productivity of 2.0 tons ha^{-1}, which is higher than the on-farm yield of the variety when it is released. The results from seed dressing improved farmers' attitude especially towards the management of faba bean gall disease. This district is known for its moisture stress that enhances faba bean gall disease incidence and severity. Faba bean gall disease control using Bayleton fungicide seed dressing could also be applied to the local variety that is very susceptible to avert complete crop failure. However, integration of fungicide with relatively tolerant faba bean varieties such as Dosha is preferable for better disease control and higher yield. Bogale *et al*., (2014) reported that those farmers who used faba bean gall disease control with Bayleton seed dressing harvested more than 95% yield advantage over the local variety without Bayleton seed dressing.

Tracing farmer-to-farmer seed exchange of the improved variety revealed that at least 170 farmers delivered seed to other farmers through bartering or sale.

Training and field days

Training was given for farmers and extension agents about faba bean technology package, application of Bayleton fungicide for control of gall disease, and the importance of integrating Bayleton with the relatively tolerant improved faba bean variety to increase the efficacy of the fungicide. In total, 210 (25 females) farmers, seven experts from district agriculture office and kebele development agents, and four researchers from SrARC participated in training and field day (Table 1). Trainings and field days enabled experience sharing amongst farmers, extension agents, and researchers. Farmers and other field day participants confirmed the best performance of Bayleton treated improved variety in comparison with the untreated local variety. Farmers' concern was rather the availability of the fungicide in the local market.

Table 1. Summary of activities and achievements

Activities or items or participants	Quantity	Participants		Descriptions
		Male	Female	
Area covered for popularization	10 ha	29	5	Number of farmers participated directly in implementing the activity
Total quantity of seed planted (tons)	1.75			Planted mid-June
Source of seed planted (tons)	1.3			Purchased directly from producers
	0.45			Revolving seed from previous year
Fungicide application (kg)	0.525			Bayleton fungicide as recommended by Bogale et al. (2014)
Training and field day	221			Total number of participants
Farmers	210	185	25	Trained and participated in field day about improved faba bean technologies
Experts	7	6	1	Trained and participated in field day to facilitate and increase awareness
Researchers	4	4	0	Participated as trainers and organizers of the trainings and field days
Seed produced (tons)	20			Total amount of seed produced by all 35 farmers
Minimum number of farmers who gave seed to others	170			Eeach seed producer agreed to give seed to five other farmers not participating in the demonstration and popularization

Note: t=tons and 1 ton is equivalent to 100 kg

Challenge

The major challenge during this activity was to make agreement with farmers to cluster the fields for faba bean production to avoid undesired cross-pollination.

Conclusion and Recommendation

Popularization of seed treatment (300 g Bayleton with 300 ml water for dressing 100 kg seed) of Dosha variety significantly improved faba bean productivity and production in the target areas of Meket district. Therefore, further scaling up of this improved technology on a wider scale in the district and similar areas in the highlands of North Wollo would be important to control faba bean gall disease. However, further study on the management options of this disease is crucial to substitute Bayleton fungicide since it is not easily available in the local market.

I FABA BEAN: Chapter 4: Faba Bean Technology Multiplication and Scaling

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Scaling-out Faba Bean Technologies on Vertisols of South Wollo Zone

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One of the major production constraints contributing to low faba bean production and productivity in the highlands of South Wollo zone is lack of improved varieties which are high yielding, and tolerant to waterlogging and disease (Awol, 2014). Most farmers use their local variety and crop management system that leads to low yields. To improve production and productivity of faba bean in these areas, there is a need to scale up the recommended improved faba bean variety with its management package that passed through participatory variety selection process.

Therefore, this scaling out of improved faba bean technologies for Vertisols areas in South Wollo was initiated with the objectives of making wider scale awareness to improve farmers' production management practices and thereby increase productivity and production.

Approaches

Description of sites

The scaling out was conducted in Legambo and Woreilu districts of South Wollo zone. Wheat, barley, faba bean, teff, lentil, field pea, grass pea and fenugreek are among the major annual crops produced in these two districts. These two districts represent the major faba bean growing Vertisols areas of South Wollo. In addition, these districts are food insecure areas. Additional descriptions of the test locations are presented in Table 1.

Table 1. Training participants in 20116/17-2017/18

District	Altitude (masl)	Longitude	Latitude	Soil type	Temperature (⁰C)		Rainfall (mm)
					Min.	Max.	
Legambo	2950	480 90 70'E	110 82 71'N	Vertisols	11	25	900
Woreilu	2896	510 06 56'E	110 54 50'N	Vertisols	13	24	993

Description of the variety

Faba bean variety, Walki, was released by Holeta Agricultural Research Center based on its higher productivity and tolerance to waterlogging stress on Vertisols areas in Ethiopia. Walki, released in 2008, matures within 133-146 days and recommended for areas with altitude range of 1900-2800 masl. On-station grain yield ranges from 2.4 to 5.2 tons ha^{-1} whereas the grain yield on farmers' fields ranges from 2.0 to 4.2 tons ha^{-1}. Sirinka Agricultural Research Center (SrARC) evaluated its adaptability during the meher season of 2014 through participatory variety selection and recommended it for production based on the performance and preference of farmers. Thus, SrARC initiated the scaling out of Walki variety with its management package on Vertisols areas of Legambo and Woreilu districts during 2015-2017 meher cropping seasons.

Site and farmer selection

A total of 1526 (215 females) farmers with the total land of 423 ha were selected and directly participated in the implementation. During monitoring and evaluation, 12 extension experts in the districts and development agents in the kebeles, and 6 researchers from SARC participated. Trainings were conducted for capacity building and field days organized for promotion of the technology.

Crop management

Most farm activities were implemented by farmers on selected sites through technical guidance by researchers and extension agents. The planting was done in mid-June each year during meher cropping season. The seed sources were direct purchase (47 t) from producer, revolving seed from previous cropping season (24 t), and farmer-to-farmer seed exchange (3.0 t). Farmer-to-farmer seed exchange was implemented in such a way that farmers participated in the pre-scaling up and out should give seed through bartering or sale at least to five farmers that have interest but not participate in the activity. In total, 423 kg of NPS fertilizer was applied although the total planted area in the scaling out period during 2015-2017 was 423 ha (Table 3), which shows that most of the scaling out fields were not fertilized with NPS fertilizer. Farmers under the supervision of researchers and development agents applied all agronomic practices including row planting, and weeding.

Achievements

Seed produced and farmer seed exchange

During the scaling out activity in 2015-2017 In both districts, 1526 participant farmers produced 761.4 tons from 423 ha of land during the scaling of activities from 2015-2017 (Table 2), which shows average productivity of 1.8 tons ha^{-1}. The productivity is low although the field performance of Walki was best at vegetative stage (Figures 1 and 2) in both districts. Farmers complained about frost and terminal stresses of moisture deficit, which might have contributed to low productivity (Table 2). Based on the agreement to implement farmer-to-farmer seed exchange, 1526 participant farmers provided seed through bartering or sale to 7630 farmers who have interest but missed to participate in the scaling out activity (Table 3). These two districts are also serving as seed source for neighboring faba bean producing districts.

Table 2. Summary of activities and achievements in Legambo and Wereilu districts

Activities or items or participants	Quantity	Participants		Description
		Male	Female	
Area coverage of planted farm (ha)	423	1311	215	Number of farmers participated directly implementing scaling out activities
Total seed planted (tons)	74			Planted mid-June each year
Seed source (tons)	47			Purchased seed
	24			Revolving seed scheme
	3			Farmer to farmer seed exchange
NPS fertilizer application (kg)	423			Total amount of fertilizer for both districts
Seed produced (tons)	761.4			Total seed produced by all 1526 farmers
Training	267			Total number of participants
Farmers	250	232	18	Trained on faba bean production package and seed production in both districts
Experts and extension agents	17	14	3	Trained to facilitate and increase awareness about the scaling out activity
Researchers	5	5	0	Participated as trainers and organizers
Field day	498			Total number of participants
Farmers	453	442	11	Farmers who shared experience and showed increased demand to produce improved variety
Experts and extension agents	21	19	2	Accounted to popularize faba bean technologies to farmers in other area for future scaling
Researchers	15	15	0	Participated as organizers
ARARI management	9	9	0	Technical directors and senior researchers
Minimum number of farmers who gave seed to others	7630			Each seed producer provided seed to five other farmers through bartering or sale

Figure 1. Scaling of improved faba bean var. Walki on Vertisols at Legambo, 2015

Figure 2. Scaling of improved faba bean var. Walki on Vertisols at Woreilu, 2017

Training and field days

The scaling out activities on Vertisols increased not only faba bean production and productivity in the areas but also improved farmers' production system and experience through training, field day and revolving seed system. Five researchers from SrARC trained 250 (18 females) farmers and 17 (3 females) extension agents on the improved Walki faba bean variety and its production package, and seed production in both districts (Table 2).

Field days were organized and 453 (11 females) farmers, 3 South Wollo zone agricultural experts and 18 (2 females) extension agents, 15 researchers from SARC, and 9 technical directors and senior researchers from Amhara Agricultural Research Institute for enhancing awareness, further promotion of the scaling out, and experience sharing. In these field days, model farmers were particularly accounted to facilitate further popularization of the improved variety through farmer-to-farmer seed exchange.

Discussions during the field days revealed that farmers accepted Walki variety due to its better performance on Vertisols and its disease tolerance. However, they also raised key issues, which could hinder an increase of faba bean production in the districts. These problems include shortage of quality seed of the improved variety, shortage of fertilizer, diseases and frost. There was some market problem in terms of lower price compared to the seed price they expected. Thus, SrARC was accounted to identify and develop disease and frost resistant/tolerant varieties. Zone and districts agricultural offices accounted to facilitate expanding seed production and input supply system experience of this project.

Challenge

The major challenge during this activity was to convince farmers for clustering their fields for faba bean production to avoid genetic mixtures through outcrossing with other varieties.

Conclusion and Recommendation

The improved variety Walki, with good soil management on Vertisols, is a key breakthrough to enhance production and productivity of faba bean in the highlands of South Wollo and similar areas. Therefore, it is recommended that further scaling out of this improved technology for Vertisols areas should be done through the leadership of agricultural development offices at different levels.

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Management of Parastic Weed (*Orobanche crenata*) of Faba Bean in South Wollo Zone

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Orobanche crenata is the most serious parasitic weed among agricultural pests of economic importance. It is an obligate holophrastic weed that causes severe damage to many important vegetable and field crops (Sauerborn, 1991). It is considered as one of the major factors limiting the production of legumes including faba bean. Several attempts and intensive research were conducted in different countries to screen for potential herbicides against Orobanche. Herbicides applied to the host at low rates that are safe to the faba bean but can reach lethal concentrations in the parasite would be effective to control it.

Sirinka Agricultural Research Center (SrARC) in collaboration with ICARDA conducted different research activities and recommended that the integrated application of Orobanche tolerant faba bean variety with 0.3 liter ha^{-1} Glyphosate chemical, coupled with two times spray and continuous hand weeding effectively controls Orobanche. Therefore, this study was initiated to promote this integrated weed control approach in wider scale, to create awareness and demand for the technology and increase faba bean productivity and production in Orobanche affected areas of South Wollo.

Approach

Description of study areas

The promotion of the integrated orobanche control for faba bean production was conducted during 2016-2017 at Kutaber and Dessiezuria districts, where orobanche infestation caused faba bean out of production for the last 30 years. The altitude range of these specific locations are 2868-3000 masl. Average annual rainfall is 900 mm with the respective minimum and maximum temperature of 9oc and 20oC. The dominant soil types are light Vertisols and Lithosols.

Technologies

Technology promotion included the Orobanche tolerant faba bean variety, Hashenge, alone or with integration of the recommended two times spray of 0.3 litre ha^{-1} Glyphosate herbicide mixed with 250 to 300 litre ha^{-1} water at the start of faba bean flowering and one week after first spray. Farmers were also advised to do continuous hand weeding of Orobanche before flowering to reduce the seed bank. The performance of Hashenge was also compared with the local variety. Seed production of Hashenge and farmer-to-farmer seed exchange was also promoted.

Trainings and field days

Trainings were provided for smallholder farmers, kebele development agents, and district agricultural development office experts about the improved technologies to control Orobanche in faba bean fields. Field days were organized to create awareness about the improved technologies of Orobanche control, exchange and share of experience, and promote further expansion of the technologies in Orobanche-infested areas.

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Achievements

Performance of improved technology

Hashenge faba bean variety with two times spray (0.3 liter ha^{-1} Glyphosate herbicide in 250 to 300 litre ha^{-1} water) at the start of faba bean flowering and one week after first spray showed good control of the weed yielding up to 2.6 t ha^{-1} grain.

Promoting the Orobanche tolerant Hashenge variety in Orobanche hotspot sites without the application of Glyphosate also showed good level of tolerance and gave higher yield than the susceptible local faba bean variety. Hashenge variety with the application of 100 kg ha^{-1} DAP fertilizer, biofertilizer, and with no DAP and no biofertilizer gave the respective average grain yield of 1375, 1325 and 1275 kg ha^{-1}. The productivity of the local variety with the application of 100 kg ha^{-1} DAP fertilizer, biofertilizer, and with no DAP and no biofertilizer generally was low, giving the respective grain yield of 775, 750, and 450 kg ha^{-1}.

Glyphosate is a broad-spectrum and systemic herbicide. Its systemic nature enabled it to translocate through faba bean plants xylems into the germinating seeds of parasitic weed at the time of attachment and can damage the Orobanche weed seedlings. It was also reported elsewhere that in small dose of application, Glyphosate does not damage the faba bean plants but controlled the Orobanche weed (Singh *et al*., 2012).

Seed production and distribution

In 2016, through small seed pack distribution for technology promotion, about 6 ha of Hashenge variety was planted with the participation of 18 farmers (3 female) and produced 9 tons of basic seed. Farmers also produced 19.85 tons of quality seed from revolving seed scheme on 13.2 ha in 2016. Similarly, farmers produced 1.5 tons basic seed on 0.62 ha of land; and 155.812 tons quality seed on 53.28 ha of land in 2017. About nine ton of quality seed produced in 2017 at Kutaber district was sold to Tenta, Meqidela, and Desie Zuria districts for planting in 2018 meher cropping season. Sale price of the seed of Hashenge variety was 3200 ETB per 100 kg^{-1} of seed while that of the local variety was 2100 ETB. Moreover, 25 t seed of Hashenge variety produced in 2017 was distributed through farmer-to-farmer seed exchange for planting in 2018. The seed distributed through sale and farmer-to-farmer seed exchange would directly benefit at least 907 farmers at the seed rate of 150 kg ha^{-1} with the assumption that each farmer allocates 0.25 ha of land for faba bean production.

Training

Trainings were provided to 135 participants (23 female) including farmers, development agents, and experts of district office of agricultural development. The training addressed suitable agro-ecologies for faba bean production, improved technologies to control orobanche, quality seed production, the importance of continuous hand weeding (rouging) of orobanche to deplete soil seed bank, and the importance of seed quality control and quarantine in curtailing seed distribution in Orobanche free areas. The importance of clustering fields to maintain genetic purity of Orobanche tolerant Hashenge variety was also covered during the training.

Field days

Repeated field days were conducted at Kutaber district by involving large number of farmers from each kebele infested by this parasitic weed (Orobanche), kebele development agents, experts from district and zonal agricultural development offices, farmers' cooperatives and union, Desie Seed Inspection and Quarantine Branch, and researchers (Table 1). Field day participants from Orobanche affected districts were also brought to Kutaber where the main activity was conducted to promote experience sharing on the effectiveness and application of the improved technologies for controlling Orobanche, curtailing the spread of this parasitic weed to new areas, and faba bean seed production and distribution in parasitic weed affected areas.

Participants were very impressed by the performance of the Orobanche tolerant Hashenge variety and its integration with the minimum dose of glyphosate herbicide in controlling this parasitic weed that enabled the reintroduction of once abandoned faba bean production. This is a big breakthrough to improve faba bean productivity and production and thereby food and nutrition security of the farming community. Thus, participants of the field day shared responsibilities on the way forward:

- Agricultural development offices coordinate and lead promotion efforts of the improved technologies on a wider scale in order to fully address Orobanche affected areas;
- Unions and cooperatives enhance seed production and marketing in the orobanche affected areas; and
- SrARC provide training and technical support to maintain genetic purity of the improved Hashenge variety in addition to its role of producing breeder and pre-basic seed of this variety.

Table 1. Summary of field day participants in promoting improved technologies for control of Orobanche

Participant institutions	*Male*	*Female*	*Total*
Farmers from different kebeles	*85*	*23*	*108*
Development agent from different kebeles	*17*	*5*	*22*
District experts	*6*	*1*	*7*
Zone experts	*4*	*0*	*4*
Unions and cooperatives	*2*	*0*	*2*
Dessie Seed Inspection and Quarantine	*1*	*0*	*1*
Researchers	*8*	*0*	*8*
ICARDA	*1*	*0*	*1*

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Conclusion and Recommendations

Promotion of Orobanche-tolerant Hashenge variety alone and with integration of the minimum dose of glyphosate herbicide in controlling Orobanche weed enabled the reintroduction of faba bean production, which was abandoned because of this parasitic weed. Therefore, it is recommended that further promotion of these improved technologies to wider scale in all Orobanche-affected areas. Seed production and distribution through sale and exchange should be limited to Orobanche-affected areas and therefore there must be a strict control to curtail seed movement out of these areas not to introduce the seed in the Orobanche free areas. Continuous training and follow ups are required to ensure farmers are well acquainted with minimum dose glyphosate application since higher doses can kill faba bean crop. Continuous hand weeding (rouging) to deplete the soil seed bank of Orobanche weed should also be an important area of action.

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II CHICKPEA

CHAPTER 1

OVERVIEW OF ACHIEVEMENTS AND BASELINE SURVEY

Achievements of Seed Production and Scaling of Chickpea Innovations in Ethiopia

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Introduction

Pulses play a significant role in the integrated crop-livestock farming systems and provide multiple benefits to the smallholder farmers in Ethiopia for farming system productivity and sustainability (Bishaw *et al*., 2018). The main grain pulses produced are faba bean, field pea, chickpea, grass pea, lentil, and lupine in the highlands, and common bean, soybean and mung bean in the lowlands. Among the highland pulses, chickpea is the second most important food and nutrition security and cash crop after faba bean for many households in wheat- and teff-based cropping systems. In 2014/15, chickpea was grown on 239,755 ha by 1.08 million smallholder households (CSA, 2015). At national level, 23% of chickpea produced by small holder farmers is used for sale and 57% is used for home consumption and the rest is used as seed sources. Moreover, chickpea straw is an important source of animal feed in crop-livestock mixed farming systems.

In Ethiopia, two types of chickpeas are grown: (i) Desi types with smaller and darker grain color -traditionally produced and consumed in domestic markets; and (ii) Kabuli type with larger and lighter grain color - recently introduced and are most preferred in high-value international markets. Kabuli chickpea production is increasing due to high demand for export markets (Alemu & Bishaw, 2019).

Chickpea is the second most important food legume crop after faba bean in terms of cultivated area and production. However, its national average productivity was 1.9 t ha^{-1} which is much lower than the achievable yield of 4 t ha^{-1} (Korbu *et al*., 2020). The main reasons include, among others, low dissemination and utilization of improved technologies, shortage and limited supply of quality seed, and poor extension services for transferring available technologies to farmers. Significant yield gaps are observed in chickpea due to limited access to improved technologies, poor extension services, late planting on residual moisture exposing the crop to drought, poor soil fertility and diseases and insect pests.

Although the national research system has released 21 Desi and Kabuli chickpea varieties over the last three decades, only few Kabuli chickpea varieties released from ICARDA breeding materials are making an impact particularly in Eastern Shewa Zone. For example, results from recent technology scaling work in major chickpea growing areas of northern Ethiopia showed that farmers can produce up to 4.8 tons ha^{-1} using improved varieties compared to 1.1 t ha^{-1} from local varieties. Advancing Kabuli chickpea with Ascochyta blight

and wilt/root rot resistances, planting time to mid-August on Vertisols reported to increase grain yield by about 50% due to efficient use of available moisture. Early planting in July in low moisture stressed environments was found to be advantageous (Eshete and Fikre, not dated). The same authors reported that increased chickpea grain and straw yields were obtained from seed inoculated with effective rhizobium strain and P-fertilization across locations. These studies showed a very clear evidence of significant yield gaps that need to be narrowed through interventions that include new and improved crop technologies (varieties and agronomic practices), dissemination of knowledge/information, innovative seed systems and capacity development.

Narrowing chickpea yield gaps and scaling innovations are fundamental in increasing production and reducing food and nutrition insecurity and increase rural incomes. During 2015-2018, the chickpea project has been promoting and scaling up/out improved chickpea technologies with the overall goal of improving the livelihoods of smallholder farmers. This paper describes the approaches and summarizes the achievements of the chickpea under the project Better Livelihoods for Smallholder Farmers Through Knowledge-based Technology Interventions in the Highlands of Ethiopia: Increasing the Productivity of chickpea in Wheat-based Cropping System implemented in partnership with federal and regional research for development partners and stakeholders along the chickpea value chain.

Project Goal and Objectives

The overall goal of the project was to improve the livelihoods of chickpea producing smallholder farmers through increased productivity and production, and linkages to export markets. The objectives were to:

- Validate, demonstrate and popularize improved chickpea varieties with the integrated crop production packages to increase awareness, create demand, ensure access and adoption
- Enhance the availability, accessibility, and affordability of quality seed of improved varieties through the involvement of farmer seed producers and formal seed companies in producing and marketing quality seed of chickpea varieties
- Understand the systemic bottlenecks in chickpea seed and grain value chains and propose interventions and create market linkages among the key actors; and
- Strengthen human resources and infrastructure capacity for research, seed production, advisory services of the NARS, seed companies, farmer groups and other seed sector stakeholders

Approaches

A framework for scaling has been developed and used for dissemination of crop technologies for a meaningful adoption and impact at scale (See Bishaw *et al*.,. under the faba bean section in this volume) as specified for wheat (Bishaw *et al*., 2016) and malt barley (Bishaw and Adamu, 2020). The approaches included:

- Validation, demonstration, and popularization of new chickpea varieties and integrated crop management practices. Farmers hosted demonstrations where field days were organized for farmers, development agents and subject matter specialists as well as technical and administrative staff and senior and policy makers from district, zonal, regional and federal offices for experience sharing and improving linkage;

- Accelerated early generation seed (breeder, pre-basic and basic) production by National Agricultural Research System) during the main- and off-seasons. NARS engaged farmer groups such as cooperatives and unions to produce seed under their supervision and linked them to regional seed certification agencies to ensure quality and enhance marketing and sustainability. The seed produced would be used for further multiplication of certified or quality declared seed (QDS) through formal or informal sectors;
- Accelerated certified seed or QDS production through distribution of small seed-packs and mobilizing, organizing, and training farmers to engage in seed production and marketing. Seed producers were linked to regional seed certification agencies to ensure quality. Farmers had the options of marketing the seed produced through formal and/or informal sectors; and paying back the seed in kind as revolving seed fund scheme to produce quality seed for scaling or local distribution by district Office of Agriculture (OoA);
- Strengthening capacity of project partners and stakeholders including farmers through training to upgrade knowledge and skills and providing critical facilities for NARS and seed producers; and
- Characterizations of farm households to establish benchmarks and measure the impact of the project on adoption and impact on farmers' food and nutritional security and income.

Partners and Stakeholders

A broad range of research for development project implementing partners and chickpea value chain stakeholders from the federal and the three target administrative regions were involved in the different platforms. These included:

- **Policy makers:** The Federal Ministry of Agriculture (MoA) and three regional Bureaus of Agriculture (BoA) in Amhara, Oromia and Tigray and their affiliated administration and extension services at zonal, district and kebele levels in project target areas. They facilitated project implementation and created enabling environment for increasing chickpea production;
- **National Agricultural Research Systems:** The Ethiopian Institute of Agricultural Research (EIAR) and egional agricultural research institutes (Amhara Regional Agricultural Research Institute (ARARI), Oromia Agricultural Research Institute (OARI), and Tigray Agricultural Research Institute (TARI). Deber Zeit and Holetta ARCs from EIAR; Adet, Debre Birhan, Gondar and Sirinka ARCs from ARARI; and Sinana ARC from OARI; and Alamata and Mekelle ARCs from TARI were partners implementing the project in the respective target regions. NARS not only generate the improved technologies but played a key role in implementing the scaling projects, provision of early generation seed, technical backstopping of farmer-based seed production and strengthening the capacity of partners and stakeholders;
- **Public seed producers and suppliers:** Ethiopian Seed Enterprise (ESE) and regional parastatal seed enterprises (PSEs) such as Amhara Seed Enterprise (ASE), and Oromia Seed Enterprise (OSE);

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- **Private seed producers and suppliers:** Private seed producers including farmer's primary cooperatives and unions and associations like licensed and non-licensed farmer seed producer and marketing cooperatives, farmers' cooperatives seed unions and farmer seed producer associations which are involved in local seed production and marketing;
- **Private agri-input producers and suppliers:** Menagesha Biotech Industry PLC project for making available biofertilizers and Mkemba for agro-chemicals, xx for PICS
- Seed regulatory agencies: Regional seed regulatory and quality control and quarantine agencies of respective administrative regions providing quality assurance for seed produced by SPCs and farmer groups;
- **Development practitioners:** NGOs and development agencies involved in promoting and scaling improved technologies like Africa RISING, Integrated Seed Sector Development-Ethiopia, Tropical Legumes Project, pulse traders and sector association, and Agricultural Transformation Agency working in target areas;
- **Farmers:** Farmers in Agricultural Growth Program (AGP) and Productive Safety Net Program (PSNP) districts. Farmers were engaged as main participants of the project involved in hosting demonstration, producing and marketing seeds and as beneficiaries.

The project worked closely with the National Chickpea Stakeholders' Platform, established, and led by the EIAR coordinating the chickpea value chain. The forum brought together chickpea producers, processors and exporters and provided an opportunity for joint planning and monitoring to avoid duplication of efforts with other projects. Moreover, the platform organizes series of consultation meetings where common challenges are discussed, experiences shared, and possible solutions suggested for the chickpea sector (Picture 1).

Picture 1. Chickpea stakeholder's platform meeting organized by DZARC

Project Target Regions

The chickpea project focused on three major chickpea producing administrative regions covering Amhara (124,854 ha and 633, 235 households); Oromia (102,667 ha and 357,951 households); and Tigray (6,242 ha and 37,473 households) which collectively cover 98% of chickpea area and 98% of production in the country (CSA, 2014). The project covered a total of over 60 districts in AGP and PSNP intervention areas (Figure 3).

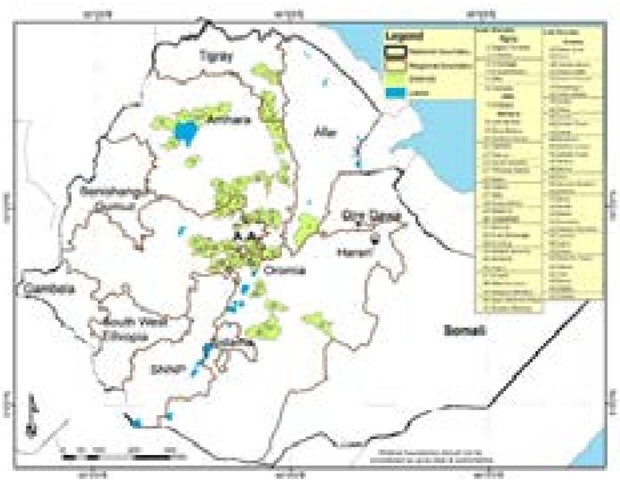

Figure 3. Chickpea seed production and scaling districts

Achievements

The major achievements and lessons learned of the seed production and scaling of chickpea under the project Better Livelihoods for Smallholder Farmers Through Knowledge-based Technology Interventions in the Highlands of Ethiopia: Increasing the Productivity of Chickpea in Wheat-based Cropping System during 2015-208 cropping seasons are summarized below.

Demonstration and Popularization of Technologies

During the project period, several demonstrations and popularizations activities were conducted to create awareness on and demand for the improved chickpea varieties and technologies in the project target areas. Demonstrations created opportunities for beneficiary farmers to get direct access and observation and firsthand information on the performance and provide feedback on improved chickpea technologies. The field days attended by value chain actors including policy makers enabled to identify key constraints along the crop value-chain and the opportunities to link and to create synergy among development practitioners within the research for development continuum.

Poor crop management is one of the most important yield-reducing factors that limits productivity of improved varieties of chickpea in Ethiopia. In total, 657 demonstrations were conducted on as many farmers' (12.3% female) fields. Demonstrations included improved varieties with crop management technologies, and insecticide application to control pod-borer (Table 1). Improved technologies showed yield advantage of 4.7 to 239.4% over conventional technologies in the test locations. The highest yield advantage of 239.4% was obtained from pod-borer chemical control measures on Habru chickpea variety in warm mid-altitude areas of Ginir and Goro districts. Bale Administrative Zone, Oromia Regional State. This indicates that pod borer is economically important yield reducing pest in warm mid-altitude areas of Ethiopia.

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Mechanical planting and harvesting of chickpea showed good results although data from some recently released varieties for mechanical harvesting yielded lower than the standard check variety (Habru). This result indicated that wider scale demonstrations should be carried out to measure not only yield but also export quality parameters since mechanization is an important area of intervention for improving productivity of chickpea.

Table 1. Productivity and yield advantage of chickpea varieties and management practices in 2015-2017

Districts	*Improved technologies*	*Average yield (t ha^{-1})*		*Average yield advantage (%)*
		Improved practices	*Farmer practices*	
Enemay	*Arerti & Ejerie[1]*	*1.8*	*1.5*	*20*
	Teketay[1]	*2.6*	*1.5*	*73*
Kersamalima & Sebeta-Hawas	*Habru[1]*	*1.7*	*1.3*	*31*
	Naatolii[1]	*1.8*		*38*
Ginir & Goro	*Dhera, Hora & Habru[2]*	*2.1*	*2.6*	*-18.7*
Ginir & Goro	*Dimtu, Teketay & Naatolii[3]*	*2.4*	*2.1*	*12*
Duga-Tembien	*Arerti: Early planting (1st week July +BBF) & late planting (August)[4]*	*2.7*	*1.6*	*69*
Ginir & Goro	*Habru: Pod borer control (Diazenon and Karate) & no control[5]*	*2.1*	*0.7*	*195*

Note: [1]Compared to landraces; [2]Compared to var. Habru; [3]Compared to var. Naatolii; [4]Late planting in August; [5]No control

Field days

Lack of knowledge and awareness of productive and profitable chickpea varieties and crop management practices are factors that are limiting the scaling up/out of these technologies. Technology demonstrations, community-based seed production, and scaling up/out activities associated with the project provided farmers with the opportunity to become aware of the performance of the improved varieties and accompanying production technolgies within the environments in which they are operating. In addition, organizing field days accelerates awareness creation by reaching a greater number of farmers who are able to exchange experiences, enhance farmer-to-farmer seed exchange, and provide an oportunity to improve linkage among the value chain actors.

During the project period, field days were jointly organized by partner research centers and district Offices of Agriculture which worked together in promotion and scaling of improved technologies (Picture 2). A toal of 11,255 farmers (14.4% female) and 2,140 other staff (17.3% female) stakeholders of chickpea value chain participated in various field days to have awareness and witness the performance of improved technologies of chickpea in different production systems and agro-ecologies.

Picture 2. Participants of field day organized by HARC and Karsamalima district in Southwest Shewa zone, Oromia region (2015)

Among the value chain stakeholders were district and zonal political and sectoral authorities, zonal and distrtict experts of agricultural extension, experts of zonal seed quality inspection and certification agencies, experts of zonal cooperatives organizing and licensing agencies, agricultural marketing and input suplying unions, seed marketing and input supplying unions, public and private seed enterprises, development agents, and researchers from NARS, ICARDA, and ICRISAT.

These field days, in addition to creating awareness on the performance of the technologies being promoted and scaled up/out, emphasized linkages with various actors along the chickpea value chain with a particular focus on promoting farmer-based seed production as a means of overcoming the prevailing critical shortage of improved seed supply. Quality seed production and timely certification were also major issues of discussion during the field days.

One of the significant achievements observed in the field days was the impressive results of early planting of improved chickpea in Kersamalima, Ensaro, East Belesa, and West Belesa districts in central and northwest of Amhara and central Tigray Regions in the northern parts of the country. Farmers in these areas used to plant chickpea from late August to late September as the rainfall ceases, leaving the crop to grow on the residual soil moisture which is not enough to support the full crop life cycle and hence exposes it to terminal stress that drastically reduces yield. Farmers practiced late sowing mainly to escape waterlogging of Vertisols and susceptibility of local chickpea varieties to Ascochyta blight and root rot diseases. NARS in cooperation with ICARDA developed Ascochyta blight resistant Kabuli chickpea varieties like Arerti and Habru which made early sowing (at least one month earlier than the traditional practice) possible. However, these varieties are susceptible to root rot complex on waterlogged Vertisols when sown early. Therefore, integration of the improved varieties with better soil drainage using broad-bed and furrows as well as the traditional ridge and furrow enabled early sowing and up to three-fold yield increase when compared to the traditional late sowing practice.

Traveling Workshop

The project team and partners gained considerable experiences during project implementation working with broad range of stakeholders across the country. One notable practice observed locally known as 'Shrubie' was farmers' experience of managing poorly drained Vertisols and advancing early planting of chickpea in North Shewa Zone. Farmers' practice early planting on hand made broad bed and furrows in North Shewa and ridge and furrow in East Shewa to drain excess water to improve chickpea productivity and production on poorly drained Vertisols (Picture 3).

Cognizant of this game changing practice, a traveling workshop was organized to share experiences by visiting chickpea activities implemented by Adet ARC, Debre Birhan and Debre Zeit ARCs in North Shewa Zones (Oromia and Amhara Regions) and East Gojam Zone (Amhara Region). About 37 staff from 13 partner research centers, and 7 heads of district Office of Agriculture and/or extension departments from hosting districts participated and contributed to the sharing of experiences.

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During the experience sharing and learning travelling workshop, the participants practically observed farmers' context specific practices relevant to each farming system, agroecology and production system (Picture 3). All participants recognized a greater need to demonstrate, promote and further scaling the technologies observed through the support of the government and other projects, and conduct action research on emerging issues in chickpea production.

Picture 3. National chickpea travelling workshop in 2017

Trade Fairs

ICARDA participated in the Trade Fair organized by Feed the Future Ethiopia Value Chain Activity on 27-28 January 2018 at Finoteselam in West Gojam Administrative Zone of Amhara Regional State. ICARDA exhibited and displayed 11 Kabuli and 13 desi chickpea varieties with full oral and written explanations to the visiting farmers. Kabuli chickpea varieties had more demand and price (3000 ETB) compared to desi chickpea (1800 ETB) because of their Ascochyta blight resistance and bold seed due to demand for export market.

The trade fair provided an opportunity to create awareness about the available improved chickpea varieties and accompanying management technologies and link farmers with project partner research centers and universities for further research and scaling of technologies. Major chickpea production constraints based on farmers feedbacks during exhibition include lack of optimum sowing dates and appropriate crop combination in double cropping system and diseases, such as wilt and cut worm.

Accelerated seed production

Development of improved varieties should be coupled with commercialization where the need for robust seed sector remains critical. Bishaw *et al*., (2018) summarized the systemic bottlenecks of the legume seed sector. Neither the public nor the private formal sector was able to address the seed demand and supply gap. To increase access of quality seed of improved chickpea varieties, the project made concerted effort for production of different seed classes working with NARS, seed producers and suppliers including seed producer cooperatives and farmer groups. The effort included off-season seed production where irrigation is feasible in the lowlands and highlands particularly for early generation seed (EGS) production.

Early Generation Seed Production

The availability and access to EGS (breeder, pre-basic and basic) remains a major constraint in the Ethiopian seed sector least for pulses including chickpea. Limited land availability in partner research centers and a shortage of nucleus and breeder seed hindered EGS production and supply. Hence EGS multiplication of chickpea varieties was one of the key activities of the project. A total of 32.14, 163.91 and 509.43 ha, respectively of breeder, pre-basic and basic seed was planted and a corresponding 45.7, 174.1 and 1113.3 tons of seed was produced. Productivity of breeder and pre-basic seed production appeared low due to intensive rouging and partly due to complete crop failure from frost and drought in some of the target locations.

To address the shortage of EGS, the project introduced two innovative approaches which were successfully implemented. The first innovative approach of the project was the use of farmer-based seed production involving seed producer cooperatives (SPCs) or farmer groups which contributed to 86% of basic seed production. About 794 farmers (19.5% female) participated in basic seed production during the project period. Another innovative approach of the project was the process of decentralized EGS production with partner research centers which is partially implemented instead of being dependent for EGS on ARCs which releases the variety.

Certified Seed Production

From the outset, the project had no objective to engage in large-scale certified seed production; the plan was only to fill the gap on the availability of basic seed in the multiplication process. It was anticipated that the public or private seed suppliers to directly access pre-basic seed from the NARS to produce their own basic seed or linked to NARS-cum-farmer seed producer groups to access the basic seed to produce certified seed using their own resources. Attempts were made to establish linkages with federal and regional public seed enterprises (PSEs), and/or emerging private seed companies and engage them in certified seed production of chickpea. These partners participated in the project launch workshops and partnership meetings as well as the annual review and planning meetings of 2015, 2016, and 2017. This engagement facilitated the federal (Ethiopian Seed Enterprise) and the four regional public seed enterprises (PSEs) such as Amhara Seed Enterprise, Oromia Seed Enterprise, and South Seed Enterprise to become members of the Project Steering Committee (PSC).

Although PSEs not directly involved in certified seed production for the project in target districts in 2016 and 2017, they have accessed EGS from NARS partners and produced certified seed of some chickpea varieties within the centrally managed production plan under the Ministry of Agriculture (MoA), which is not included in this report. The project made tremendous efforts to strengthen and/or establish farmers' seed producer cooperatives or seed producer groups to fill the gap of basic and certified seed production created due to the limited capacity and interest of public and private seed enterprises. Some of these farmers who have been organized into SPCs have already established contractual agreements for basic or certified seed production and marketing with public seed enterprises. This contractual arrangement not only accelerated seed production but also opened market opportunities for SPCs.

Farmer-based seed production and scaling

Farmer-based seed production through seed producer cooperatives (SPCs) or groups has been a priority intervention aimed at improving access to quality seed by smallholder farmers in the project target areas. Smallholder farmers indicated that improved seed produced by PSEs are not easily accessible or arrives late for timely planting or perceived as expensive. It was anticipated that decentralization of seed production through farmer-based seed production (Picture 4) allows farmers access to low-cost seed and ensures availability and ease of access, which encourages use of the technology. Since the seed is produced in their community, farmers have an opportunity to see the performance of improved variety and develop confidence in the use of these varieties.

Picture 4. Chickpea seed production (var Habru) on 30 ha cluster in West Belesa district, North Gondar zone, Amhara region (2016)

The project has strived to establish sustainable farmer-based seed production in the project target areas working with several primary farmer cooperatives and their umbrella organization farmer cooperative unions and group of farmer seed producers. This effort enabled the project to work with 14 farmer seed producer cooperatives, five farmer multi-purpose cooperatives, and four unions of cooperatives working on seed production and marketing with membership of 11,024 (13.8% female) farmers. Some of these cooperatives have been linked to farmer cooperatives unions, and in a limited number of cases to public seed enterprises. For example, six cooperatives working with the Debre Birhan Agricultural Research Center have established linkages with Wodera Multipurpose Union and Tegulet Seed Producers Union. Two seed producer cooperatives working with Debre Zeit Agricultural Research Center have established linkages with the Ethiopian Agricultural Business Corporation and Yerer Union. Two multipurpose cooperatives working with Sinana Agricultural Research Center have established linkages with Sofomar Union in Goba district.

Picture 5. Chickpea small seed packs for distribution by DZARC

Small seed-pack distribution: The project distributed small seed packs (Picture 5) for farmer-based seed production using seed producer cooperatives and seed producer groups through revolving seed schemes for scaling up/out of chickpea varieties. The small seed pack distributed handled in two ways (Bishaw and Molla, 2020): First, all farmers who receive the seed take the full responsibility to produce and market the seed directly through formal and informal channels based on demand from users. Second, all farmers pay back the quantity of seed provided to them in kind as revolving seed fund which can be used to produce quality seed for local distribution by district Office of Agriculture. The latter exercise termed as 'scaling' as it aimed at reaching more farmers with the seed of new chickpea variety. Farmers were supervised by district Offices of Agriculture and ARCs and linked to regional seed certification laboratories to produce and market quality seed of new chickpea varieties.

For on-farm seed production, about 524.1 tons of chickpea seed was provided to farmers through small seed-pack distribution (including basic seed production, and small seed packs/ revolving seed for certified and/or 'quality seed production), covering about 4,316.2 ha which directly benefited 15,508 farmers (23% female) who produced 9,391.9 tons certified/quality seed. Revolving seed contributed 29.9% of seed provided to farmers through small seed pack distribution.

Furthermore, 181.2 tons of seed disseminated through farmer-to-farmer seed exchange covered about 1,497.5 ha and produced 3,285.4 tons quality seed. Farmer-to-farmer seed exchange is important and much advocated by the project as a means of technology diffusion among smallholder farmers. Our experience during the project period shows that 6,282 farmers (9.6% female) directly benefited from farmer-to-farmer seed exchange. Farmers who were seed source for others on average gained 433 ETB per 100 kg seed compared to local grain price.

Farmer seed producers were linked to projects and formal sector institutions working in their area. For example, three universities, four cooperatives, five unions, ILRI-Africa RISING project, World Vision, Water Action project, Tropical Legume-III project, and Angolelana-Tera district agricultural development office purchased chickpea seed from project partner seed producer cooperatives and farmers in East and North Shewa Administrative Zones of central Ethiopia. This approach provided about 656 tons of chickpea seed for planting about 5,478 ha, directly benefiting 25,358 farmers (15% female) who could produce 14,557.1 tons quality seed. In summary, 11,291.7 ha of land was planted through farmer-based seed production scheme which directly benefited 47,148 farmers (15.8% female) who produced 27,234.4 tons of basic, certified and quality seed.

In 2016/17, the profitability analysis of chickpea seed production by the seed producer cooperatives was conducted by Adet and Debre Birhan ARCs and the analysis showed that seed production generated 44,664 ETB net income per hectare in Enemay district of northwest Ethiopia; and 2,828.09 ETB net income per hectare in Moretina-Jiru district of central Ethiopia, compared to grain production.

Biofertilizer distribution

Biofertilizers are important biological inputs which reduces the need for inorganic fertilizers thereby minimizing risks associated with environmental pollution while improving productivity of chickpea as well as subsequent cereal crops. Rhizobium inoculants are also important in wheat-chickpea cropping system for improving fertilizer use efficiency and wheat productivity with lower rates of fertilizer required. The project provided 20,329 packs of chickpea rhizobium inoculant (strain EAL-029) to partner research centers for further distribution to farmers in the project target areas for chickpea production. About 16,679 farmers (13.9% female) were directly benefited in applying rhizobium inoculants for chickpea production.

A total number of farmers who have applied improved chickpea technologies on 15,944.5 ha was 62,920 (15.2% female) without duplication where farmers who used improved variety and/or rhizobium inoculants counted once (improved variety + inoculant, improved variety or rhizobia).

Chickpea Variety Suitability Mapping for Scaling

The suitability map of chickpea varieties for further scaling up of technologies in non-project target areas will save resources and accelerate technology dissemination. One of the requirements in suitability analysis is identifying and determining the environmental requirements and limitations for various crops. The main factors considered in this land suitability analysis include climate layers (rainfall and temperature during the growing period and length of growing period), topography (Digital Elevation Models. i.e. altitude and slope data), soil types and soil properties (pH, depth, texture, and drainage).

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Land suitability maps for seven selected improved varieties of Kabuli (Arerti, Habru, Kasech and Yelbey) and Desi (Mastewal, Naatolii, and Teketay) chickpea types were developed (Figure 4). Despite limitations in availability of detailed data, the suitability maps could serve as a guide for prioritizing varieties to target locations to minimize or avoid the occurrence of negative responses. Land suitability areas of selected chickpea varieties are presented in Table 2. The working paper of these maps has been completed and published for sharing the information (Nigussie *et al*., 2019).

Early maturing chickpea varieties, such as Kasech and Yelbey, adapted to moisture-deficit areas have vast potential land area in the mid- to low-altitude areas that are yet to be fully exploited for chickpea production. Late maturing varieties like Arerti and Habru are more adapted to mid- to high- altitude areas. Interesting, Habru was observed performing well in the lowlands as low as 750 masl under irrigated condition of Afar Regional State, with grain yield as high as 2 tons ha^{-1}. Harbu may serve as a potential break crop in the double cropping system with cotton and wheat production in irrigated lowlands.

Generally, the land suitability map of chickpea varieties revealed that there are varietal choices to use in different agro-ecological niches and socio-economic needs: productivity, large seed size for export, disease resistance, earliness, adaptation to moisture deficit, and double cropping system (Table 2). Arerti and Habru are currently being widely grown improved varieties in Ethiopia for their export quality in terms of seed size and resistance to Ascochyta blight in terms of production.

Table 2. Area (ha) under different category of land suitability for chickpea varieties in Ethiopia

Varieties	*Key traits*	*Highly suitable (85-100%)*	*Moderately suitable (60-85%)*	*Marginally suitable (40-60%)*	*Not suitable (0-25%)*
Desi chickpea					
Mastewal	*Seed size- 240 g per 1000 seeds; grain yields-2.5 to 3.1 t ha^{-1}; tolerant to fusarium wilt; early maturing being used in double cropping system*	*671,104*	*25,515,252*	*3,991,328*	*82,840,536*
Naatolii	*Seed size -240 g per 1000 seeds; grain yields-2.5 to 3.6 t ha^{-1}; resistant to fusarium wilt*	*714,592*	*11,313,604*	*350,700*	*100,639,324*
Teketay	*Seed size-310 g per 1000 seeds; grain yields-1.8 to 4.4 t ha^{-1}*	*1,378,200*	*25,893,852*	*2,905,632*	*82,840,536*
Kabuli chickpea					
Arerti	*Seed size-257g per 1000 seeds, grain yields-1.6 to 5.2 t ha^{-1}; resistant to Ascochyta blight*	*2,287,616*	*26,387,416*	*924,428*	*83,418,760*
Habru	*Seed size-319 g per 1000 seeds; grain yields- 2.4 to 3.2 t ha^{-1}; moderately resistant to wilt; resistant to Ascochyta blight*	*1,293,476*	*26,565,352*	*1,723,964*	*83,435,428*
Kasech	*Seed size-275 g per 1000 seeds; grain yields- 2.0 to 2.5 t ha^{-1}; early maturing adapted to moisture deficit areas; resistant to Ascochyta blight*	*2,395,140*	*9,615,612*	*90,248*	*100,917,220*
Yelbey	*Seed size-355 g per 1000 seeds; grain yield- 1.8 to 2.3 t ha^{-1}; early maturing adapted to moisture deficit areas; resistant to root rot & wilt; resistant to Ascochyta blight*	*1,222,992*	*17,054,524*	*358,924*	*94,381,780*

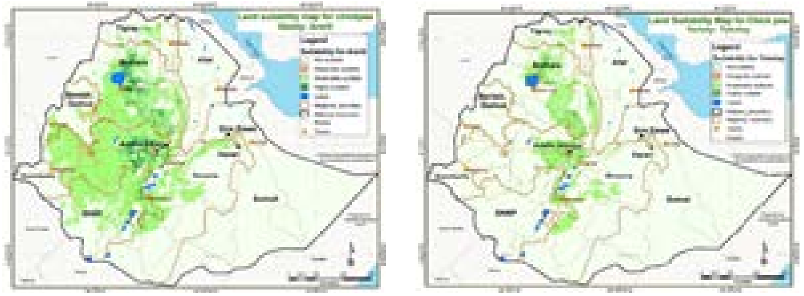

Figure 4: Land suitability map for Kabuli chickpea var. Arerti (left) and Desi chickpea var. Teketay (right)

Chickpea Seed System Study

The study of chickpea seed systems was conducted in 2016/2017 with the following objectives: (i) understanding the main characteristics of chickpea seed system with emphasis on the role of informal and formal seed sector, characterization of actors involved, and understanding of the seed value chain; (ii) characterize the overall performance of the seed system in terms of certified seed use, varietal coverage, demand-supply relations, adoptions and yield gaps; and (iii) characterize the seed commercial behavior of smallholder chickpea producers considering market and chickpea types (Kabuli vs desi).

The study conducted in Amhara and Oromia Regional States since 92% of the total area allocated for chickpea production in the country is found in these two regional states (52% in Amhara, and 40% in Oromia). A total of 18 districts and 36 kebeles were identified to have 612 households which were selected randomly. Summary of the results are presented below:

- Production and productivity trend of chickpea show that there is an increase in total production over the years (2004-2016) attributable to production area expansion and productivity increment.
- Of the total chickpea producers, about 57.5, 32.7, 9.8% are engaged in desi, Kabuli, and both chickpea types, respectively.
- Land allocation by chickpea producer farmers indicates that 0.8, 0.53 and 0.51 ha per household was allocated to both desi and kabuli chickpea, desi and Kabuli types, respectively.
- The national average yield (1.83 tons ha^{-1}) in 2016 was lower by 17.49% and 44.81% than the yield achieved on farmers' fields with improved variety and recommended practices, and at research stations, respectively.
- From the total chickpea producers, 43% were full adopters of improved chickpea varieties whereas 9.5% partial adopters and the rest 47.5% non-adopters. However, all Kabuli chickpea producers are full adopters of improved varieties since it is new introduction to the country, whereas the adoption rate of improved varieties of desi chickpea was only 16.8%.
- From the total chickpea producers, 47.5% used own saved seed whereas about 25% used purchased non-certified seed, and 19% used purchased certified seed. However, 42% of Kabuli chickpea producers use certified seed compared to only 8% of desi chickpea producers who use certified seed.

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- The commercial behavior of chickpea seed indicates that 55.4% of the farmers were autarkic where they did not engage in chickpea seed markets both as buyers or sellers, 22% used purchased seed, 11.4% sold seed, and 11.1% were engaged in chickpea seed market both as buyers and sellers which has implications on seed demand and supply.

Mechanization of Chickpea

Chickpea is usually planted by hand-broadcast method and the seed covered with oxen drawn implements, harvested by pulling the crop manually by hand particularly by female family or hired labor. DZARC and ICARDA, piloted machine planting and harvesting of chickpea in collaboration with Kulumsa ARC, Ethiopian Seed Enterprise and GIZ Farm Training Center in 2017 (Picture 6). Chickpea was machine planted at Gonde basic seed farm of ESE and Kulumsa ARC. Chickpea varieties Dhera (recently released Kabuli chickpea with higher yield and erect plant type suitable for mechanization) and Naatolii (desi chickpea with higher yield and early maturity than Kabuli types). The experience was found successful although some adjustments were suggested in terms of date of planting to avoid soil crusting due to high soil moisture.

Picture 6. Mechanical planting of chickpea at Gonde Basic Seed Farm: (i)desi chickpea var. Naatolii (left) and Kabuli chickpea var Dhera (right)

Picture 7. Mechanical harvesting of chickpea by Bale Green in Bale zone, Oromia region in 2019

Encouraged by the demonstration trials, the initiative subsequently demonstrated the viability of large-scale chickpea production systems, partnering with Bale Green, a private commercial farm, in two districts, Ginir and Goro in 2019/19 (Picture 7). A total of 269 farmers, including 30 female farmers, were given 22.5 tons of source seed – of the chickpea varieties Areti and Habru – and planted the seed on a 172 ha. Bale Green provided agricultural farm services - planting, spraying, and harvesting – and Dejen Gebremeskel Import and Export Company, provided inputs such as biofertilizers and agrochemicals, and sponsored field days to promote the varieties. External support was also provided: Fintrac provided training for farmers under the USAID 'Feed the Future-Ethiopia Value Chain' initiative. The Bale Zonal Bureau of Agriculture provided overall coordination.

Some 602 tons of chickpea were harvested in February 2019, yielding an average 3.5 tons ha^{-1}. The harvested crop was delivered to exporters at a negotiated price, providing an assured market for farmers. About 22.5 tons of the total production was set aside as part of a revolving seed scheme, increasing seed production for following year's cycle, facilitating dissemination, and expanding the cultivated area along with mechanization.

Strengthening Capacity of Human Resources and Facilities

Strengthening the capacity of technical staff of NARS and farmers, and provision of critical physical facilities are key to the success and sustainability of the project.

Knowledge and skill development: Training of trainers (ToT) of subject matter specialists (SMS) from agricultural research and district were carried out by ICARDA and ARCs to narrow the knowledge and skill gaps in chickpea value chain. The SMS organized hands-on practical training for development agents and farmers on various topics of chickpea production.

Young researchers and subject matter specialists: Short-term ToT courses were organized for researchers and subject matter specialists from partner organizations who in turn provided hands-on practical training for farmers and development agents. A total of eleven courses were organized (six by ICARDA and five by partner agricultural research centers) and trained 500 participants (11.2% female). Moreover, partner research centers also organized short-term courses for enhancing implementation of the project. Providing ToT was important since staff turnover within the project partner districts was high.

Farmers: Smallholder farmers should have adequate knowledge in management of weeds, diseases and insect pests which not only reduce yield but also reduce seed quality in the field and in storage. However, farmers have limited knowledge and skills in local seed business in project target areas. To bridge this gap, nine partner research centers and district agricultural development offices trained 9,706 farmers (16.9% female) and 1,811 staff of implementing partners and stakeholders (17.6% female) that included development agents, district extension experts, and junior researchers. A very high success was achieved since the district and kebele agricultural extension staff had organized training activities, apart from those organized by the respective partner research centers, to promote the dissemination of improved chickpea technologies. Trainings included both theoretical and practical sessions in the field. These trainings covered a broader range of topics including chickpea production technology (available technologies, agronomy, crop protection, bio-fertilizers, safe use of pesticides) and seed production technology (production, processing, storage, marketing, quality assurance,) and management (sustainability of local seed business, enterprise development and management).

Provision of critical facilities for research centers and seed producers: After identifying critical gaps of facilities required for NARS and seed producer cooperatives, efforts have been made to provide support during the project. Two twin-cab pickup trucks were provided to NARS that partnered in the faba bean-malt barley project. Lack of seed packing facilities is one of the problems facing partner research centers and cooperatives in quality seed distribution and marketing. Therefore, this project purchased 30 bag sealers and distributed to 13 partner research centers and 17 seed producer cooperatives that participated in the faba bean-malt barley project.

Project Coordination and Management

Monitoring, evaluation, and learning (MEL) is important component of this project with the aim of ensuring efficiency and effectiveness in implementing the project. Project's Steering Committee meetings, Annual Review and Planning meetings, monitoring field visits, Annual and Biannual reports, and indicator based FTFMS annual reports have been key monitoring and evaluation processes implemented in the project period (2015-2018). Consistency among data collection activities have been maintained through training workshops, annual review and planning meetings, monitoring field visits, and feedbacks on written reports. Field visits and meetings are presented below whereas indicator-based reports are covered in each output above.

Project Steering Committee (PSC) Meetings and Visits: The PSC members included the Crop Research Directors of the five implementing partner research institutes (ARARI, EIAR, OARI, SARI and TARI); representatives of seed enterprises (ESE, ASE, OSE and SSE); representatives from the USAID mission in Ethiopia and USAID Headquarters; and from ICARDA Headquarters and its Sub-Saharan Africa (SSA) Regional Program Office. The PSC meet regularly twice a year to monitor and evaluate the performance of the project, approve yearly work plans, and budget, and provide guidance to project technical staff for project implementation (Picture 8). The project technical staff composed of the principal investigator and project coordinator are responsible for running the day-to-day activities of the project and are supported by the thematic component leaders and the administrative staff from ICARDA. The PSC members also participate in annual planning meetings and made field visits to observe the progress of the project on the ground and interact with implementing partners and stakeholders and provide the necessary guidance.

Picture 8. PSC members, DBARC staff, extension staff and farmers visiting chickpea seed production and scaling activities in Moretina-Jiru district, North Shewa zone, Amhara region (2016)

Annual Review and Planning Meetings: Annual planning meetings were organized every year, where on average about 56 participants attended the planning and review meeting (Picture 9). The participant organizations included: 13 partner agricultural research centers from federal and regional research institutes; public and private seed enterprises; MoANR/BoAs; regional seed quarantine, inspection, and certification agencies; agriculture clustering and commercialization offices, input suppliers; ATA; ISSD; Syngenta and MeKamba agro-chemical companies; Menagesha Biotech Industry PLC, USAID; and ICARDA. The attendees actively participated in a plenary session of reviewing achievements followed by working group discussions to develop the plan of work and budget (PoWB) and completed

Picture 9. Annual review and planning meeting of the scaling projects

with a summary of presentation and discussion in a plenary session. These meetings were very helpful in bringing all value chain actors onboard, share responsibilities and spearhead implementation towards achieving the project's goal of improved livelihood and nutrition security of smallholder farmers.

The project team also participated in the Feed the Future and Global Development Laboratories Partners' Meeting organized by the USAID Mission in Addis Abeba on 23-24 February 2017 bringing together bi-lateral (mission managed) projects and research for development projects and have a strong focus on Ethiopia. The chickpea scaling project leaders participated in the meeting and presented the achievements of the project and the way forward. This meeting provided an opportunity to interact and exchange experience with various projects being funded and managed by USAID, opportunities, and challenges, and how to scale innovations and maximize impact. Similar consultation meetings were held where experiences were shared among USAID project implementing agencies during the project implementation phase.

The project team also participated in USAID-funded Feed the Future Innovation Lab for Climate-Resilient Chickpea Project annual meetings in 2016 in Izmir, Turkey (Picture 10), and 2017 at ICRISAT, Hyderabad, India. USAID Chickpea Scaling Project team members from ICARDA presented posters and oral presentations on the achievements. This annual meeting provided an opportunity to interact and exchange experience with various projects being funded and managed by USAID, opportunities and challenges, and how to scale innovations and maximize impact for improving the livelihood of smallholder farmers.

Picture 10. Chickpea Innovation Lab Annual meeting, Izmir, Turkey

Monitoring, evaluation, and learning (MEL) field visits: The ICARDA project team made regular MEL field visits to assess the progress of the project, provide technical support and document the achievements. The field visits are made to chickpea grain and seed production during growing periods, harvesting and post-harvesting operations. The team had discussion with implementing partners, farmers and development agencies to review the progress, achievements, and challenges in project implementation. These MEL field visits helped in collecting important data, feedbacks and cross-learning experiences brought up to annual review and planning meetings, steering committee meetings, and training workshops for having common understanding and improve effectiveness in implementing the project.

ICARDA project team and staff of USAID Mission in Ethiopia visited the activities of chickpea project in Aleletu implemented in partnership with DZARC and in Basona-Worana, Siyadebrina-Wayu, Moretina-Jiru and Ensaro districts implemented with DBARC (Picture 11). Similar field visits were made to activities of chickpea implemented by DZARC and observed chickpea seed production of Arerti, Ejeri, Habru, Minjar and Naatolii varieties by Kolbie and Denkaka-Megertu seed producer cooperatives in Liben and Ada districts (Picture 12). The

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mission visited chickpea seed production fields and interacted with farmers, researchers, district administrators, development agents and extension staff who appreciated the on-going activities and ICARDA's support through the project. The team from USAID mission also appreciated the ongoing work and the linkage with the national programs in scaling out chickpea technologies.

Picture 11. Field visits of chickpea seed production (var Habru) in Moretina-Jiru district

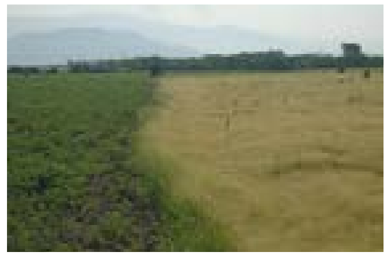
Picture 12. Field visits of chickpea seed production (var Arerti) in Ada'a district

The ICARDA project team also visited project actvities in difernet parts of the country. Some of the notable observations during the MEL are as presented below:

- In East Gojam Zone barley-chickpea double cropping in Enemay (8808-10,000 ha) and Shebel-Berenta (1361-4500 ha) districts was found to be a common practice depending (Picture 13). Farmers' demand for improved chickpea technologies is high in all visited districts. Both partner research centers, Adet and Debre Zeit, should make concerted effort to make improved chickpea technologies available and accessible to these innovative smallholder farmers.

Picture 13. Chickpea production in Shebel Berenta district, East Gojam zone, Amhara region

- In North Wollo Zone, a huge potential was observed for introducing irrigated chickpea production in the triple production system of vegetables, cereals, and pulses under Kobo-Girana irrigation project in Kobo plain (Picture 14) where about 3680 ha was already developed for irrigation. In picture 14 a chickpea crop planted in August after onion harvest (on the left) and tef crop planted after onion harvest (on the right) in Kobo plain (1486±3.2 masl and 12o07.912'N and 39o37.678'E). Scaling of improved chickpea technologies including Habru variety initiated by Sirinaka ARC and supported by the project showed a great promise for improving the livelihood of smallholder farmers and



Picture 14. Chickpea production (left) in Kobo-Girana irrigation, North Wollo zone, Amhara, region

sustainability of the production system. The cooperatives are very much interested to produce chickpea as a break crop in the triple cropping system provided that reliable market linkage is created.

- In Afar region, the project team visited irrigated chickpea seed production at Werer ARC (736±3.4 masl and 9o20.389'N and 40o10.528'E) in collaboration with DZARC (Picture 15). The chickpea seed production (var Habru) field was sown during the first week of December and expected to yield about 2 tons ha^{-1}. However, the productivity could be improved if sowing is done during early October to November when the temperature is relatively cooler than in the succeeding months. The initiative demonstrated the opportunity for expansion of chickpea into new frontiers for irrigated production in the lowlands where it can also serve as a break crop in double cropping system of irrigated wheat and cotton production in the lowlands of Afar Regional State and similar agro-ecologies. Farmers appreciated the chickpea demonstration as source of feed for livestock and minimum management for production.

Picture 15. Irrigated chickpea seed production (var. Habru) at MARC, Afar region

- The visit to demonstration of machine planting of chickpea in Gondie basic seed farm of the Ethiopian Seed Enterprise (ESE), Kulumsa Agricultural Research Center (KARC) and GIZ Farmer Training Center showed the potential for chickpea mechanization (see Picture 6). Early planting of chickpea in late July as opposed to the old late planting in late August to September improved crop growth which was expected to yield up to 4-5 t ha^{-1} under improved management by Kolbie and Denkaka-Megertu seed producer cooperatives around Debre Zeit.

Success Stories

- **Adoption of early planting of chickpea to mitigate late drought and climate variability:** Farmers in Ethiopian highlands generally accustomed to plant chickpea late in September towards the end of the main season when the rainfall ceases. This practice is more common in waterlogged Vertisols because Ascochyta blight would devastate early planted chickpea.
  - Demonstrations and scaling up/out early planting (July to late August) of Ascochyta resistant Arerti and Habru varieties brought dramatic increase in area and productivity (up to three-fold) increases in drought prone areas of Tigray, West and East Belesa districts in North Gondar, and Kersamalima district in Southwest Shewa, compared to late planting (late August to late September).
  - Demonstration and scaling-up/out of broad bed and furrow soil drainage and Ascochyta blight resistant varieties for early planting in late August increased yield and production area as compared to late September planting characterized by very low yield In Ensaro district (at 2600-2750 masl) in North Shewa, where waterlogging was severe on Vertisols.

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- **Building sustainable decentralized seed supply through mobilization of farmers:** Collaboration with district Office of Agricultural Development, farmers' cooperatives and unions enabled decentralized on-farm quality seed production and certification. However, these activities need concerted effort and further support and to strengthen the linkages among stakeholders in the chickpea seed value chains to ensure sustainability.
- **Farmer-to-farmer seed exchange:** This is important and much advocated by the project as a means of technology diffusion among smallholder farmers. Even though not fully tracked by partner research centers and agricultural extension development agents in each target district, our experience during the project period shows that 6,282 farmers obtained 181.2 tons of chickpea seed through farmer-to-farmer seed exchange for planting 1,497.5 ha of land. Farmers who served as source of seed for exchange gained extra 433 ETB per 100 kg seed on average as compared to local grain price.
- **Mechanization of chickpea production:** Large-scale mechanical planting and harvesting of chickpea has been demonstrated providing an opportunity to introduce and expand chickpea as a break crop in areas where wheat mono-cropping dominates. Farmers are accustomed to mechanization of wheat production and are reluctant to introduce legume production in the rotation. Mechanization of chickpea in addition to providing opportunities for crop diversification also reduces drudgery of female labor where they harvest chickpea by hand pulling of the crop in traditional production system.
- **Introduction of chickpea to lowland areas:** Chickpea adaptation trials in the lowlands identified heat-tolerant improved varieties that provides an opportunity for chickpea area expansion under irrigated condition where it could serve as a break crop in double cropping system of irrigated wheat and cotton production (for example in Afar Regional State). Moreover, there is a huge potential for introducing chickpea in the triple production system of vegetables, cereals and pulses under Kobo-Girana irrigation project in Kobo plain, in Amhara Regional State.
- **Partnership established with district offices of agriculture and administration at local level and key public and private sector stakeholders at federal and regional states:** The commitment and ownership of the project activities from local administration to federal offices was unprecedented. This would bring about lasting changes in raising agricultural production while maintaining environmental sustainability and improving the livelihoods of smallholder farmers.

Lessons Learned and Way Forward

- Early planting dates particularly in drought prone or moisture deficit lowland areas showed better yields. Such practice of early planting is already reported from West Belessa district and should be promoted in other similar areas.
- Farmers in Ensaro district adopted early planting on broad bed and furrows by draining excess water to improve chickpea productivity and production. Such innovative approach should be upscaled to increase chickpea productivity and make it competitive with cereals and expansion of the crop in other Vertisol areas.
- Mechanization of chickpea for planting and harvesting was demonstrated on a large-

scale and showing great promise. Development and deployment of erect type chickpea varieties and provision of mechanization services need to be strengthened to expand chickpea production as a break crop in pre-dominantly wheat mono-cropping areas.

- Concerted efforts should be made to promote and popularize the use of bio-fertilizers along other complimentary inputs.
- Variety suitability mapping of chickpea enables expansion of chickpea production in non-traditional areas. Moreover, development of niche varieties suitable to diverse agro-ecologies and farming systems are required since breeding for developing resilient variety across variable environments depresses potential productivity. This approach goes with ensuring decentralized farmer-based seed production scheme;
- Decentralized seed production through seed producer cooperatives and farmers groups, and farmer-to-farmer seed exchange scheme ensured availability of, access to and use of seed technologies compared to the formal public or private seed sector. Policy reforms should continue to recognize and promote the diversity of seed business models (formal, intermediate, and informal) and diversity of seed certification schemes (certified seed and QDS) for ensuring sustainable chickpea seed system. Moreover, strengthening capacity of quality control and quarantine services is also important investment to ensure timely seed quality control and certification;
- Regardless of the innovative approach of decentralizing early generation seed production by NARS, breeder and pre-basic seed production it is still a challenge since research centers have no sufficient land for this purpose. This needs policy level decision since most research centers remain the sole source of EGS;
- Among pulses chickpea is the second, next to common bean, in export volume and foreign currency earnings. Developing a functional chickpea value chain, generating market preferred chickpea varieties and provision of incentives to both seed and grain producers and exporters may require forging an effective public-private partnership to ensure competitiveness and sustainability of the sector.

Conclusion and Recommendations

The project aimed at expanding chickpea production to meet the demand from the domestic and export markets. Development of an agricultural technology should be accompanied by a deployment strategy to bring about tangible changes on the production systems and livelihoods of farmers. The project demonstrated the scaling frameworks and catalyzed the partnership platform to transform chickpea production in Ethiopia. It is expected that research for development partners and stakeholders take this forward.

Demonstrations of improved chickpea varieties and integrated crop management technologies proved successful in raising productivity and increasing production in target project areas, but the partial adoption of the full package of improved technologies by smallholder farmers remains an outstanding and persistent reason for a significant yield gap in the farmers' fields. Concerted efforts should be made in making available and use the full production technology packages to realize the potential productivity and production.

Early planting of chickpea in drought prone moisture deficit areas and draining waterlogged Vertisols using broad bed and furrow demonstrated increased productivity and production

compared to chickpea production on residual moisture and flat seed bed. Such useful practices need to be demonstrated and scaled up in similar areas across the country.

Introducing chickpea to irrigated lowlands would enable cotton-wheat rotations whereas mechanization of chickpea would enable to overcome wheat mono-cropping in rainfed highland areas. The former brings chickpea to new frontiers and is well aligned with government strategy of irrigated wheat production for wheat self-sufficiency

EGS production by NARS and certified seed production by public and private seed sector remain a critical challenge that currently limits the adoption of improved chickpea varieties. Adequate planning of EGS with RARIs including decentralization to overcome the chronic problem of source seed and strengthening and consolidating decentralized seed production with SPCs will make the chickpea seed sector in a sustainable footing.

Strengthening capacity and linkage among actors in chickpea value chain is essential to maintain quality standards and competitiveness in the international markets. This needs further effort to strengthen capacity, create linkage among actors, bulk production and aggregation, and marketing of chickpea.

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Analysis of Chickpea Farming System and Farmers' Livelihoods in North Shewa Zone

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Introduction

Legumes in general occupied about 13% of cultivated land and their contribution to agricultural value addition is around 10% (Ronner *et al*., 2012). In Ethiopia, chickpea is the third pulse crop next to faba bean and haricot bean in area coverage and volume of production (CSA, 2016); it is the most important pulse crop in Vertisols areas (Asamenew *et al*., 1993).

Chickpea is one of the major legume crops grown by in the highlands of North Shewa zone of Amhara Regional State. It is grown for market, home consumption and crop rotation, but in smaller proportions in terms of farm area coverage. Lack of access to improved technologies and production challenges of diseases, pests and waterlogging limited its expansion. Chickpea is planted on residual moisture later in the season after planting all other crops.

Chickpea productivity in Ethiopia increased from 1.3 to 1.9 t ha^{-1} due to the introduction of new technologies with the highest yield gain reported from among 10 producing countries in the world (Foyer *et al*., 2016). Minale *et al*. (2009) also reported steady increase in both area coverage and production of chickpea from 1995 to 2008 in Ethiopia. Amhara and Oromia are the major chickpea producing regions accounting for more than 90% of area and about 92% of production. North Shewa is one of the major chickpeas producing zones in the Amhara region.

Pulses are the third-largest export crops of Ethiopia after coffee and sesame, contributing USD 90 million to export earnings in 2007/08 (IFPRI, 2010b), thus, have important economic contribution to the economy of Ethiopia (Atnaf *et al*., 2015). Chickpea is the second most exported commodity next to haricot bean; and Ethiopia exported 48,739 tons of chickpea and received 22.56 million USD (FAO, 2014). However, over 80% of the total chickpea production is traded in the domestic market using various market outlets (Bekele *et al*., 2007).

The overall objectives of our study were to get deeper understanding of farmers by characterizing and assessing the farming system and status of chickpea production in the highlands of North Shewa Zone. The study focused on production potentials and livelihood impacts of chickpea producer farmers; the status of introduced improved chickpea varieties; and identifying factors affecting adoption of improved chickpea technologies.

Methodology

Study area

The study was conducted in Ensaro district characterized a teff- wheat based production system, where chickpea, lentil, faba bean and grass pea are potential crops. The relative physical position of Ensaro district in Amhara region is indicated in Figure 1.

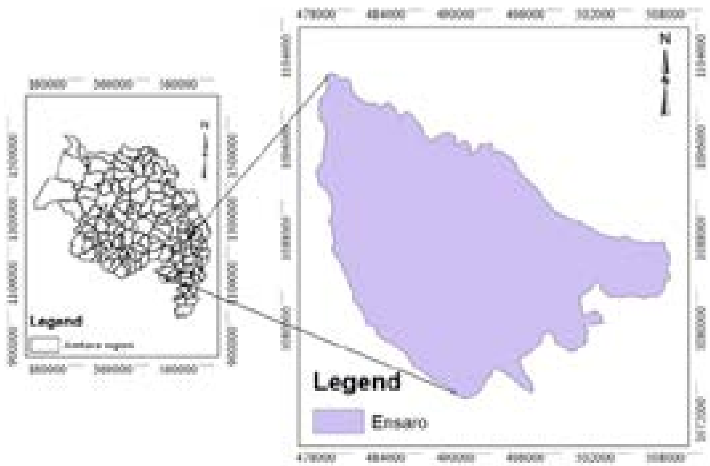

Figure 1. Maps indicating the relative physical position of Ensaro district in Amhara Regional State

Sampling procedure

The study district was purposively selected based on the potential for chickpea production and introduction of new production technologies. Four chickpea producer kebeles (2 targeted and 2-non-targeted kebele) were selected systematically. Finally, 230 representative sample household farmers were randomly selected based on probability of proportional sampling technique.

Data collection and analysis

Both primary and secondary data from published and unpublished documents were collected. Qualitative and quantitative data were obtained through focus group discussions, key informant interview, and household surveys. The primary data were collected using appropriate data collection questionnaires. The primary data pertained to land holding, livestock holding, income, crop yield, social networks, seed sources, inputs use for chickpea production, extension contacts, participation in extension events, and chickpea production constraints and challenges.

Descriptive and inferential statistics like frequency, mean, and percentage were used to characterize the farming system. The adoption of new technologies evaluated to identify the status of introduced technologies through intervention. The level of adoption and introduction of new technologies was expected to be low level and at early stage. The collected data also indicated that the level of adoption was not symmetric in the [0, 1] interval as well. There were imbalance observations of technology adopters and non-adopters. In this situation, the complementary log-log model might give a solution to evaluate the level of adoption of improved chickpea technologies. Hence, instead of logit and probit models, complementary log-log (CLOG_LOG) method was employed to evaluate the adoption status and identify factors that affected the adoption of introduced chickpea technologies.

Model specifications

In many research activities, interest was directed at the effects of the explanatory variables X1. . ., Xk and observed dependent variate Y. A commonly employed model in these settings relates the mean response E(Y) and the explanatory variables in a linear fashion: E(Y) =η= $\beta_0 + \beta_I X_1 + \ldots + \beta_K X_K$, when the dependent variate is dichotomous.

E(Y) is simply the probability of response p. The associated linear models can be generalized to:

$$g\{E(Y)\}=g(p)=\beta_0+\beta_1 X_1 + \ldots + \beta_k X_k \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Alternatively, g (p) = η, for some function g (‘). Since it links the random and systematic components of the linear model, “g” is known as the link function (McCullagh and Nelder, 1989). As Duffy and Santer (1989), the commonly seen link functions in this setting are the logit, g(p)=log{p/(1-p)}, the probit, g(p)= I-1(p); and the complementary log-log, g(p)=log{-log(1-p)}. All three share the feature that they map the unit interval onto the real line. The logit link also shares theoretical connections with the natural parameter for the binomial model, 0=log {p/ (1-p)} and provides a useful interpretation in certain applications as the log odds of success (Cox 1970, sec. 2.3). Its use in logistic regression has become quite popular in recent years (Duffy and Santner, 1989). The three link functions may be inappropriate, however, for certain experimental applications. In some of these cases, a useful alternative link is the complementary:

$$\log g(p) = -\log(1-p), \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

in which it maps the unit interval into the positive real line.

Notice that the inverse function is p = 1 – exp (- η) for η> 0. For η≤ 0, one could define the inverse link as simply p = 0, so that the inverse function is continuous and non-decreasing, ∀η. Thus, the inverse link can be viewed as a form of distribution function, corresponding to an exponential random variable with unit mean. This connection between inverse links and distribution functions is common in binary regression models (Duffy and Santner, 1989): The inverse probit clearly corresponds to a standard normal distribution, while the inverse logit corresponds to a standard logistic distribution with density function ex/ (l+ex) 2 (Hastings and Peacock, 1975). The complementary log link has been applied in a wide variety of experimental settings. Under the assumption of binary response, there are two alternatives to logit model such as probit model and complementary-log-log models.

They all follow the same form

$$\pi(x) = \Phi(\alpha + \beta x) \quad \ldots\ldots\ldots\ldots\ldots\ldots (3) \text{ for a continuous cdf } \Phi$$

Complementary log-log model says

$$(\log\{-\log[1-\pi(x)]\} = X^{T}_{pxn}\beta_{px1} \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

The expression on the left-hand side is called complementary log-Log transformation. Like the logit and the probit transformation, the complementary log-log transformation takes a response restricted to the (0, 1) interval and converts it into something in (-∞ +∞) interval. Here, we need to mention that the log of 1- (x) π is always a negative number. This is changed

to a positive number before taking the log for the second time. The model can also be written as

$$\pi(x) = 1-\exp[-\exp(X^{T}pxnX^{T}_{pxn}\ \beta^{T}_{px1})] \quad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Results and Discussion

Demographic characteristics and economic activities

The family size in the study areas varied among households with the average family size of 5.2 at a minimum of 1 and maximum 10 per household. The average age of respondents was 47.6 years with minimum of 20 and maximum of 67 years. The sex category of the study indicated that about 90% of the respondents were male and the balance was female. Household heads and their family members participated in off-farm and on-farm business activities. More male farmers participated in on-farm activities while higher proportions of female farmers participated in off-farm activities.

Major crops grown in the study area

The major legume crops grown in the area were chickpea, grass pea, and faba bean and accounted as the third and fifth major crops grown next to teff and wheat, which are the primary and secondary crops, respectively. About 56% of the respondents produce chickpea in the study area where both desi and Kabuli type varieties are grown in the study area (Figure 2).

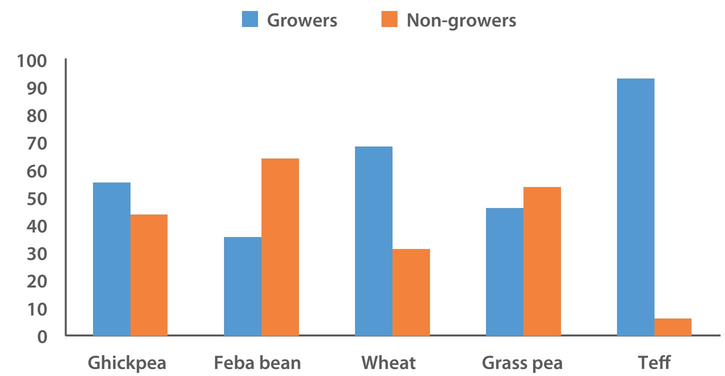

Figure 2. Major crops grown by sampled farmers in the study area (%)

Market proximity for access to services

The market of agricultural inputs such as seed, chemical fertilizer, and agrochemicals found in various distances from the residence of farmers in the kebeles. It is available nearly in their residence in Dembie next to Salayish kebele while it is relatively far for Diremu kebele (Figure 3).

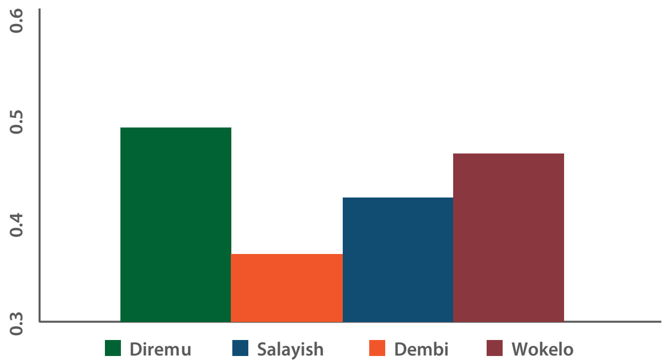

Figure 3. Average distance in walking hours from farmers' residence to input markets

The distance of farmers residence to where economic and social institutions were located was relatively far. It may require a maximum of three hours walking distance to the main market and health services which is located at the district town. It is about one hour to thirty minutes walking distance for accessing the agricultural inputs such as seed, fertilizer, and agrochemicals. It is also one to half hour walking distance for farmers training center (FTC) and the school (Table 1).

Table 1. Distance of farmers' residences in walking hours from local institutions

Local institutions	Mean walking distance (minutes)	STD.	Min	Max
Village market	20	30	0	180
Main market and district town	80	45	0	180
Inputs source	25	25	0	90
Farmers' cooperative and FTCs	25	23	0	90
Office of Agriculture	2	0.25	0	25
Health service center	45	35	0	180
Primary school	20	30	0	90

Social capital and networks

Most farmers voluntarily participate in different socio-economic local networks or institutions (Table 2). Majority (90%) of farmers are members of multipurpose cooperative and interested to continue their memberships and participation. The social groups facilitate members access to input and output markets.

Table 2. Social groups established and membership

Social groups	Membership			Membership continuation		
	Participation	Frequency	%	Participation	Frequency	%
Agricultural marketing cooperative	Participant	43	18.7	Yes	43	100
	Non-participant	187	81.30	No	-	-
	Total	230	100	Total	43	100
Women association	Participant	41	17.8	Yes	36	87.8
	Non-participant	189	82.2	No	5	12.2
	Total	230	100	Total	41	100
Saving and credit cooperatives	Participant	92	40	Yes	84	91.3
	Non-participant	138	60	No	8	8.7
	Total	230	100	Total	92	100
Multipurpose cooperatives	Participant	215	93.5	Yes	214	99.57
	Non-participant	15	6.5	No	1	0.43
	Total	230	100	Total	215	100

Household assets

The average total livestock holding of households was 3.2 in Tropical Livestock Unit (TLU) that competes with land share of crop production since farmers allocate grazing land for livestock. Average land holding per household varied in research intervention and non-intervention areas. The average per capita land holding is below half hectare in the study areas (Table 3).

Table 3. The average land holdings size in the study areas

Kebele	Land holding in ha	Land owned in ha per adult equivalent	Land owned in ha per capita
Diremu *	2.37	0.56	0.5
Dembi *	2.21	0.5	0.45
Salayish**	1.36	0.28	0.25
Wokelo**	2.21	0.63	0.54
Average	2.04	0.5	0.43

*Note: * and ** are target and control kebeles, respectively*

From the total land owned by the smallholder farmers over 85% of the farmland was cultivated land in the study area. This indicated crop production is the main economic sector in which the smallholder farmers rely on. The information obtained from the sampled farmers during the study indicated that farmers in chickpea promotion target areas allocated more land for chickpea production compared to non-target areas (Figure 4).

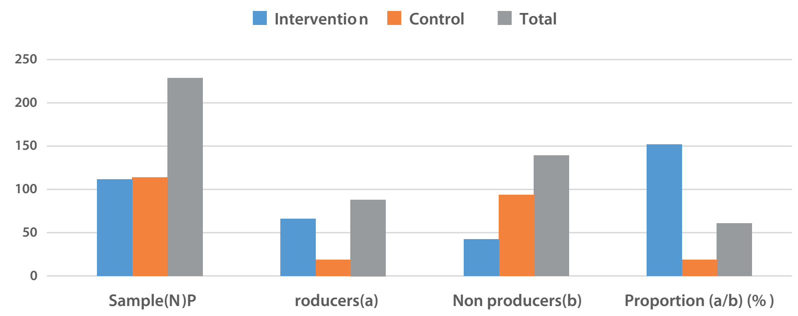

Figure 4. Comparisons of chickpea producer farmers in intervention and control areas

Human labor days requirement

Human labor days required for crop production varied by the study areas and estimated below 200 days per year per land holding of each household. Irrespective of sex differences, the highest human labor days requirement per annum per land holding of each household was the highest in one of the target areas while it was the lowest in one of the control areas. Females contributed a smaller number of crop labor days compared to their counterparts (Figure 5). The average oxen days required for ploughing and threshing was below 30 days per annum per landholding of each household. The required amount of oxen days depends on the size of farmlands owned by the rural households. Farmers keep oxen for a year to work on limited number of agricultural operations of 30 oxen days per annum per landholding of a household.

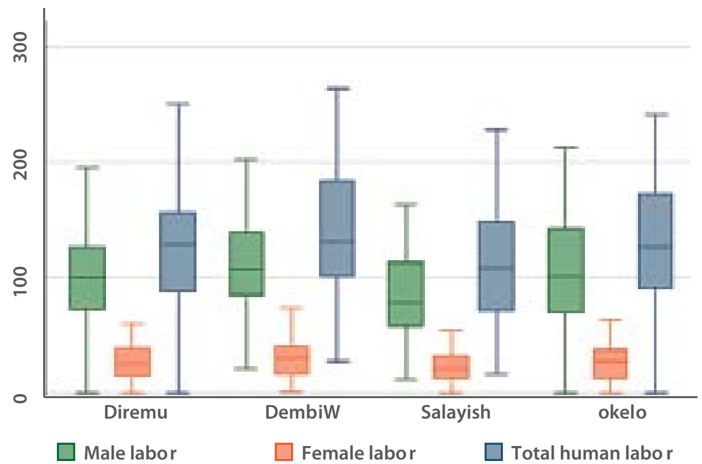

Figure 5. Average crop labor days required for crop production per annum per landholding of each household in target kebeles

Sources of initial seeds and adoption levels

Chickpea growing farmers initially adopted improved Kabuli chickpea than desi types, but continuous adoptions declined in Kabuli than in desi types (Table 4). Adopters of chickpea producer farmers were interested continue to adopt desi chickpea because of local market influences. Consumers in the local market preferred desi type chickpea than Kabuli type.

Table 4. Adoption of improved chickpea varieties by producer farmers

Chickpea types	*Response*	*Initial adopters*		*Continuous adoption*	
		Adopters	*Non-adopters*	*Adopters*	*Non-adopters*
Kabuli chickpea	*Frequency*	*20*	*81*	*9*	*11*
	Per cent	*19.6*	*80.4*	*45*	*55*
Desi chickpea	*Frequency*	*17*	*84*	*12*	*5*
	Per cent	*16.8*	*83.2*	*75*	*25*

The main initial seed sources for Kabuli chickpea were offices of agriculture and neighboring farmers through extension linkages with seed enterprises and seed producer farmers through local seed markets and exchanges (Figure 6). The main initial source of seed for improved desi chickpea was DBARC through demonstration and pre-scaling up interventions (Figure 6).

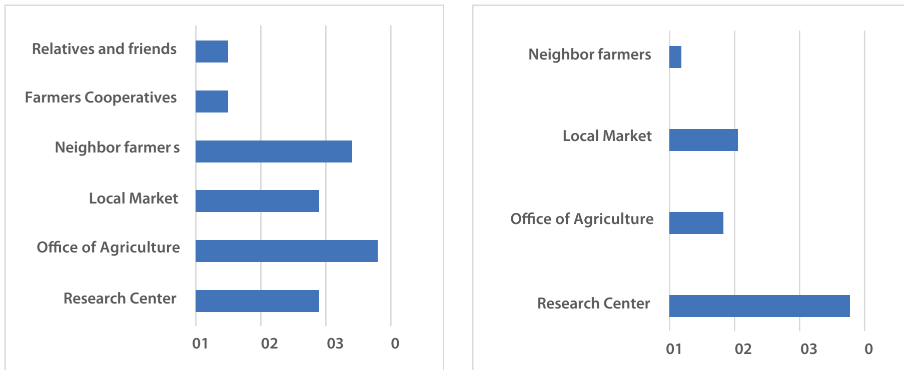

Figure 6. Seed sources (%) of improved Kabuli (left) and desi (right) chickpea varieties

Chickpea varieties under production

Table 5 indicates that most repeatedly reported improved chickpea varieties under production in the study areas were Arerti (Kabuli type) and Mastewal (desi type). However, most farmers grew local chickpea varieties due to easy access of local seed and limited seed supply of improved varieties.

Table 5. Number of respondent farmers growing chickpea varieties in the study areas

Kebele	Arerti	Naatolii	Mastewal	Local	Unknown	Total
Diremu	0	1	8	18	0	27
Dembi	10	1	2	11	2	26
Salayish	1	0	0	3	0	4
Wokelo	1	0	0	6	0	7
Total	12	2	10	38	2	64

Chickpea productivity

The estimated productivity of chickpea during the study was 1,200 kg ha^{-1}. Productivities were higher in intervention areas than non-intervention controls (Figure 7). Farmers' awareness and orientation on improved chickpea production practices varied in the study areas. Poor management of Vertisols, late planting, disease and insect pest infestations contributed to low productivity.

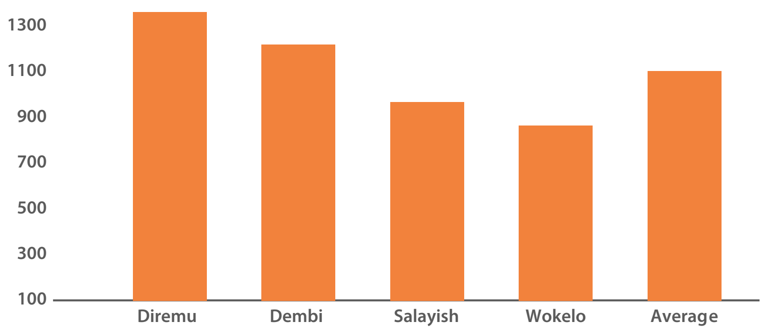

Figure 7. Productivity of chickpea (kg ha^{-1}) in study areas

Food insecurity and its causes

Some of the households faced food shortage over the period of 12 months during the study time. The problem was higher in control areas compared to the intervention areas (Figure 8). This was because of low-level production (Figure 9), and low productivity of chickpea (Figure 7).

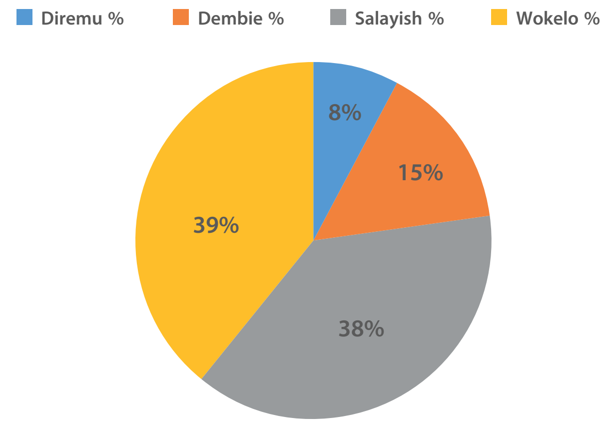

Figure 8. Household food insecurity (%) in the study areas

Poor harvest trends and land shortage of the households contributed to critical food shortage. Poor harvesting time contributed to wastage, , over drying, untimely rainfall, and field pests and damages attributable to animals. Limited access to land caused limited production of the required amount and type of grain for food self-sufficiency (Figure 9).

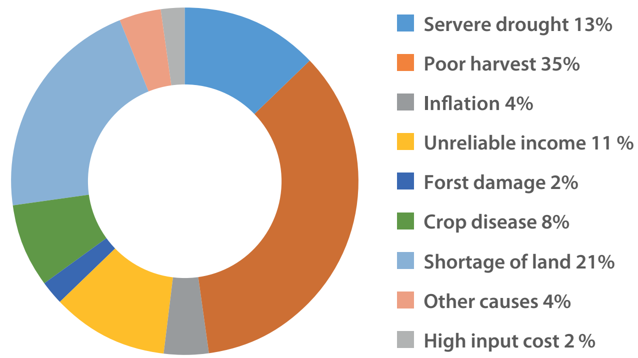

Figure 9. Major causes of food shortages/insecurities

Impacts of improved chickpea technologies

Impacts on farmer's welfare: Figure 10 shows that farmers in the intervention areas (Diremu and Dembi kebeles) generated more gross margins than those in the control areas (Salayish and Wokelo kebeles). High gross margins in interventions areas were due to high productivity and high market price of the improved varieties.

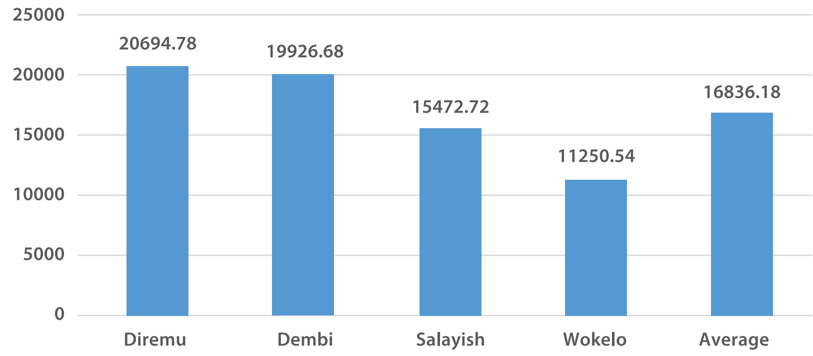

Figure 10. Gross margins (ETB ha^{-1}) of chickpea in the study areas

Impact on farmers' income: Intervention areas generated higher amount of cash per hectare of farmland in chickpea production compared to others (Figure 10). This is because of high productivity of chickpea of improved varieties intervention. Household average monthly income and expenditure indicates that high monthly income was obtained in intervention areas without affecting the expenditures (Table 11). This resulted from high gross margins generated from chickpea production.

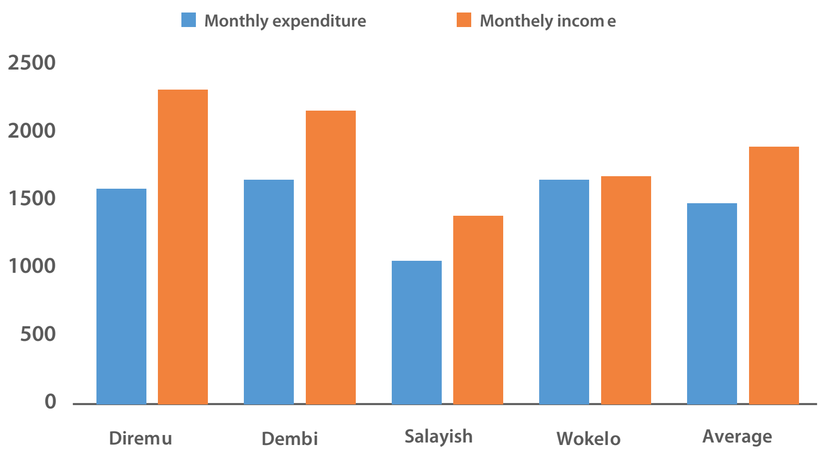

Figure 11. Monthly income and expenditure (ETB) per household in each kebele

II CHICKPEA: Chapter 1: Overview of Achievements and Baseline Survey

Regression analysis

The major socioeconomic and institutional factors that affected the allocation of land resources to produce improved chickpea varieties showed various levels of significance (Table 6). These include main market distance, extension contacts, and access to training on chickpea production. The main market distance affected the adoption of chickpea technologies negatively and significantly, while number of extension contacts and access to training affected the continuous adoption of improved chickpea technologies positively and significantly.

Table 6. Factors affecting continuous adoption of improved chickpea technologies

Variables	Coefficient.	t	P value
Age	-0.04	-0.2	0.84
Sex	-0.32	-0.34	0.70
Family size	0.1	0.80	0.43
Adult literacy ratio	0.01	1.24	0.22
Main market	-1.50***	-3.26	0.001
Distance from agricultural office	3.53	0.62	0.532
Distance from seed source	-0.32	-0.38	0.707
Frequency of extension contacts	0.03***	2.35	0.019
Training access	0.32***	2.57	0.010
Field day participation	-0.13*	-1.89	0.058
Constant	-2.46*	-1.83	0.067

Conclusions and Recommendations

Chickpea is the third major crop grown in terms of area coverage next to wheat and teff. Neighbor farmers, research centers, and offices of agriculture are the main seed sources of improved varieties of chickpea. The intervention areas showed good status in food security, farm income, chickpea productivity, and monthly income compared to the controls. This indicated that the research intervention played an important role to convince the farmers in allocating land resources for chickpea production. Many of the farmers who adopt new technologies were convinced to continue production of improved chickpea varieties particularly desi type chickpea. Market distance, access to training and frequency of extension contact were the main factors significantly influencing the allocation of farmland to the improved chickpea varieties and adoption of improved production technologies.

Facilitating farmer-to-farmer seed exchange will improve the production and productivity of chickpea. Increasing the number of extension contacts and access to training for the rural households will help to improve the awareness of farmers for the adoption of improved agricultural technologies. The aggregation of agricultural produce through organizing the farmers helps to improve the market participation of chickpea producer farmers and improves the adoption rate of chickpea. This will further improve household income of chickpea producer farmers. Provision of new technologies through the existing farmers' institutions and extension system enhances the adoption rate of similar technologies.

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CHAPTER 2

CHICKPEA TECHNOLOGY VALIDATION AND DEMONSTRATION

Participatory On-farm Evaluation and Demonstration of Improved Chickpea Technologies in East Gojam Zone

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Adet Agricultural Research Center (AdARC) conducted chickpea adaptation trials and recommended that the improved varieties Arerti, Teketay and Ejeri to be evaluated by and demonstrated to farmers. Enemay is one of the most potential districts in chickpea production in Amhara region. This activity was implemented in two kebeles, namely Bichena-Debir and Mankorkoya. The objectives of the study were to: i) introduce choices of available improved chickpea technologies to farmers, and ii) assess farmers' technology preferences and enhance demand-driven technology dissemination.

Materials and Methods

Description of the study areas

Participatory evaluation and demonstration of improved chickpea technologies was carried out at Bichena-Debir and Mankorkoya kebeles of Enemay district, East Gojam zone. Enemay district lies in altitudes from 1600 to 3600 masl. Annual rainfall ranges from 900 to 1150 mm with an average annual temperature of 21OC. From the total area of the district, 75% of land is Vertisols. The major crops grown in the district are tef, barley, wheat, maize, sorghum, chickpea, grass pea, faba bean and field pea (EWOA, 2016). Our demonstrations were conducted on mid-altitude areas on Vertisols. Additional descriptions of the testing sites are presented in Table 1.

Table 1. Description of two testing locations (kebeles)

Attributes	Mankorkoya	Bichena-Debir
Altitude (masl)	2438	2483
Agro-ecology		
o Woinadega (%)	100	95
o Kolla (%)	-	5
Topography (%)		
o Plain	85	60
o Rugged	15	10
o Mountain	-	30
Soil color		
o Black	95	50
o Red	5	50
Total population	4011 (2001 females)	2901 (1480 females)
Total area (ha)	-	1619
Major crops	Teff, chickpea, barley, wheat, grass pea & maize	Teff, wheat, barley, chickpea, & grass pea

Note: Woinadega and kola are equivalent to mid-highland and lowland, respectively

The evaluation and demonstration activities were conducted on three farmers' fields in 2017/18 cropping season. Demonstration sites (host trial farmers) were selected in close collaboration and discussion with agricultural extension agents and farmers.

Research design

Three improved chickpea varieties, namely Arerti, Ejeri, and Teketay were compared with farmers' local variety in all locations. Single plot observation (farmers as replication) was used. The plot size of the evaluation and demonstration plot was 100 m^2 for each variety. Seed rate of 125 kg ha^{-1} with fertilizer rate of 121 kg ha^{-1} NPS (Nitrogen, Phosphorous and Sulphur) were applied on the demonstrations plots. All NPS fertilizer was applied during planting. Row planting with a spacing of 30 cm and 10 cm between rows and plants, respectively, was used. All the varieties were treated equally with the recommended agronomic practices. Demonstration plots were planted on 13-18 September 2017 with the collaboration of kebele development agents; harvesting was done in January 2018.

Research-extension approach

Participatory agricultural research approach was followed in implementing the evaluation and demonstration activity. Farmers Research Extension Groups (FREGs) were established and used to enhance farmers' capacity in problem identification, joint planning, implementation, and monitoring and evaluation events during evaluation and demonstration activity.

FREG is a small group of farmers (15-35 members) and extension agents who have common problems and are interested to work in groups in collaboration with research, extension and with other non-public organizations in the process of technology generation, verification, demonstration, and improvement (JICA, 2015; Chimdo, 2008). FREG groups were formed in each kebele comprising 20 to 30 member farmers, who participated throughout the planning to implementation process of the technology evaluation and demonstration activities. Moreover, for easy communication and facilitation, farmers were able to organize themselves and elected their chairperson and secretary after conducting discussion with multidisciplinary team of researchers on the objectives and implementation of the already planned demonstration activity.

Technology evaluation and demonstration

FREG member farmers evaluated the technologies with the support and facilitation of researchers and extension agents. Participatory variety evaluations were carried out at the maturity stage of the crop and farmers were able to identify evaluation criteria based on their own experiences of chickpea production. The criteria were ranked and prioritized in order of their importance by using pair-wise ranking method. Each variety under evaluation was then evaluated under each criterion by direct scoring methods (1= the best) and scores given to each variety. Each criterion of group results was added together and then ranked in ascending order in each kebele (the lowest sum gives the best score).

Sum of preference value (score*weight) of each variety across all criteria were used to determine final acceptability rank among the varieties in each location. Additionally, Spearman's rank correlation coefficient (rs) was used to see the degree of coincidence between farmers' preference acceptability rank and the rank of the actual yield obtained.

Partnership arrangement

The role of different stakeholders in technology demonstration and modality for partnership was properly designed, and the roles and responsibilities of each actor were as follows.

- Adet Agricultural Research Center (AdARC): AdARC was delivering inputs (seed and fertilizer), organizing training and field days, and joint monitoring and evaluation events with stakeholders.
- Farmers: They provided their own labor and land free of charge for implementing the experiment. Moreover, they were participating in planning, implementation, and evaluation of activities.
- Enemay office of agriculture (district and kebele level): The district office of agriculture including the kebeles was facilitating experimental sites (host farmers) selection, and mobilizing farmers for technology evaluation, training, and field day events. The agricultural office also participated in the joint monitoring and evaluation events.
- ICARDA: Apart from overall coordination and guidance of the chickpea scaling project, it provided funds and participated in the joint monitoring and evaluation events; organizing training of trainers, workshops, and annual review and planning meetings.

Trainings

Training by different researchers comprised of breeders, agronomists, crop protection specialists, and social scientists was provided to farmers and experts to improve and strengthen their attitude, skill and knowledge on the technologies to be demonstrated.

Field day

Field day was organized at the maturity stages of the demonstration plots by inviting different stakeholders across the value chain of chickpea including farmers, and research for development partners and stakeholders.

Monitoring and evaluation

Team of researchers, district and kebele agricultural experts and development agents, and farmers jointly monitored and evaluated, at least two times per season, the implementation of the planned participatory evaluation and demonstration activity of chickpea technologies. During monitoring and evaluation (Figure 1), implementation in terms of agronomic and cultivation practices, any challenges and constraints faced were assessed, and correction measures were suggested according to each actor's roles and responsibilities.

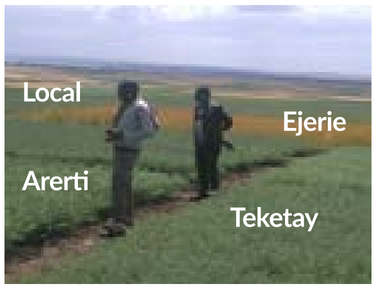

Figure 1. Monitoring and evaluation of the demonstration plots by researchers and development agents, Enemay district Ethiopia, 2017/18

Data collection and analysis

Qualitative and quantitative yield-related and social data were collected. Yield data was collected after harvest and social data (farmers' and experts' opinions/feedbacks) were collected during M & E and field day events. Data were analyzed using simple descriptive statistics such as mean, maximum and minimum values, and social data (farmers' and experts' opinions/feedbacks) were qualitatively described and classified by themes and contents.

Farmers' preference

Spearman's Rank correlation coefficient, "r_s" was used to see the degree of relationship between farmers' preference with actual value of measured attributes.

Spearman's rank correlation coefficient rs was calculated as indicated below:

$$r_s = 1 - \frac{6 \sum d^2}{n(n^2 - 1)} \quad \text{expersed in percentasge}$$

Where,

d = difference in the ranks assigned to the same individual or phenomenon (actual yield rank minus farmers preference rank in this case) and

n = number of individuals or phenomena ranked (number of varieties in this case)

Results and Discussions

Training

Training was given for 36 (1 female) farmers and 24 agricultural experts and development agents (3 female) at all evaluation and demonstration sites in the district. The training content included chickpea production (agronomic practices/production packages), disease and pest management, seed production technique and marketing linkages. During training, power point presentations, leaflets, posters, and audio visuals were used as a training aid material.

Field day

A total of 155 (16 female) farmers and partners' staff participated, of which 121 (10 females) were farmers and 34 (6 female) were agricultural experts and officials from different organizations. During the field-day event, zonal, district and kebele level agricultural experts, officials (heads) and administrators, researchers, seed agency and farmers' cooperative and union experts and heads; and Amhara Mass media journalists participated and provided their reflections and feedbacks about the technology under evaluation and demonstration. Moreover, Amhara Mass Media broadcasted the field day event on Television and radio programs.

Performance of varieties

Productivity data of improved chickpea varieties under evaluation and demonstration is presented in Table 2. On average, across all demonstration sites, Teketay chickpea variety gave the highest grain yield (2.59 tons ha^{-1}) followed by Ejeri (1.82 tons ha^{-1}) and Arerti (1.78 tons ha^{-1}). Local variety gave the lowest grain yield (1.54 tons ha^{-1}).

Table 2. Mean grain yield of chickpea varieties at two kebeles of Enemay district, 2017/18

Variety	Host farmers field (F) and mean grain yield (t ha^{-1})				Rank
	F1	F2	F3	Mean	
Arerti	1.86	1.39	2.10	1.78	3
Teketay	2.62	2.04	3.12	2.59	1
Ejerie	2.43	1.31	1.72	1.82	2
Local	1.36	1.61	1.67	1.54	4

Farmers' preference

During technology evaluation event, FREG member farmers and non-members who could represent the area and have experience in chickpea production were selected to participate. Before the beginning of the evaluation and selection process, farmers were asked to set their selection criteria in prioritized order. Disease and pest resistance, tillering (branch number), number of pods, plant height, and seed color were their main selection criteria for chickpea production (Table 3, 4, 5 and 6).

Farmers gave great emphasis to diseases resistance and seed color followed by high number of pods per plant (high yield) at Bichena-Debir kebele (Tables 3 and 5). Pair-wise ranking and final preference value analysis result showed that Teketay chickpea variety was highly preferred for its disease tolerance, more pods per plant (high yield), vigorous crop stand and lodging resistance while it was less preferred due to its seed color (red seed color is not preferred by local market). Ejeri and Arerti varieties were preferred due to their white seed color and relative disease tolerance and tillering capacity (high biomass or straw yield). Local chickpea variety was the least preferred in terms of all criteria set by farmers.

In overall evaluation criteria, Teketay, Ejeri, Arerti and local were selected and ranked as 1st, 2nd, 3rd and 4th, respectively, at Enemay district (Tables 4 and 6). The sample grain yield also indicated that Teketay, Ejeri, Arerti and local chickpea varieties gave 2.59, 1.82, 1.78 and 1.54 tons ha^{-1}, respectively. Generally, farmers highly preferred Teketay variety to produce and scale up for its high yield potential (both grain and biomass yield) and its vigor (relatively disease tolerance).

Table 3. Pair-wise ranking of farmers' selection criteria at Bichena Debir kebele

Farmers' selection criteria	Disease resistance (DR)	Number of pods per plant (NP)	Tillering/ Branch (NB)	Stalk strength (SS)	Plant height (PH)	Seed color (SC)	Rank
Disease resistance (DR)		DR	DR	DR	DR	DR	1
Number of pods per plant (NP)			NP	NP	NP	SC	3
Tillering/Branch (NB)				NB	NB	SC	4
Stalk strength (SS)					SS	SC	5
Vigor/Plant height (PH)						SC	6
Seed color (SC)							2

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Table 4. Sum of score and final rank of varieties with farmers' selection criteria at Bichena-Debir kebele, 2017/18

Farmer's selection criteria	Varieties sum of scores			
	Arerti	Teketay	Ejeri	Local
Disease resistance (1)	26	10	24	40
Number of pods per plant (3)	102	36	96	114
Tillering/Branch (4)	104	160	96	160
Stalk strength (5)	160	65	100	190
Vigor/Plant height (6)	186	60	132	222
Seed color (2)	20	80	20	20
Total score	578	331	448	726
Overall Rank	3	1	2	4

Note: The lowest score is the best

Table 5. Pair wise ranking of farmers' selection criteria at Mankorkoya kebele

Farmers' selection criteria	Disease resistance (DR)	Number of branches (NB)	Number of pods (NP)	Vigor/ Plant height (PH)	Seed color (SC)	Rank
Disease resistance (DR)		DR	DR	DR	DR	1
Number of branches (NB)			NP	NB	SC	4
Number of pods (NP)				NP	SC	3
Vigor/Plant height (PH)					SC	5
Seed color (SC)						2

Table 6. Sum of score and final rank of varieties with farmers' selection criteria at Mankorkoya kebele, 2017/18

Farmers' selection criteria	Varieties sum of scrores			
	Arerti	Teketay	Ejeri	Local
Disease resistance (DR)	28	10	34	25
Number of branches (NB)	116	48	88	144
Number of pods (NP)	96	30	90	84
Vigor/Plant height (PH)	140	50	120	180
Seed color (SC)	20	80	20	80
Total score	400	218	352	513
Overall Rank	3	1	2	4

Note: The lowest score is the best

Farmers' preference versus actual yield

As shown in Table 7, Spearman's Rank correlation coefficient, "rs" 1 (100%) and this indicates that the farmers preference and actual yield obtained are in a perfect match so that farmers' preferred varieties could be promoted to farmers for wider scale production.

Table 7. Farmers' preference value and actual yield (tons ha^{-1}) comparison of varieties

Varieties	Preference value		Yield data		d	d2
	Score	Rank	Yield	Rank		
Arerti	400	3	1.78	3	0	0
Teketay	218	1	2.59	1	0	0
Ejerie	352	2	1.82	2	0	0
Local	513	4	1.54	4	0	0

rs = 1-0 = 1

Conclusions and Recommendations

Farmers were able to set their own criteria and able to select suitable varieties according to their locality and awareness and demand was created on the evaluated and demonstrated improved chickpea technologies (varieties). Farmers highly preferred Teketay variety to produce and scale up in the next season for its high yield potential (both grain and biomass yield) and its vigor (relatively disease tolerance). The local variety has been devastated by disease, which forced farmers to abandon its production. According to farmers, Teketay is good for home consumption (nutrition) and local market supply to generate income.

Teketay improved chickpea variety can be promoted and scaled up at Enemay district since it has been preferred by farmers due to good grain yield and relatively good disease tolerance, suitable for home consumption, and local market demand.

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On-Farm Demonstration of Early-Planting of Chickpea in Southeastern Tigray

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Chickpea production is affected by moisture stress in the dryland areas of Tigray region. The conventional planting that is practiced by the farmers does not fit to the current climate variability. Limited emergence of chickpea after planting or even total failure due to moisture stress is becoming a common incidence. Recent research results indicated that with proper water management of the field, chickpea could be planted earlier than the traditional practice. Therefore, early planting by using broad-bed and furrow method (BBM) to drain excess water of Vertisols on chickpea production in the area is critical. The purpose of this research was to increase production and productivity of chickpea through early planting (that is at the onset of rainfall) with the removal of excess water using the improved chickpea variety, Arerti, and to increase farmers' awareness on early planting and use of BBM on chickpea production in the Southeastern zone of Tigray.

Materials and Methods

Description of the study areas

Degua Tembein is one of the 36 districts in Tigray region. Its district town, Hagereselam, is 50 Km away from Mekelle, the capital city of the region. The altitude of the district ranges from 2412- 2650 m above sea level (m asl), while the temperature ranges from 19-23^{o}C (DWOARD, 2017). The average landholding size per household in the district is 0.79 ha (CSA, 2007).

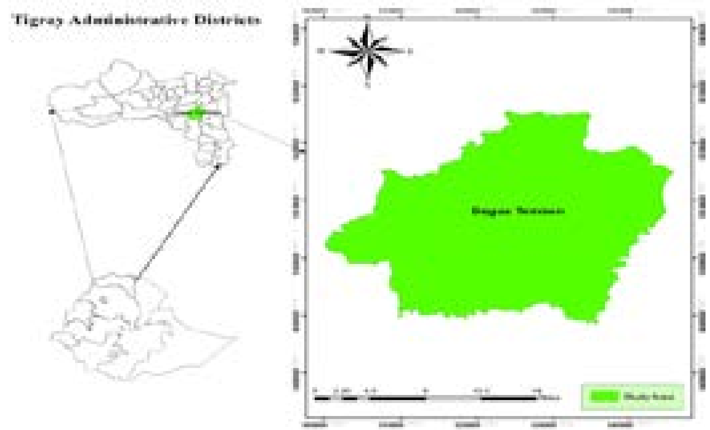

Figure 1. Maps showing the relative position of DeguaTemben district in Tigray region

Selection of farmers and experimental management

The activity was performed in Degua Temben district on-farm, comprising purposely selected 13 farmers who volunteered to participate in the demonstration of the improved technology. Each demonstration plot was 100 to 200 m^2 in single plot observation. Improved chickpea variety, Arerti, was planted on each plot. The early planting, which is the improved technology (planting right on the onset of rainfall, usually during the first week of July) on 1.5 m beds raised to 30 cm, each bed having drainage furrows on both sides, was compared with the farmers traditional practice of late planting in last week of August on flat seed bed. All other agronomic practices were applied as per the recommendations.

Training and field days

Training on the objectives and implementations of the demonstration, and improved management practices of chickpea production were provided before planting. Field days were organized at pod-filling stage for awareness creation and experience sharing for further scaling.

Data collection and analysis

Qualitative data were collected through focus group discussion and informal discussion with farmers and development agents. Quantitative data were also collected through personal interview. Besides, data on farmers' perception were collected using Likert scale method. Yield was estimated by taking quadrant samples from each demonstration plot. Production costs were collected to calculate the profitability of the different treatments.

Coding and data entry into SPSS version 20-computer program were used for the analysis. Data analysis was done using statistical analytical techniques such as descriptive, frequency and percentage.

The partial budget analysis was done to determine the economic feasibility of the study. It was calculated by considering the additional input costs (variable costs) involved and the gross returns obtained from the treatments. The variable cost included the labor cost involved for plowing, weeding and winnowing as their cost varied according to the yield obtained in a particular treatment (CIMMYT, 1988). Therefore, the estimation of the marginal rate of return (MRR) was calculated as follows:

$$\text{Marginal rate of return (MRR\%)} = \frac{\text{The chnage in net return (NR)}}{\text{The change in total costs that vary (TCTV)}} x100$$

Results and Discussions

Yield performance

An average grain yield of 2720 kg ha^{-1} was harvested from the improved practice of early planting in July with broad–bed and furrows drainage method (Table 1). While an average of 1603 kg ha^{-1} was harvested from the traditional farmers' practice (last August planting on flat seed bed). Figure 2 also shows the field performance of chickpea on the improved practice was by far better than that of the farmers' practice. Thus, the improved practice gave a yield increment of 69.68%. This would imply that early planting with improved variety could play significant roles in enhancing the productivity of the crop as well as improving the food security status of smallholder farmers.

Table 1. Chickpea productivity on improved and farmer's planting practices in 2015/2016 cropping season

Time and method of planting	Mean grain yield (Kg ha^{-1})	Yield increment %
Improved practice (early planting in July with BBM)	2720	69.68
Farmers' practice (late planting in August on flat bed)	1603	

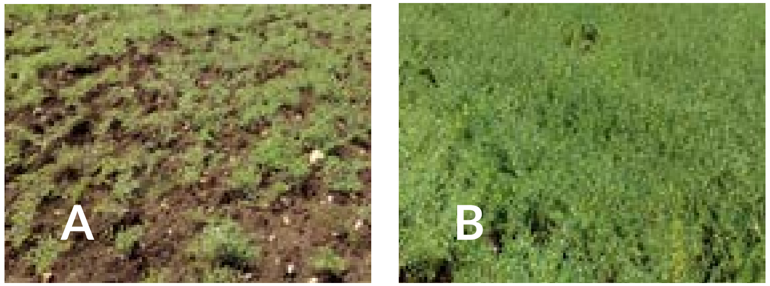

Figure 2. Field performance of chickpea on farmer practice of late planting in August (A) and on improved practice (B) planting first week of July with BBF

Partial budget analysis

The improved practice of chickpea production showed better economic benefits compared to the farmers practice (Table 2). The total variable cost and total benefits for the improved practice was higher than the farmers practice used in each kebele, which means that the cultivation of new improved variety with the combination of improved agronomic practices and packages increases the total costs incurred in a production function and the total benefits gained. The average MRR of the improved practice was about 1572%, which is higher than the minimum acceptable rate of return (100%). This demonstration shows that for every one-ETB investment in the improved practice for chickpea production, there would be a return of 15.72 ETB.

Table 2. Partial budget analysis of improved and farmers' practices of chickpea production

Attribute	Farmers' practice	Improved practice
Grain yield (kg ha^{-1})	1603	2720
Gross field benefit	35266	59840
Cost of plowing	450	450
Cost of weeding	750	2220
Total variable costs	1200	2670
Net benefit (ETB ha^{-1})	34066	57170
Change in variable cost		1470
Change in net benefit		23104
MRR (%)		1571.7

Note: Farmers' practice = planting chickpea towards end of August on flat seed bed; improved practice = planting chickpea in the first week of July on broad bed and furrows to drain excess soil water; 1 Ethiopian Birr (ETB) is equivalent of 0.0365 US Dollar (National Bank of Ethiopia accessed on March 25, 2018)

Farmers' perception

The beneficiary farmers evaluated the improved chickpea variety against different quality attributes. The attributes of the improved chickpea variety were pre-identified as pre- and post-harvest ones and grouped into 13 statements (Table 3). Most of these statements were measured against farmers' local practice. Farmers had positive perception on most of the attributes of the improved variety and the improved practice (Table 3).

Table 3. Pre- and Post-harvest harvest attributed of the improved Arerti chickpea variety on the improved planting practice

Attributes	*Farmers' perception*				
	Very Poor	*Poor*	*Moderate*	*Good*	*Very good*
Maturity	-	-	-	35	65
Germinationability	-	-	-	16.7	83.3
Vegetative growth	-	-	-	14.7	85.3
Time of planting	-	-	-	33.3	66.7
Method of planting	-	-	-	33.3	66.7
Pod borer tolerance	-	33.3	-	50	16.7
Disease tolerance	-	10	-	50	40
Drought tolerance	-	-	-	50	50
Branch capacity	-	-	-		100
Pod size	-	-	-	11.7	88.3
Seed weight	-	-	-	33.3	66.7
Seed size	-	-	-	10	90
Yield	-	-	-	22.3	77.7

Note: Farmers' perception level is expressed in percentage of the number of respondents

Training and field days

Training was provided to 13 farmers, four development agents and two experts of the study areas. The training topics covered the approach of farmers' research group, value chain and how to improve chickpea production, importance of crop diversifications (crop rotations), use of improved agronomic practices, integrated weed management packages, and use of broad-bed and furrows to drain excess soil water.

Field days on the demonstration of the improved chickpea production practice indicated that there was a growing interest by the farmers, experts and other stakeholders in the early-planting practice of chickpea. For early planting of chickpea to be successful, the water management was critical especially on the clay soils where waterlogging is the main problem. With this understanding, field day participants appreciated the demonstration of early-planting practice of chickpea, which comprised planting on the onset of rainfall (usually in the first week of July) by using broad-bed and furrows method for draining excess soil water. The district experts and regional bureau of agriculture requested a proper technology package and user manual for further scaling up of this improved practice of chickpea production. Participants also suggested that disease and pest management practices should be part of the technology package. They suggested that the early planting practice was more suitable for the Kabuli type chickpea varieties as they have better vegetative growth.

Conclusions and Recommendations

The demonstration revealed that the study area has high production potential of chickpea so long as the appropriate technologies are applied. The demonstration of early planting of chickpea as soon as the onset of rainfall, on broad-bed and furrows increased chickpea grain yield by 69.7% over the farmers' practice of late planting on flat field. Consequently, the improved chickpea production practice gave MRR of 1572% compared to the farmers' planting practice. The results suggest that this improved chickpea production practice should be promoted on wider scale for improving chickpea productivity and production in Southeastern Tigray.

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Participatory Evaluation and Demonstration of Improved Chickpea Technologies in mid-Highlands of Bale Zone

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Bale zone is characterized by mixed farming systems where most of the crop areas are under cereal production. The current cereal-based mono-cropping puts the sustainability of the crop production system at risk. Thus, crop diversification using improved chickpea technologies could be a means to minimize cereal mono-cropping cycle and improve sustainability of crop production in the Zone. However, lack of access to improved chickpea varieties in mid-altitude areas of Bale zone is the main problem hampering chickpea production.

NARS has released more than 20 chickpea varieties with their full recommended production packages over the last three decades. Among these, Dhera and Hora (Kabuli types), and Dimtu and Teketay (Desi types) were recently released chickpea varieties with recommended practices. Thus, participatory on-farm evaluation, validation, and demonstration of the varieties with the participation of farmers and other stakeholders were undertaken in 2017 cropping season with the financial and technical support of the ICARDA-USAID project.

The objectives of the demonstration and evaluation were to:

- Evaluate the performance and farmers' preference of improved chickpea technologies under farmers' condition in Bale zone for possible recommendation.
- Create awareness on the importance of and demand on improved chickpea technologies among farmers and participant stakeholders.
- Improve farmers' knowledge and skills on chickpea production and management packages.

Materials and Methods

Description of the study areas

Chickpea technology demonstration and evaluation was carried out in Goro and Ginnir districts of Bale zone (Figure 1). The altitude of Goro district is 1272 m – 3275 masl, receives 797 – 1138.48 mm annual rainfall, the minimum and maximum temperature is 12.93^{o}C and 22.59^{o}C, respectively. The dominant soil types are Chromic Cambisols and Vertisols. The altitude of Ginnir district is 907–2524 masl, receives 612.16–1214.73 mm annual rainfall, the minimum and maximum temperature is 11.31^{o}C and 24.72^{o}C, respectively (Adamu, 2018). The dominant soil types are Pellic Vertisols and Distric Nitosols.

Crop-livestock mixed farming system characterizes agriculture in both districts. The major crops grown in the districts are wheat (bread, durum and emmer), food barley, teff, maize, sorghum, chickpea, lentil, haricot bean, field pea and faba bean (BZADO, 2018). Chickpea is used as a break crop (rotation), food and cash crop for farmers.

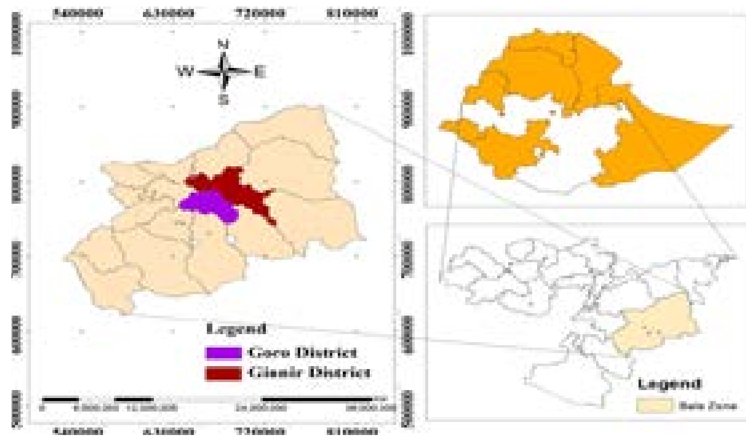

Figure 1. Maps showing the relative position of study target districts in Ethiopia

Sites and farmers' selection

The study was conducted at project intervention districts on four sites (two sites each at Goro and Ginnir for both Kabuli and desi types). Two kebeles were selected from each district based on their accessibility and production potential of the crop. Kebeles were considered as replication, i.e. the demonstration activity was replicated in two kebeles per district.

Selection of host farmers was based on good history of compatibility with groups and integrity, having suitable and sufficient land to host the demonstrations, accessibility for supervision, commitment to implement the activity, good in field management, willingness and openness to share innovations with other farmers. Besides, a combination of resource rich, medium and low-income category of farmers including men, women and youth farmers were considered.

Materials and field design

For Kabuli chickpea demonstration, recently released varieties, Dhera and Hora, were compared with the standard check variety, Habru. For desi chickpea demonstration, varieties Dimtu and Teketay were compared with the standard check variety, Naatolii. The demonstrations were carried out in 2017 meher cropping season. Plot size of each variety was 10 m x 10 m. Sinana Agricultural Research Center was the source of all agricultural inputs (seed of improved varieties and fertilizer-NPS). The varieties were treated with the recommended chickpea production and management packages. Row planting method and other crop management practices were employed during the research work. The spacing of 30cm between rows and the recommended seed rate of 120 kg ha^{-1} for Kabuli type, and 80 kg ha^{-1} for desi type were used during planting by drilling in the rows. Shallow planting of 5cm depth was used in the presence of sufficient soil moisture. The recommended inorganic fertilizer rate of 121 kg ha^{-1} NPS was applied at planting.

Depending on weed infestations, weeding was done twice: The first one month after sowing and the second two months after sowing of improved chickpea varieties. Farm operations (land preparation-ploughing two to three times using oxen plough) were carried out by host farmers, whereas activities such as land leveling, planting, weeding, cultivation, harvesting, threshing, cleaning, and other laboratory works were handled by Sinana Agricultural Research Center (SnARC) researchers and technical assistants. In these districts, the planting time of chickpea is early September, and the harvesting time of the crop was end December to early January.

Technology demonstration and evaluation

A total of 124 participants from two districts (104 farmers, 14 DAs and supervisors and six experts) and three researchers participated in the selection of the varieties at maturity stage of the crop. First, the evaluators were grouped into manageable groups (one group each of 10 members including one group leader and one secretary). At each demonstration kebele, orientation was given to the evaluators on how to integrate researchers' criteria to their own criteria to select among the demonstrated varieties in order of their importance, how to carefully assess each variety by considering each criterion and rating scale, how to organize collected data, how to make group discussion and reach on consensus, and finally how to report through their group leader.

Training

Participatory training was given to farmers, development agents, supervisors and agricultural experts just before planting to create awareness and bridge knowledge gaps in improved chickpea production technologies, ensure commitment and strengthen linkages to implement the demonstration and evaluation.

Data collection and analysis

Both qualitative and quantitative data were collected using direct field observation/ measurements and focused group discussion (FGD). Agronomic data such as flowering date, disease score, maturity date, stand, branches per plant, pods per plant, seeds per plant and yield data per plot in all locations were recorded. Farmers' preferences to the demonstrated technologies were identified and ranked.

Descriptive statistical technique such as percentage was used to analyze the data using SPSS. Pair-wise ranking matrix was used to rank the varieties in order of their importance. Pair- wise ranking was used as a tool to summarize farmers' preference towards important variety traits (Boef and Thijssen, 2007). The agronomic data were analyzed using GENSTAT computer software. Yield advantage of the demonstrated technologies was estimated as:

$$\text{Yield advantage \%} = \frac{\text{Yield of new variety-yield of commercial variety}}{\text{Yield of commercial variety}} \times 100$$

Results and Discussion

Training

A total of 120 trainees (86 farmers, 14 development agents and supervisors, 12 agricultural experts and 8 researchers) participated in the training, out of which 10% was women farmers. The training topics covered available improved chickpea technologies and use, FREG approaches, technology evaluation and selection criteria, chickpea production and management packages, major chickpea pests and their control measures, and the importance of chickpea for crop rotation in the project target areas.

Yield performance and farmers' preference

Kabuli chickpea: For Kabuli type, the mean grain yield of the standard check, Habru, was 2.55 t ha^{-1} at Goro, and 2.61 t ha^{-1} at Ginnir, which was higher than the recently released varieties, Dhera and Hora in both districts (Table 1).

Table 1. Productivity and yield advantage of demonstrated Kabuli chickpea varieties

District	Mean grain yield of standard check (tons ha^{-1})	Mean yield (tons ha^{-1}) & yield advantage (%) of demonstrated chickpea varieties			
	Habru	Dhera	%	Hora	%
Goro	2.55	2.15	-15.7	2.08	-18.4
Ginnir	2.61	2.18	-16.5	1.95	-25.3

At both districts, Habru was also the most preferred variety by farmers, followed by Dhera variety. Statistical analysis also confirmed that the standard check variety, Habru, was significantly superior in the number of branches per plant, number of pods per plan and average grain yield over the demonstrated varieties (Table 3). Although Dhera is lower yielder than Habru, farmers observed its suitability for mechanization because of its plant height and relatively erect growth habit.

Table 2. Rank of the demonstrated Kabuli chickpea varieties based on farmers' selection criteria

Varieties	Rank	Reasons (all sites)
Habru	1st	Average branches per plant (16), pods per plant (184 branches and full of pod), attractive seed color, well adapted, high yielder, has uniformity, no disease
Dhera	2nd	Average branches per plant (14), pod per plant (114 long but not full of pod), well adapted, good for mechanization due to its plant height and relatively erect growth habit
Hora	3rd	Average branches per plant (10), pod per plant (110), small seeded, well adapted, disease

Table 3. Performance of Kabuli chickpea varieties demonstrated across the two districts

Varieties	Number of branches per plant	Number of pods per plant	Mean grain yield (tons ha^{-1})
Habru	16a	181a	2.58a
Dhera	13b	114b	2.165b
Hora	10.5b	110b	2.015b
LSD0.05	3.9	8.6	0.19
CV (%)	9.3	2	2.7

Desi chickpea: Productivity and yield advantage of demonstrated desi-type chickpea varieties are presented in Table 4. The highest yielding chickpea variety, Dimtu, gave the mean grain yield of 2.47 t ha^{-1} at Goro, and 2.58 t ha^{-1} at Ginir with the corresponding yield advantage of 15.42% and 19.44% over the standard check variety, Naatolii.

The FGD result showed that the participant farmers ranked the demonstrated chickpea varieties based on their preferences and level of satisfaction. farmers' preference summary result showed that Dimtu variety was preferred as the first choice, followed by Teketay at both districts (Table 5). Statistical analysis also confirmed that Dimtu was significantly superior in number of branches and pods per plant, and grain yield compared to the standard check variety Naatolii. The performance of Teketay variety in grain yield was not significantly different from that of variety Dimtu (Table 6).

Table 4. Productivity and yield advantage of demonstrated desi chickpea varieties

District	Mean grain yield (tons ha^{-1}) of standard check variety	Mean grain yield (tons ha^{-1}) and yield advantage (%) of demonstrated chickpea varieties			
	Naatolii	Dimtu	%	Teketay	%
Goro	2.14	2.47	15.42	2.18	1.87
Ginnir	2.16	2.58	19.44	2.31	6.94

Table 5. Rank of the demonstrated desi-type chickpea varieties based on farmers' selection criteria across the two districts

Varieties	Rank	Reasons (all sites)
Dimtu	1st	Average branches per plant (11), pods per plant (162 good branches and full of pods), well adapted, high yielder, has uniformity, no disease
Teketay	2nd	Average branches per plant (9), pod per plant (148), well adapted, good yield, big seed size
Naatolii	3rd	Average branches per plant (7), pod per plant (111), small seeded, late maturing, disease

Table 5. Rank of the demonstrated desi-type chickpea varieties based on farmers' selection criteria across the two districts

Varieties	Number of branches per plant	Number of pods per plant	Mean grain yield (tons ha^{-1})
Dimtu	11^{a}	162^{a}	2.525^{a}
Teketay	8.5^{b}	148^{b}	2.28^{ab}
Naatolii	6.5^{b}	111^{c}	2.15^{b}
$LSD_{0.05}$	3.2	4.5	0.3
CV (%)	11.5	3	6.6

Conclusions and Recommendations

In participatory demonstration and evaluation of improved chickpea varieties (both kabuli- and desi-type), the best performing variety/ies for the target areas were identified, validated and ranked based on participant farmers assessment and grain yield data.

In Kabuli type chickpea, the demonstrated Dhera and Hora varieties performed lower than the standard check variety Habru in both test locations (Goro and Ginir districts). Therefore, Habru is still the leading variety at both districts and recommended for wider scaling up/out in the test locations; Dhera can be recommended for wider scaling up/out for its mechanization merit.

On the other hand, in desi-type chickpea, the demonstrated Dimtu and Teketay varieties performed better than the standard check variety, Naatolii in both Goro and Ginir districts. Therefore, Dimtu and Teketay are recommended for wider scaling up/out activity in the study districts and other similar agro-ecologies.

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On–Farm Demonstration of Insecticides to Control Chickpea Pod Borer in Bale Zone

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Chickpea (*Cicer arietinum L.*) is susceptible to several insect pests, which attack the roots, foliages and pods. Among these, Chickpea pod borer (*Helicoverpa armigera Hubner*) (Lepidoptera: Noctuidae) is a major field insect pest affecting pulses in several agro-ecological zones in Ethiopia (*Damte et al., 2018*) and all growing environments elsewhere in the world (*Gaur et al., 2018*). There is a high infestation of pod borer on chickpea, field pea and lentil in three districts of Bale zone, namely Goro, Ginnir and Golelcha. Farmers are trying to control this pest by spraying different insecticides purchased from local pesticide dealers and farmers' cooperatives union. Due to the low efficacy of the pesticides being used on other crops and lack of experience on chickpea, farmers are demanding for effective insecticides and spray frequencies to manage chickpea pod borer.

Therefore, this study for the control of chickpea pod borer was initiated with the objectives to:

- Demonstrate different insecticide for the control of pod borer on chickpea.
- Create awareness on the use and effectiveness of the insecticide against pod borer on chickpea

Materials and Methods

Description of the study areas

This experiment was conducted on the farmer's field each at one site in Ginnir and Goro districts during 2017-2018 cropping season. The selected locations represent hotspot areas of pod-borer infestation every year under natural conditions. Soil type in Goro district is Chromic Cambisols while that of Ginir it is Pellic Vertisols.

Treatments and experimental design

The experiment was conducted using an improved chickpea variety, Habru. Two insecticides Diazenon (1.2 liter ha^{-1}) and Karate (400 milliliter ha^{-1}) were tested in the experiments. The experiment was laid out in non-replicated plots in each site; each site having three plots: (i) Plot one: Diazenon sprayed plot; (ii) Plot two: Karate sprayed plot; and (iii) Plot three: Control (unsprayed plot). The size of each plot was 100 m^2 (10 m x 10 m).

Crop management and data collection

The recommended agronomic practices were applied for chickpea production. Each insecticide was applied starting from the appearance of the chickpea pod borer in the respective plot.

Data on pod-borer population before and after insecticide application was recorded from five randomly selected plants in each treatment. Thus, the number of larval populations per plant was recorded at seven-days interval. The reduction percentage of larvae was estimated by counting of larval population in insecticide treated plots compared to the untreated control. Data on yield, farmers' perception, and variable costs of production were also collected. Larval reduction and yield increment compared to the control were computed as follows:

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$$\%\ \text{Larval reduction} = \frac{\text{larval population on untreated plot-larval population on treated plot}}{\text{larval population on untreated plot}} x100$$

$$\%\ \text{Yield increased over check} = \frac{\text{Yield on treated plot-Yield on untreated plot}}{\text{Yield on treated plot}} x100$$

Results and Discussion

Larval count

The result revealed that both insecticides were effective against pod borer even if they have different percent larval reductions at both locations (Table 1). At Ginnir, larval count of chickpea pod-borer ranged from 1.6 to 3.4 larvae per plant before spray and 0.3 to 3.2 after spray during the season. This indicated that the pest was active during December; this period coincides with the flowering and pod formation stage of the crop. The pod borer damage reduction by different treatments ranged from 71.87 % to 90.63 % compared to that in control at Ginnir. The highest pod borer larval reduction (90.63%) was in Diazenon sprayed plot followed by Karate 5% EC (71.87%) sprayed plot.

At Goro, the larval count of chickpea pod borer per plant ranged from 1.3 to 3.6 larvae before spray and 0.8 to 2.4 after spray during the season. The effects of the insecticide treatments in reducing pod-borer damage on chickpea ranged from 58.33 % to 66.66 % compared to that in the control. The highest effect in reducing pod borer larval damage on chickpea (66.66%) was from Diazenon sprayed plot followed by Karate 5% EC (58.33 %) sprayed plot.

Table 1. Average chickpea pod borer larval count per plant before and after spray of insecticides at Ginnir and Goro districts in 2017/2018 cropping season

Districts	Insecticides	Mean larval count per plant		Per cent (%) reduction over check
		Before spray	After spray	
Ginnir	Diazenon	1.6	0.3	90.63
	Karate 5 % EC	3.3	0.9	71.87
	Check (no spray)	3.4	3.2	
Goro	Diazenon	3.6	0.8	66.66%
	Karate 5 % EC	1.3	1	58.33
	Check (no spray)	2	2.4	

Grain yield

The results obtained at Ginnir revealed that Diazenon insecticide treatment gave the highest chickpea grain yield of 2.61 tons ha^{-1}, followed by Karate 5% EC insecticide treatment that gave 1.8 tons ha^{-1}, whereas the lowest grain yield of 0.82 tons ha^{-1} was on the control (unsprayed plot). The respective yield increments due to Diazenon and Karate 5% EC insecticidal treatments was 68.58% and 54.44% over the control.

Similarly, at Goro, Diazenon gave the highest grain yield of 2.2 tons ha^{-1}, followed by Karate 5% EC that gave 1.6 tons kg ha^{-1}, whereas the lowest grain yield of 0.6 tons ha^{-1} was on the control plot. The respective yield increments due to Diazenon and Karate 5% EC insecticidal treatments was 72.7% and 62.5% over the control plot.

Table 2. Average grain yield of chickpea with chemical control at Ginnir and Goro districts in 2017/2018 Season

Districts	Insecticide treatments	Grain yield (tons ha^{-1})	Percent (%) yield increase over control
Ginir	Diazenon	2.61	+68.58
	Karate 5%EC	1.80	+54.44
	Check (no spray)	0.82	
Goro	Diazenon	2.20	+72.73
	Karate 5%EC	1.60	+62.5
	No spray (check)	0.60	

Profitability of chickpea pod borer management

At Ginnir, plots sprayed with Diazenon insecticide gave the highest net return of 75,348 ETB ha^{-1} and the highest benefit cost ratio of 4.7, while the control plots gave the lowest net return of 15,054 ETB ha^{-1} and the lowest benefit cost ratio of 1.10 (Table 3).

Similarly, at Goro district, plots sprayed with Diazenon gave the highest net return of 61,120 ETB ha^{-1} and the highest benefit cost ratio of 3.85, while the control plots gave the lowest net return of 7,420 ETB ha^{-1} and the lowest benefit cost ratio of 0.55 (Table 3).

Table 3. Profitability of chickpea pod borer insecticide control at Ginnir and Goro districts in 2017/18 cropping season

Districts	Insecticide treatments	Grain yield (tons ha^{-1})	Total variable cost (ETB ha^{-1})	Gross return (ETB ha^{-1})	Net return (ETB ha^{-1})	Benefit cost ratio (NR/TVC)
Ginir	Diazenon	2.61	16,002	91,350	75,348	4.71
	Karate 5% EC	1.80	15,760	63,000	47,240	2.998
	No spray (check)	0.82	13,646	28,700	15,054	1.10
Goro	Diazenon	2.2	15,880	77,000	61,120	3.85
	Karate 5% EC	1.6	15,700	56,000	40,300	2.57
	No spray (check)	0.6	13,580	21,000	7,420	0.55

Note: Grain sale price was 35,000 ETB ton^{-1}

Farmers' perceptions

Fifty-four farmers at Goro and 56 farmers at Ginir participated in the evaluation and selection of insecticides. In both districts, the farmers selected the plot sprayed by Diazenon as their first choice and Karate as the second one. During the evaluations and selections, farmers mostly considered the number of damaged pods per plot. Accordingly, they observed that the plots with no insecticide applications had a greater number of damaged pods by the larvae as compared to the chickpea plots treated with insecticides. To avoid the biasness during evaluation and selection, farmers had no clue on the insecticide sprayed and unsprayed plots. They simply observed the level of pod damage in each plot and provided their feedbacks, which were interpreted and disclosed to them by the responsible researcher.

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Conclusions and Recommendations

The results revealed that Diazenon and Karate 5% EC were effective insecticides to cause high mortality of pod borer on chickpea under field conditions. The highest economic benefit for pod-borer management was obtained from Diazenon sprayed plot, followed by karate sprayed plots. Diazenon insecticide is preferable in terms of enhanced efficacy, productivity, and profitability of chickpea production in the chickpea pod borer hotspot areas. However, it is also important to consider Karate 5% EC insecticide as an alternative since insecticides availability is not reliable.

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CHAPTER 3
CHICKPEA SEED PRODUCTION

Profitability of Community-Based Seed Production of Chickpea in Western Amhara Region

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The formal seed sector in Ethiopia focuses mainly on hybrid maize and bread wheat. On the other hand, most smallholder farmers rely on their own saved seed and local informal market to grow legumes including chickpea. Although many new improved varieties have been developed with potential to drastically improve production, farmers are still not aware and hence not using them due to the weak and even non-existence seed system for chickpea.

Therefore, Adet Agricultural Research Center (AdARC) promoted chickpea Community-Based Seed Production (CBSP) to increase seed access and boost production of smallholder farmers in Amhara Region. The effectiveness of CBSP or farmer-based seed production in bulking and distributing of new chickpea varieties depends on the financial profitability. Although CBSP and dissemination has been promoted as a means of accelerating the diffusion of new varieties and to create seed access for chickpea, its profitability has not been evaluated based on farmers' condition. Hence, this study was conducted to assess the costs and benefits of community-based chickpea seed production in Amhara Region.

Materials and Methods

Description of the study areas

Community based chickpea seed production and dissemination system was promoted at Enemay, Yilmana-Densa and Enarj-Enawuga districts (Figure 1). The description of districts is as shown in Table 1.

Table 1. Description of Enemay, Yilmana-Densa and Enarj Enawuga distircts

Description	*Enemay*	*Yilmana-Densa*	*Enarj Enawuga*
Geographic location	*East Gojam*	*West Gojam*	*East Gojam*
Altitude (masl)	*1600-3600*	*1800-3200*	*1100-3200*
Annual rainfall (mm)	*900-1150*	*1051.8-1488.2*	*700-2000*
Rainfall pattern	*Unimodal*	*Unimodal*	
Temperature (^{0}C)	*21*	*8.8-25.2*	*8 – 25*
Soil type	*Vertisol (75%)*	*65% red, 20% black and 15%*	*30% black, 24% brown, 25% red and 21% grey (sandy)*

Source: EWOA, 2016; YDWOA, 2016; and EEWOA, 2016

Enemay district: The major crops grown are tef, barley, wheat, maize, sorghum, chickpea, grass pea, faba bean and field pea in the crop-livestock mixed farming system (EWOA, 2016). Chickpea is grown in residual moisture and is usually planted from September to October (mostly in mid-September when rainfall ceases) and harvested in January.

Yilmana-Densa district: The major crops cultivated are teff, bread wheat, maize, barley, potato, chickpea, faba bean, field pea, and finger millet. Chickpea is produced in residual moisture and planted from September to November (mostly end of September) and harvested in January. Farmers do practice haricot bean-chickpea, tef-chick pea, and barley-chickpea double cropping depending on the nature of the rainy season replacing the traditional fallow land-chickpea practice.

Enarj-Enawuga district: Major crops grown include tef, barley, wheat, chickpea, grass pea, faba bean and field pea. Chickpea production is widely practiced by farmers by using their own small seeded desi-type local chickpea varieties on the residual soil moisture as tef-chickpea double cropping system.

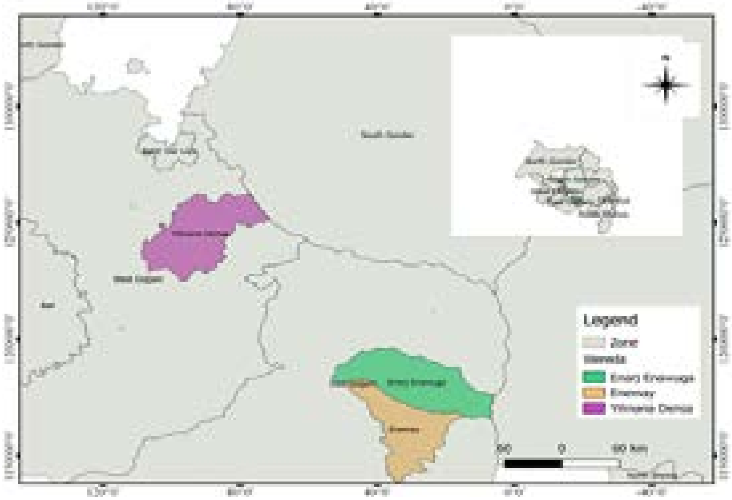

Figure 1. Maps showing the relative position of chickpea Community-based Seed Production districts in Amhara Region

Technology packages

The improved chickpea variety, Arerti, was used for the CBSP in all the three target districts. A seed rate of 120 kg ha^{-1} with fertilizer rate of 100 kg ha^{-1} DAP and/or NPS (Nitrogen, Phosphorous and Sulphur) were applied. All DAP or NPS was applied during planting. The bio fertilizer (inoculants) used was MBI-CP EAL-029 strain, mostly bought from Menagesha BioTech Private Limited Company (MBioTech PLC) in Ethiopia, at the rate of 500 g ha^{-1}. Famers with 0.125 to 0.75 ha of land per farmer and are willing to participate were engaged in the CBSP activity based on land clustering approach.

Data collection and analysis

Qualitative and quantitative yield-related attributes and social data were collected from host farmers who participated in chickpea CBSP through face-to-face interview. Yield data were collected after harvest by taking quadrant plot sampling technique and social data using

survey by preparing checklists for 650 host famers who implemented the activity. Three quadrant samples (each quadrant is 1 m^2) were taken from each farmer's chickpea field, the total number of farmers' fields being 65. Direct field observation, individual host farmers' interview using checklists, focused group discussion (FGD), and Key Informants Interview (KII) were some of the methods of data collection.

Detailed information for the cost-benefit analysis study was collected on all the variable production costs incurred from land preparation to harvesting and post-harvest handling as well as materials used in seed production. Market prices for chickpea seed were collected from farmers, traders and marketplaces.

Data was analyzed using simple descriptive statistics such as mean, maximum, and minimum, while social data (farmers' and experts' opinion/feedbacks) was simply qualitatively described and classified by themes and contents. Cost-Benefit analysis was used to determine the profitability of CBSP system. All the input, output and production cost data collected were used in the calculation of the net margins or profit (defined as the residual after variable production costs are deducted from the total revenue of seed production activities). Enterprise budgeting method was followed, and net returns analysis was used to determine the profitability of chickpea community-based seed production.

To determine the cost and returns of chickpea CBSP, the gross margin (GM) analysis was employed. The gross margin is the difference between the total revenue (TR) and the average total variable cost (TVC). The total revenue is the product of chickpea seed/grain quantity produced and its sale price. The total cost is given by sum of the total fixed cost (TFC) and the TVC (Katungi *et al.*, 2011).

Gross margin analysis could be mathematically stated as:

$$GM = GR - TVR \quad \text{..............................} \quad (1)$$

Where,

GM = Gross Margin (ETB ha^{-1}),

GR = Average Gross Return (ETB ha^{-1}), and

TVC = Total Variable Costs (ETB ha^{-1}).

Moreover, benefit-cost ratio (BCR) was used to determine the profitability of the CBSP as stated below:

$$Benefit - Cost\ Ratio = \frac{Total\ Revenue\ (TR)}{Total\ Cost\ (TC)} \quad \text{..............................} \quad (2)$$

If BCR > 1, then the total revenue is greater than the total cost; if BCR = 1 then the total revenue is equal to the total cost; and if BCR < 1 then the total revenue is less than the total cost.

Results and Discussion

Costs of chickpea CBSP

The major variable costs of CBSP at smallholders' farmers' level could be divided into inputs (materials) and field operation costs. The average total variable costs of CBSP were 11,383.75 ETB ha^{-1} for chickpea (Table 2). Average input (material) costs accounted 42.5% while field operation costs accounted 57.5% of the average total cost of chickpea CBSP.

Since most of the farmers use family labor in seed production, monetary value of wage rate that prevails in the locality was attached to the man-days spent by the family to account for the cost of labor. Out of the average total variable cost, seed constitutes the major input cost component (26.35%). Land preparation (plowing) takes the largest share (about 23%) among operational costs. Since bio-fertilizer (inoculant) was applied instead of urea fertilizer for chickpea, urea is not part of input cost. Weeding cost is minimal for chickpea since it is sown in residual moisture that reduces weed infestation. Next to land preparation, harvesting, and threshing are major operational cost components in order of importance.

Table 2. Estimated average variable costs of chickpea CBSP in target districts of Amhara region in 2017/18

Description of field operation	Measurement Unit	Requirement per hectare	Unit Cost (ETB)	Total cost (ETB ha^{-1})	% of total cost
Cost of inputs				4,837.50	42.49
Seed	kg	120	25	3,000	26.35
DAP fertilizer	kg	100	14.80	1,480	13.00
Biofertilizer	kg	0.50	320	160	1.41
Bags	Number	19.75	10	197.50	1.73
Cost of field operation				6,546.25	57.51
Plowing	Man days	12	225	2,700	23.72
Planting	Man days	4	56.25	225	1.98
Fertilizer application	Man days	2	56.25	112.50	0.99
Weeding	Man days	8	72.50	580	5.09
Roguing	Man days	4	72.50	290	2.55
Plant protection	Man days	2	72.50	145.00	1.27
Harvesting and					
stacking	Man days	20	71.25	1,425.00	12.52
Threshing	Man days	10	71.25	712.50	6.26
Bagging and transporting	Man days	5	71.25	356.25	3.13
Average total variable cost				11,383.75	100.00

Revenue of chickpea CBSP

Revenue of chickpea CBSP mainly comes from grain (seed) and straw (biomass) yield. The average chickpea grain yield obtained was 1925 kg ha^{-1} (Table 3) while the national and regional chickpea grain yields were 1899 kg ha^{-1} and 1730 kg ha^{-1}, (CSA, 2016). The chickpea straw yield obtained was 19 bundles ha^{-1}, one bundle being 75 kg. The selling price was recorded immediately after harvest at farm-gate and the average selling price of seed was 22.8 ETB kg^{-1} while straw price was 215 ETB bundle^{-1}. Thus, revenue of chickpea CBSP was computed as the total value of seed and straw yields that brought a mean gross return of 47,975 ETB ha^{-1} (Table 3).

Table 3. Chickpea harvested yield, average unit price and revenue of CBSP study in target districts of Amhara region in 2017/18

Variable description	Unit	Total yield obtained	Unit price (ETB)	Total revenue (ETB)
Total harvested grain yield	Kg ha^{-1}	1925	22.80	43,890
Total straw/biomass yield	Bundle ha^{-1}	19	215	4,085
Total gross revenue (ETB)				47,975

Note: One bundle = 75 kg; average exchange rate of one USD was 27.67 ETB in 2018

Table 4. Costs and returns of chickpea CBSP in the study target districts of Amhara region in 2017/18

Variable description	Values
A. Total revenue (ETB ha^{-1})	47,975
B. Average total variable cost (ETB ha^{-1})	11,383.75
Profitability measures	
C. Gross Return: (A-B)	36,591.25
Profit margin (%): (C/A*100)	76.3
Benefit-cost ratio (BCR): (A/2)	4.21

Sensitivity analysis

The sensitivity analysis result showed that chickpea CBSP enterprises are likely to be more sensitive to yield than to price fluctuations or reductions (Table 5). Thus, a reduction in price of seed grain by 20% reduced the profitability of chickpea by 4.68% while 20% yield reduction reduced profitability by 5.93%. About 50% reduction in yield reduced the profitability of chickpea by 23.73% while a 50% reduction in yield coupled with 20% increment in total variable cost (TVC) reduced profitability of chickpea by 33.22% (Table 5). In general, the business of chickpea CBSP was found profitable over different scenarios considered unless extraordinary conditions would happen.

Table 5. Sensitivity analysis on profitability of chickpea CBSP in target districts in Amhara region in 2017/18

Item description	Initial values	20% decrease in seed price	20% decrease in seed yield	20% decrease in seed yield and 20% increase in TVC	50% decrease in seed yield	50% decrease in seed yield and 20% increase in TVC
(A) Total revenue (ETB ha^{-1})	47,975.00	40,074.80	38,380.00	38,380.00	23,987.50	23,987.50
(B) Average total variable cost (ETB ha^{-1})	11,383.75	11,383.75	11,383.75	13,660.50	11,383.75	13,660.50
Profitability measures						
(C) Gross Return (ETB): (A)-(B)	36,591.25	28,691.05	26,996.25	24,719.50	12,603.75	10,327.00
Profit margin (%): [(C)/(A)]*100	76.27	71.59	70.34	64.41	52.54	43.05
Benefit-cost ratio (BCR): (A)/(B)	4.21	3.52	3.37	2.81	2.11	1.76

Conclusions and Recommendations

The results of study indicated that producing chickpea seed by smallholder farmers in CBSP scheme is a promising and profitable business enterprise in the target areas even under the existing low-productivity and/or low-price scenarios. Chickpea CBSP enterprises are likely to be more sensitive to yield reduction than to price fluctuations or reductions. In general, this study suggests that this kind of chickpea CBSP can be replicated in similar areas by grouping and empowering farmers to meet the demand for seed of improved varieties in the country since crops like chickpea are not multiplied by formal seed enterprises or agencies.

Farmers need technical assistance and material backstopping on training, initial seeds, new varieties, agronomic practices, field selection, isolation methods, field inspection and seed certification from research centers in collaboration with office of agriculture, farmers' cooperatives, and seed enterprises with ease of accessibility and availability. In addition, chickpea CBSP scheme can be promoted to a wider scale to reach more farmers and unaddressed similar areas by office of agriculture in collaboration with farmers' cooperatives unions and/or universities.

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Profitability of Community-Based Chickpea Seed Production on the vertisol areas of North Shewa Zone

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The Ethiopian public seed enterprises provide more than 90% of the total formal seed supply, primarily of cereals (maize and wheat). Legume seed supply covers less than 7% of the total formal sector. Although some progress has been made on the overall performance of the formal sector (Alemu and Bishaw, 2015), decentralized alternative farmer-based seed production and marketing has been advocated for legumes including chickpea. The farmer-based seed production (FBSP) implies the organization and establishment of a group of farmers to operate seed business at a local level (Seth *et al*., 2015).

In the highland vertisol areas of North Shewa, wheat monocropping is a dominant practice. Recognizing the need for crop rotation and the state of the limited legume seed supply, the bureau of agriculture, the cooperative office, and the Debre Birhan Agricultural Research Center (DBARC), in consultation with the farmers, devised a strategy to address the problems based on the local needs. Thus, farmer-based chickpea seed production and marketing interventions were started in 2014 to address the availability and access to quality seed of improved crop varieties. This study was conducted to evaluate the performance and profitability of farm-level chickpea seed production and marketing on the highland Vertisols of North Shewa Zone.

Approach

Description of study area

The study was conducted in Moretina-Jiru, Siadebirina-Wayu and Ensaro districts of North Shewa zone. The altitude of the districts varies from 2600 to 2800 masl with unimodal rainfall patterns and an average rainfall of 929 mm. The maximum and minimum temperatures are 21.4 and 9.0°C, respectively. Vertisols is the dominant soil type that is characterized by waterlogging with poor drainage. Wheat-based farming is the dominant cropping system in the target districts. Other crops grown include tef, faba bean, lentil, chickpea, and grass pea.

Methodology

A baseline survey was conducted by the DBARC to understand the crop production challenges. Thus, it was found that the use of improved legume technologies was limited in the target areas. This led DBARC to conduct participatory variety selection and demonstration of seven improved chickpea varieties with agronomic practices. The best three farmers selected varieties were, Habru, Naatolii, and Mastewal.

Interested farmers were motivated to produce seeds of the selected chickpea varieties. Farmers were also encouraged to cluster their fields for seed production. Both group members and the leaders were trained on technical aspects of quality seed production, and financial and business managements.

A technical team to oversee and coordinate the seed production and marketing was established at the zonal level. The office of agriculture at the district level and DBARC were responsible to provide technical support and monitor seed production fields and market linkages. DBARC also provided the initial seed and training. Dessie Seed Laboratory and Certification Center (DSLCC) provided training and field inspection. All technical support and monitoring of seed production operations were implemented by a team of researchers, agricultural experts, skilled farmers, and the field inspection was conducted by the experts of seed regulatory agency.

The community seed producers were linked with the existing seed producer cooperatives (SPCs) established by DBARC and the Integrated Seed System Development project in 2012 in Siyadebirana-Wayu and Moretina-Jiru districts, and by DBARC in 2015 in Ensaro district. Member farmers of community seed production entered into agreements with the cooperatives to produce and supply quality seed to the existing SPCs. After approval by the regional regulatory agency, farmers were able to sell the seed to the cooperatives at premium prices. The prices were set by the team of representatives selected from farmers, experts from cooperative promotion, trade, and agricultural development offices. The cooperatives would collect the produced seed, clean, pack, and sell it to other farmers. Since SPCs had limited capacity, some of the seed produced was marketed through other channels to different actors. The profitability analysis focused on the formal seed marketing of farmers to seed production and marketing cooperatives.

Profitability analysis

The profitability analysis of community-based seed production and marketing was conducted using cost-benefit, gross margin, benefit-cost ratio, breakeven analysis, and sensitivity analysis considering input costs and output prices. All cost items incurred in seed production and marketing were listed, and all benefits gained related to seed production and marketing outcomes were also registered and analyzed.

Net Benefit (NB) sometimes called cost-benefit analysis was calculated by deducting total costs incurred from the total benefits gained from the field, as indicated in equation 1.

$$NB = \text{Gross field benefit} - \text{Production costs} \quad \text{.............................} \quad (1)$$

Gross Margin (GM) is the difference between the Gross Return (GR) and the Total Variable Cost (TVC) that is calculated as follows:

$$GM = GR - TVC \quad \text{.............................} \quad (2)$$

It is a useful planning tool in situations where fixed capital is a negligible portion of the farming enterprise in the case of small-scale subsistence agriculture (Olukosi and Erhabor, 1988).

Benefit-Cost Ratio (BCR) is given by the percentages of the Total Variable Cost to the Gross Return that can be calculated as follows:

$$BCR = \frac{GR}{TVC} \quad \text{.............................} \quad (3)$$

Where GR = chickpea seed produced multiplied by price; and TVC= summation of costs of all variable inputs. If the ratio is less than one, then the costs exceed the benefit; if the ratio is more than one, then the benefits exceed the costs (Gittenger, 1982; Jehanzeb, 1999).

Break-even Analysis is the point where GR and TVC are the same or when the sales of a farm are enough to cover the expenses (variable costs) of the farm. The goal of calculating a break-even price is to find out at what price a product would have to be sold in the marketplace to pay for its production. Break-even yield also shows at what production potential (yield per unit area) a product is economically feasible given the variable cost and price.

Accordingly, breakeven analysis can be calculated as follows:

$$\text{Breakeven Yield} = \frac{TVC}{\text{Sale Price}} \quad \text{.............................} \ (4)$$

$$\text{Breakeven Price} = \frac{TVC}{\text{Total Production}} \quad \text{.........................} \ (5)$$

Results and Discussion

Performance of chickpea CBSP

The community seed producers used cluster farming for seed production. A total of 126 ha of land was clustered where the seed of improved chickpea varieties was produced. Habru, Naatolii, and Mastewal chickpea varieties were planted on 79, 32, and 15 ha, respectively. A total of 15,120 kg of seed at a total cost of ETB 332,640 was used (Table 1).

Table 1. Land area allocated, seed required, and costs for chickpea CBSP

Variety	Area covered (ha)	Seed rate (kg ha^{-1})	Total seed used (kg)	Seed cost (ETB kg^{-1})	Total seed cost (ETB)
Naatolii	32	120	3840	22	84480
Habru	79	120	9480	22	208560
Mastewal	15	120	1800	22	39600
Total	126	-	15,120	-	332,640

A total of 126 hectares of land was planted, inspected, and approved for producing 357.7 tons of seed (Table 2) by an external regulatory agency, DSLCC. This shows the technical feasibility of chickpea seed production by the communities that can meet the seed quality standards. The seed produced by the community was sold to the cooperatives for cleaning, marketing, and distribution purposes. Most of the produced seed was used by the formal seed sector since the seed was approved by the regulatory agency. The CBSP benefited host farmers through access to new varieties and quality seed as well as acquiring seed production and marketing skills. Moreover, farmers in the vicinity also get access to quality seed of new improved chickpea varieties at the local level.

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Table 2. Chickpea seed produced by CBSP scheme

Variety	Area planted (ha)	Area inspected (ha)	Area approved (ha)	Seed yield (t ha^{-1})	Total seed produced (tons)	Straw yield (Bundle ha^{-1})	Total straw produced (Bundles)
Habru	79	79	79	2.8	221.2	3	237
Naatolii	32	32	32	3.0	96.0	4	128
Mastewal	15	15	15	2.7	40.5	3	45
Total	126	126	126		357		410

Note: One bundle = 80 kg; straw productivity of chickpea is very low since its stalks are stiff and not palatable to livestock

Profitability of chickpea CBSP

The community sold the chickpea seed to the cooperatives at 20% margin plus the farm get price. The community generated net revenue of ETB 6.85 million. Habru generated the highest net benefit while Mastewal generated the lowest (Table 3).

Table 3. Estimated costs and revenues of chickpea CBSP scheme

Varieties	Total cost incurred (ETB)	Total seed produced (tons)	Total seed revenue (ETB)	Total straw produced (bundles)	Total straw revenue (ETB)	Total revenue (ETB)	Net revenue
Habru	208560	221.2	4424000	(ETB)	18960	4442960	4234400
Naatolii	84480	96.0	1920000	128	10240	1930240	1845760
Mastewal	39600	40.5	810000	45	3600	813600	774000
Total	332640	357.7	7154000	410	32800	7186800	6854160

The total cost-benefit analysis of the seed business included total seed and crop residue produced and sold against the total variable and fixed costs incurred during chickpea seed production. All the analyses indicated chickpea CBSP improved the net farm return generated per hectare of land (Table 4).

Net Benefit (NB): The net benefit (net income) from chickpea CBSP was estimated at 408,818.47 USD while the net income (net benefit per hectare was estimated at 3,244.59USD (Table 4).

Gross Margin (GM): The gross margin of chickpea seed production and marketing was estimated as a gross income of 430,053.53 USD minus a total variable cost of 21235.06 USD, which equals 408,818.47 USD. The gross margin per hectare was 3,244.59 USD.

Benefit-Cost Ratio (BCR): The average BCR calculated for seed production was estimated as 19.25, which is very safe to invest more on variable inputs for increasing production volumes. The BCR per variety showed 20.3 for Habru, 21.85 for Naatolii, and 19.55 for Mastewal.

Breakeven Analysis: The breakeven analysis was done only for seed production. If we consider straw, it will be more profitable, and the magnitude becomes higher. All the breakeven analyses indicated below show that it is profitable to produce chickpea seed.

Breakeven yield: This is calculated as the total variable cost per hectare divided by the unit sale price (USD) of a product per 100 kg seed that gives an estimated 121 kg seed yield. The breakeven yield per variety was also equal for each variety 121 kg of Habru, Naatolii, and Mastewal.

Table 4. Cost-benefit analysis of chickpea CBSP scheme

Cost-benefit descriptions	***Values***
Total seed produced (ton)	*357.7*
Total straw produced (bundle)	*410*
Average clean seed price (USD t^{-1})	*1176*
Average straw price (USD bundle^{-1})	*3*
Gross income	
Income from sale of seed (USD)	*428823.53*
Income from sale of straw (USD)	*1,230*
Total gross income (USD)	*430053.53*
Gross Costs	
Total variable cost (USD)	***19560.06***
Total variable cost (USD ha^{-1})	*155.24*
Total fixed costs (USD)	*1,668*
Total fixed cost (USD ha^{-1})	*13.24*
Total production cost (USD)	*21235.06*
Total production cost (USD ha^{-1})	*168.53*
Total net income (USD)	*408818.47*
Net income (USD ha^{-1})	*3244.59*

Note: one USD = 27 ETB

Breakeven price: This is calculated as the total variable cost per hectare in USD divided by the total production per hectare in terms of 100 kg. Thus, it gives an estimated price of 5.02 USD per 100 kg seed. When it is calculated for each variety, it gives 5.07 for Habru, 4.74 for Naatolii, and 5.26 for Mastewal varieties, in terms of USD per 100 kg seed.

Engagement of farmers in seed business

Farmers' willingness to participate, produce, and market quality seed under their responsibility was vital for this CBSP activity. Awareness creation and training of farmers were important to produce quality chickpea seed since 80% of the total seed produced was approved as seed and sold to the cooperative. Farmers understood local seed production and marketing as a new business opportunity and were convinced how seed business becomes important when they sold chickpea seed at a price of up to 26,000 ETB per ton compared to 18,000 ETB for chickpea grain.

Farmers' attitudes and opinions of introduced chickpea improved varieties, as well as experiences and skills in local seed production remarkably improved over time due to effective partnership, continuous training, and technical support. Market linkage, access to improved seed, and experiences in production and marketing are driving forces to motivate farmers' participation.

Sustainability of community-based seed production

Sustainability of the CBSP is critical where many stakeholders can play important roles to address farmers' seed-related problems. The initiative not only improves the approaches in local see business but also ensures sustainability and technology transfer.

Working with zonal and district administration, office of agriculture, cooperatives, and communication and mainstreaming the activity into their annual plan played a key role in mobilizing and organizing farmers, establishing the cooperative, and providing technical support and regular monitoring and evaluation.

Establishing and strengthening SPCs

Establishing SPCs is one of the ways to increase access to seed, expand the area covered with improved varieties, increase production and market participation of smallholder farmers. Training of members and leaders of SPCs and agricultural experts about quality seed production, cooperative management skills, business plan development, and the benefit of local seed business are important interventions to sustain the internal strength of the system.

The formation of SPCs had dual purposes as a local business in seed production, and technology diffusion. The CSBP and marketing activities were used as a technology shopping for diffusion and seed businesses. The community seed producers established in intervention areas helped to facilitate the adoption of improved chickpea technologies and market linkages for the seed system through SPCs. The idea of seed as a business was introduced in the locality and farmers gained market access and income from the seed business.

Farmer-to-farmer seed exchange

Farmers showed a tendency of depending on the informal seed system as it allows them to use seeds after observing on the primary adopter farmers. Therefore, in the intervention districts, more than 1306.6 ha of land was covered with the seed of improved chickpea varieties through farmer-to-farmer seed exchange that benefited 4168 (568 female) farmers (Unpublished report of district offices of agriculture, 2016) although it was not possible to fully track the exchange.

Opportunities

There is a growing demand for chickpea for domestic consumption to attain nutrition security and export markets. Changes in attitudes of farmers and other stakeholders in chickpea production is another opportunity for expanding the area and use as a rotation crop. Moreover, farmers' willingness to be organized as cooperative, and support chickpea production and introduction of new varieties ensure access to seed and more market choices. The partnership of seed experts and other actors are also opportunities for expanding to wider scale.

Challenges

Challenges encountered during the intervention include market demand which remains unpredictable for seed produced by farmers; lack of adequate branding and packaging for marketing; and budget constraint to strengthen SPCs with basic facilities (farm machinery, seed cleaners, and seed storage).

Conclusions and Recommendations

The net revenue generated from the seed business weighed to produce more Habru variety seed to maximize the potential profit. Training supports to the seed producer farmers improved their awareness and seed production skills. The strong partnership enabled the farmers to improve agronomic management and produce quality seed and improved market linkages for their produces. However, establishing and strengthening SPCs through training, technical backup, and experience sharing on seed production, post-harvest handling, marketing, and business management skills remains critical. The issues that need attention include:

- Clustering farmers' fields, engaging more farmers into seed producers, and linking them with markets and distribution systems need attention.
- Promote the success stories of community-based seed production and sharing lessons for the future wider scaling.
- Ensure continuous supply of early generation seed to sustain the local seed supply system.

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Community-Based Chickpea Seed Production and Supply in Mandate Areas of Debre Zeit Agricultural Research Center

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In Ethiopia, most chickpea producers obtain their seed for planting informally from own saved seed or through local exchange where the formal sector seed supply is limited; the mandate areas of the Debre Zeit Agricultural Research Center (DZARC) are no exceptions. Community-based seed production (CBSP) is considered an important strategy to increase farmers' access to diversified crop varieties in rural areas by bridging the gap between formal and informal sectors. DZARC initiated the community-based seed production (CBSP) activity through pre-scaling and technology multiplication with the support of ICARDA-USAID chickpea project in its mandate districts of the Amhara and Oromia Regional states.

Approach

Description of study area

A major work on chickpea technology pre-scaling up and multiplication was started by the DZARC in 2015/16. The initiative was undertaken in collaboration with different partners including Regional Research Extensions Advisory Council, researchers, farmers, administrative officials, extension workers, local NGOs, and traders. The partners and stakeholders made successful progress in testing, adapting, and promoting different chickpea technologies suitable for small-scale farming systems. The producer cooperatives that partnered for the CBSP are listed in Table 1.

Table 1. List of primary cooperatives involved in chickpea seed production

Cooperatives	Year of establishment	Members			Land owned by members
		Male	Female	Total	
Megertu Seed Producer Cooperative	2002	51	6	57	114
Kolbe Seed Producer Cooperative	2004	73	8	81	360

Interventions on seed multiplication and dissemination of improved chickpea varieties made during 2016 and 2017 main crop seasons is presented in Table 2. The target districts for seed production and scaling up of improved chickpea technologies are shown in Table 3.

Table 2. Chickpea technology pre-scaling and seed multiplication

Year	Participating farmers			Area covered (ha)	Average yield (ha^{-1})	Total seed produced (t)
	Male	Female	Total			
2016	620	80	620	133	3.03	402.99
2017	1047	359	2509	528	3.3	1,742.4
Total	1667	439	3129	661	3.165	2,145.39

Table 3. Chickpea technology multiplication districts under the DZARC

Zone	*Districts*
East Shewa	*Adea, Akaki, Lume, Gimbichu*
Arsi	*Shirka, Tiyo*
North Shewa	*Alelitu, Abote, Wara-Jarso*
Southwest Shewa	*Tulu-Bolo*
East Gojam	*Enemay, Shebel-Berenta*

Selection of the districts was based on the decadal interventions experience through participatory variety selection followed by demonstration and seed business incubation. High-yielding and disease resistant chickpea varieties of Arerti, Habru, Ejeri and Naatolii with full agronomic packages were used.

Capacity and partnership building

Popularization of technology and strengthening the chickpea seed system started with building the right attitude of actors through awareness creation and technical training. The trainings on principles and techniques of chickpea grain and seed production were given directly to farmers and seed producers as well as development agents and agricultural experts who further train other farmers.

To catalyze the uptake of improved technologies, an innovative platform of relevant stakeholders has been established. The multitasked platform provided support in identifying technology demanded, assessing product specialty options, updating market signals, evaluation of interventions and feedbacks. The national and regional chickpea stakeholders' innovation platform met annually and shared responsibilities on actions to be taken in improving technology multiplication and dissemination.

Farmers and sites selection

Farmers involved in seed multiplication were selected by district experts and kebele development agents were trained on chickpea production and field management. Training was given for district and kebele experts. Farmers clustered their farms, and then seeds of different class of chickpea improved varieties were provided for selected farmers in collaboration with zonal and district agricultural development offices. After training, the selected farmers managed their fields under close supervision of researchers, district and kebele development experts. The seed production fields were monitored and finally evaluated at maturity by group of researchers and seed certification experts from Ambo Seed Quality Control and Certification Agency.

Decentralized seed sourcing and production

To satisfy the demand for seeds of improved varieties, the informal seed system was strengthened through establishment and technical backstopping of farmer seed producer associations or cooperatives. The seed producers often were farmers who are organized and having better technical skill to undertake seed production. Such a decentralized seed sourcing approach was based on location of access by geography, volume and low transaction cost and affordability.

Seed quality assurance

Early generation seed (pre-basic seed, basic seed) and certified seed were approved in reference to quality standards set by the national seed regulation (ESA, 2012) which includes field and seed standards. Field standards were determined through field inspection while seed laboratory standards were through laboratory seed testing by seed quality control experts from Ambo Seed Quality Control and Certifying Agency.

Data analysis

Data on seed multiplication were used to show trends in seed multiplication. Descriptive statistics was applied to elaborate progresses, differences, and inferences.

Achievements

Training

Chickpea variety promotion started with awareness creation of improved varieties and training in technical capacity of the producers to enhance the seed system through early generation seed (EGS) multiplication and distribution. During 2016 and 2017, technical trainings on management of improved chickpea technologies were delivered to over 78 agricultural experts and development agents as training of trainers and technical backstopping (Table 4), who further trained over 3,700 farmers. The training themes covered chickpea research and technology in Ethiopia, chickpea production techniques (agronomy), pesticide application and safety measures, chickpea disease, insects and weeds; seed production technology, seed enterprise and financial management; and extension approaches and methods. As a result of training given actors engaged in the seed system were equipped with knowledge, skills and experience in seed production according to the standard set by the Ethiopian Standard Authority.

Table 4. Number of farmers and other stakeholders trained as trainers since 2016

Districts	*Participants*	*Number of TOT participants*	
		Male	*Female*
Ade'a	*Farmers*	*21*	*1*
Ade'a	*District experts and DAs*	*6*	*1*
Bishoftu	*Farmers*	*0*	*95*
	District experts and DAs	*8*	*3*
Lume	*District experts and DAs*	*5*	
Gimbichu	*District experts and DAs*	*5*	
Bechoo	*District experts and DAs*	*6*	
Shirka	*District experts and DAs*	*7*	
Abote	*District experts and DAs*	*6*	
Alelitu	*District experts and DAs*	*6*	
Werajarso	*District experts and DAs*	*5*	
Dera	*District experts and DAs*	*5*	
Enamay	*District experts and DAs*	*5*	
Shebel Bernta	*District experts and DAs*	*5*	
Akaki	*District experts and DAs*	*5*	
Total		*95*	*100*

Note: TOT = training of trainers; DAs= Development agents

Because of training, farmer's perception towards new improved technologies was changed and they were willing to adopt new chickpea varieties. Seed producer farmers adopted the knowledge acquired and managed to produce quality seed by clustering fields and applying the principles and procedures of seed production. Farmers managed up to 40 ha cluster for seed production which created an opportunity for mechanization. The produced seed fulfilled the field and laboratory seed standards, and approved by the certification agency, which enabled the two seed producer cooperatives to market certified seed using their own brands. Strengthening the capacity of farmers and stakeholders motivated some outstanding farmers to form farmers' groups, some of which evolved into small-scale formal private seed companies and seed producer cooperatives. This concept is explained by Ojewo et al (2015).

EGS production

The quantities of chickpea breeder and pre-basic seeds produced by DZARC from 2012/13 to 2014/15 before ICARDA-USAID chickpea project intervention are summarized in Table 5. Limited capacity of the agricultural research centers (land, manpower and finance) largely constrained the availability of early generation seed. Therefore, the involvements of national and/or international projects contributed towards addressing the shortage of the seed. Since the start of the project ICARDA-USAID chickpea project in 2015, the capacity of DZARC and seed producer cooperatives to produce breeder, pre-basic, basic, and certified seed to enhance the availability of seeds of released varieties significantly increased (Tables 6- 8).

Table 5. Production of pre-basic and basic seed of selected chickpea varieties by DZARC in 2012/13-2014/15 (prior ICARDA-USAID chickpea scaling project)

Year	*Quantity of seed produced (tons)*	
	Pre-basic	*Basic*
2012/13	*13.215*	*17.323*
2013/14	*12.18*	*12.343*
2014/15	*4.774*	*28.995*
Total	***30.169***	***58.661***

Table 6. Production of breeder, pre-basic and basic seed of selected chickpea varieties by DZARC from 2015-2017 (during ICARDA-USAID chickpea scaling project)

Year	*Quantity of seed produced (tons)*		
	Breeder	*Pre-basic*	*Basic*
2015/16	*0.289*	*21.61*	*3.804*
2016/17	*20.571*	*5.0*	*32.461*
2017/18	*7.381*	*30.10*	*7.381*
Total	***28.241***	***56.71***	***43.646***

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Seed production by SPCs

Engaging SPCs in chickpea seed production is one of the alternative ways to increase the availability of quality seed. During the project two SPCs, Megertu and Kolbe SPCs were engaged in chickpea seed production and marketing (Tables 6-8).

Table 7. Amount of basic and certified seed produced by SPCs in 2016 and 2017 during ICARDA-USAID chickpea project

Year	*Quantity of seed produced (tons)*	
	Basic seed	*Certified seed*
2015/16	*364.42*	*255.82*
2016/17	*338.76*	*203.86*
Total	*338.76*	*203.86*

Because of the effort made in decentralizing seed multiplication and improving the capacity of seed producer cooperatives, the availability of chickpea seed and the capacity of the farmers were enhanced. The success of DZARC in producing breeder and pre-basic seed showed an increasing trend in the volume compared to two years before the launch of the project. Similarly, the availability of basic seed increased by 12.6 folds because of additional and decentralization of basic seed production by SPCs (Tables 5 - 8). Thus, improving the seed delivery system and scaling up/out of improved production technologies would have an impact on the livelihoods of the farmers and other value chain actors.

Table 8. Comparison of seed production capacity among cooperatives and DZARC for different seed classes during 2016 and 2017

Year	*Seed producer*	*Quantity of seed produced (tons)*			
		Breeder	*Pre-basic*	*Basic*	*Certified*
2012/13	*DZARC*		*13.215*	*17.323*	
2013/14	*DZARC*		*12.18*	*12.343*	
2014/15	*DZARC*		*4.774*	*28.995*	
2015/16	*DZARC*	*0.289*	*21.61*	*3.804*	
2016/17	*DZARC*	*20.571*	*5.00*	*32.461*	
2017/18	*DZARC*	*7.381*	*30.10*		
	Sub-total	***28.241***	***86.879***	***94.926***	
2015/16	*SPCs*			*364.42*	*255.82*
2016/17	*SPCs*			*338.758*	*203.861*
	Subtotal			***703.178***	***459.681***
	Total	***28.241***	***86.879***	***798.104***	***459.681***

Note: SPCs = Seed producer cooperatives or community seed growers

From the total amount of 1284.075 tons of seed produced under the supervision of DZARC since 2016, about 90.6% was produced by the SPCs (Tables 6- 8). The quantity of basic seed produced (703.178 tons) by the two cooperative was found to be about 8-fold of the amount of pre-basic and basic chickpea seed produced by DZARC during the three years (2012/14 – 2014/15) before the start of producing chickpea basic seed with the cooperatives.

Conclusions and Recommendations

Farmers also realized that producing seed is a profitable business. The contribution of the pre-scaling activities so far undertaken in DZARC mandate areas to strengthen the informal seed sector to be the major supplier of chickpea seed in the country has been remarkable.

However, for better use of community-based seed multiplication, investment in basic infrastructure is required like development of technical skill of the farmers, access to rural road, farm machinery (mainly combiner and cleaner), storage facilities, and market linkage and credit facility mainly for commercial farmers. There is a need for central and state level institutions to plan and give proper direction to the strengthening of community seed multiplication program in Ethiopian to enhance the availability of chickpea seed.

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Improving Quality-Seed Supply of Chickpea in Belesa Area, North Gondar Zone

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West Belesa and East Belesa districts in North Gondar zone are potential chickpea production areas in the Amhara region. Most of the rural population in these districts are dependent on sorghum, teff and chickpea as the major food crops grown and consumed. Seed production of improved chickpea varieties in the area was minimal and could not satisfy the demand by smallholder farmers. Farmers use local varieties that are susceptible to wilt and root-rot disease complexes and use own saved seed for planting. To overcome the problem, seed producer cooperatives were established soon after field demonstrations on improved chickpea varieties. However, the seed producer cooperatives required further support as they had technical, financial, and infrastructural limitations. To support such engagement, USAID-ICARDA chickpea project worked for three years (2015-2018) with an objective of increasing seed production and boosting chickpea productivity and improve livelihoods of smallholder farmers in the two target districts.

Methodology

Area description

Bothe West Belesa and East Belesa districts are in Central Gondar zone. West Belesa is a lowland with elevations of 800 to 1100 masl. The average annual total rainfall is 611.7 mm. The rainy season occurs from June to September having peaks in months of July and August. The minimum and maximum temperatures are 12^{o}C and 36.2^{o}C, respectively. Vertisols is the major soil type of the study areas in the district.

The altitude in East Belesa district ranges from 1200 to 1800 masl. The rainfall and minimum and maximum temperatures are like that of West Belesa. Tef and sorghum are the dominantly cultivated crops while maize, chickpea, food barley and field pea are also being cultivated.

Early Generation Seed production

There was no agricultural research station in both districts, hence GARC produced the breeder and pre-basic seed at Delghi Station in Takussa district. Since the seed produced at this station was not enough, GARC through the support of the project, purchased additional pre-basic seed every year from Debre Zeit Agricultural Research Center (DZARC) for distribution to CBSP farmers.

Community-Based Seed Production (CBSP)

Farmers in the two seed-producer cooperatives at Qalay and Diquana kebeles were used for CBSP. The host farmers were selected from these two seed producer cooperatives based on their willingness to participate in seed production and suitability of land for clustering fields.

After training, GARC delivered pre-basic seed of chickpea and rhizobium packs to farmers based on their farm size and agreement to return the seed after harvest in kind. In every following year, when the seed production was shifted to other clusters, farmers in the former cluster that produced chickpea seed were given sorghum and/or tef improved seeds to maintain crop rotation in the farming system. To keep the continuity of the seed delivery, farmers who received seed from GARC should return in kind soon after harvest in a revolving seed scheme. The seed collected from farmers was provided to new farmers to disseminate improved varieties and increase chickpea productivity and production. All these activities were carried out in collaboration with the district office of agriculture and operational participation of the development agents of the kebele.

Training and field days

Trainings were provided for farmers who participated in the seed production to create awareness and bridge knowledge and skill gaps in seed production in general and specifically chickpea seed production.

Every year, field days were organized and different stakeholders in chickpea seed value-chain were invited to create awareness and enhance experience sharing and strengthening linkages among actors in the value chain.

Crop management

Agronomic practices starting from seedbed preparation to harvesting were implemented according to the production packages through close follow up of the responsible GARC research staff and development agents of the respective kebeles. The seed rate used for Kabuli varieties was 120 kg ha^{-1} whereas 75 kg ha^{-1} was used for desi varieties. Since chickpea production is during the main rainy season, the varieties were planted in the third week of July and harvested from late October to early November. In cases where high infestations of boll worm, Helicoverpa armigera, appropriate insecticides were applied with the recommendations and supervisions from the responsible researchers of GARC.

GARC also promoted biofertilizer application as part of the crop management where rhizobium strain namely EAL-029 for chickpea obtained from Menagesha Biotech Industry PLC was used. Chickpea rhizobium inoculant packs at the rate of 125 g pack for a quarter of a hectare was provided to farmers for which the cost was covered by the project for the first time users only.

Inspection and certification

The seed quality assurance and certification office in Gondar conducted the seed certification. Each production season, two field evaluations were conducted by seed quarantine and evaluation office. The two cooperatives purchased seed from individual member farmers who got chickpea seed production fields inspected and approved. Further inspection of seed in store was made to get approval and certification. Thus, cooperatives that received certification sold seed at additional premium price for further dissemination.

Achievements

EGS production by GARC

Breeder and pre basic seeds were multiplied during 2015–2017 at Delghi Station in Takusa district (Table 1). Breeder seed of 0.261 tons of four varieties such as Habru, Arerti, Naatolii and Teketay was produced on 0.175 ha land. The breeder seed production was carried out for variety maintenance and for further multiplication to pre-basic seed of chickpea varieties being demanded by farmers. Pre-basic seed of Habru, Arerti and Naatolii chickpea varieties were also multiplied on 0.19 ha land and produced 0.36 tons of seed. The low-level of production is attributed to the waterlogging problem of the station where the seeds were produced.

Table 1. Early generation chickpea seed production at Delghi Station by GARC during 2015-2017 main cropping season

Seed class	Variety	2015		2016		2017	
		Area (ha)	Seed produced (tons)	Area (ha)	Seed produced (tons)	Area (ha)	Seed produced (tons)
Breeder seed	Habru	0.005	0.01	0.04	0.021	0	0
	Arerti	0.005	0.01	0.04	0.014	0.015	0.011
	Naatolii	0.005	0.01	0.02	0.029	0.025	0.084
	Teketay	0	0	0	0	0.02	0.072
Total		**0.015**	**0.03**	**0.1**	**0.064**	**0.06**	**0.167**
Pre-basic seed	Habru	0.015	0.116	0.05	0.014	0	0
	Arerti	**0.015**	**0.1115**	**0.05**	**0**	**0**	**0**
	Naatolii	0.01	0.074	0.05	0.047	0	0
Total		**0.04**	**0.3015**	**0.15**	**0.061**	**0**	**0**

Community-based Seed Production

From seed produced by GARC and purchased from DZARC through financial support of ICARDA-USAID chickpea project, 7.76 tons of seed were distributed to 115 male and 14 female farmers and covered about 55.5 ha of land in 2016 and 2017 cropping seasons (Table 2). About 2750 chickpea rhizobium inoculant packs were also distributed to 899 (63 female) farmers (who received seed for CBSP and other interested chickpea producer farmers to promote the technology and covered about 630 ha.

Table 2. Quantity of seed distributed for community-based seed producer farmers in East Belesa and West Belesa districts

Year	Variety	Seed class	Amount (tons)	Area covered (ha)	Participants	
					Male	Female
2016	Habru	Pre-basic	4.21	30.08	65	9
2017	Habru	basic	2.8	20.0	42	3
2017	Ejeri	basic	0.75	5.4	8	2
Total			**7.76**	**55.48**	**115**	**14**

Seed produced using CBSP during 2015-2017 was the cumulative production of all farmers in the cluster (Table 3). Thus, 173.24 tons of seeds of Habru and Ejeri chickpea varieties were produced on 87.48 ha land.

Table 3. Community-based seed production of chickpea varieties during 2015-2017 main cropping seasons in East and West Belesa districts

Variety	Seed class	2015		2016		2017	
		Area (ha)	Production (tons)	Area (ha)	Production (tons)	Area (ha)	Production (tons)
Habru	basic	30.08	60	32	63.47	20	38.97
Ejeri	basic	0	0	0	0	5.4	10.8
Total		30.08	60	32	63.47	25.4	49.77

Farmers sold their seeds to seed-producer cooperatives at Qalay and Diquana kebeles at premium prices. After inspecting and laboratory testing of seeds in store, the cooperatives got the approval and certification to sale the seeds. Tsehay Union and Amhara Seed Enterprise were the main customers which purchased the certified seed from the two cooperatives.

Member farmers of the two cooperatives usually did not sell all the seeds they produced; instead, they reserved some seeds for the next season for themselves and exchanged some of it with other farmers in kind or cash (Table 4).

Table 4. Farmer to farmer seed exchange of chickpea in East Belesa and West Belesa districts

Districts	Variety	Amount of exchanged seed (ton)	Farmers who get seed through exchange	
			Male	Female
West Belesa and East Belesa	Ejeri	0.011	3	0
	Habru	8.945	213	35
Total		**8.956**	**216**	**35**

Training and field days

Trainings were given for those farmers who participated in CBSP and for those who received rhizobium sachets for chickpea production. The training covered techniques and procedures of chickpea seed production, pest management, rhizobium inoculation, and seed marketing and collaboration for seed production.

Experts from Tsehay Union were invited for the training and during the field days with an aim to create market linkages with the union. Participants from Amhara Seed Enterprise were also invited in the training and field days to observe the production fields and production system to make a market linkage with the enterprise.

Three field days were organized and attended by 480 farmers, 64 zonal and district level experts and development agents, and 37 researchers (Table 5). Experiences on the seed multiplication were shared, and market linkages established to reinforce future engagements in seed production. Participants discussed on the challenges and opportunities on chickpea

seed production to learn from past events and to indicate the ways to establish sustainable seed production and marketing scheme at local level. Because of the linkages made among the cooperatives, Tsehay Union and Amhara Seed Enterprise, the latter two purchased chickpea seed from the cooperatives during the two years.

Table 6. Field day participants of chickpea seed production fields in East Belesa and West Belesa districts

Field day participants	2015		2016		2017	
	Male	Female	Male	Female	Male	Female
Farmers	49	4	245	43	126	13
Zonal and district experts and DAs	9	2	33	10	7	3
Researchers (excluding trainers)	0	5	22	0	8	2
Total	**58**	**11**	**300**	**53**	**141**	**18**

Note: DAs= Development agents

Challenges

- Lack of source seeds for provision to cooperatives due to the limited capacity of GARC, which was mainly attributable to land shortage for producing breeder and pre-basic seeds.
- Limited capacity of the cooperatives to collect all the produced seed from farmers. This is because the cooperatives have shortage of storage facilities and limited financial capacity to buy and process all the seed produced.
- Diseases and insect pests were the biggest challenges. Cotton ball worm and cutworm are the major insect pests while wilt and root-rot are the diseases that occur every year and challenging chickpea production.

Opportunities

- Increasing trend of chickpea production area across years at the average annual growth rate of 2.1% (Kassie *et al*., 2009) would increase seed demand that calls for strengthening and establishing CBSP scheme.
- East Belesa and West Belesa districts are very suitable for chickpea production in North Gondar zone (CSA, 2017) that every effort should be made to exploit their potential. Farmers have interest to produce seed and participate in chickpea seed and grain marketing.

Way forward

- Rapid technology generation in variety development, pest management, and fertility management are crucial. This calls for strengthening the capacity of GARC in terms of land and physical facilities and skilled work force.
- Concerted effort of governmental and non-governmental actors is required to build and strengthen the capacity of seed producer cooperatives and unions for enhancing sustainable seed production and supply. Emphasis should be given to fulfil basic facilities that are required for maintain seed quality standards and marketing, and timely available liquidity fund for seed purchase.

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Enhancing Chickpea Seed Production Through Irrigation in the Lowlands of North Wollo Zone

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Chickpea productivity under rainfed conditions is low and subject to substantial year-to-year fluctuation due to erratic rainfall distribution (Pasandi *et al*., 2014). On the other hand, irrigated agriculture can play a major role in reaching the broader development vision of the country in achieving food security, poverty alleviation and improvement in livelihood of end-users (Tilahun *et al*., 2008).

Kobo district, North Wollo Zone, has a high irrigation potential for chickpea seed production. According to Kobo-Girana Valley Irrigation Program (KGVIP), there is more than 1200 ha of land cultivated by farmers with well-organized irrigation scheme to produce triple crops per year. Farmers in produce three different crops per season, tef-chickpea-onion or maize-chickpea-onion or sorghum-chickpea-onion. Almost all farmers produce desi type local chickpea variety, which is low yielder (0.7 – 1.0 tons ha^{-1}) and susceptible to Ascochyta blight disease. Due to these productivity limitations of the local chickpea variety, farmers are not maximizing the benefits of the multiple cropping system in Kobo-Girana valley. Therefore, to increase production and productivity of chickpea in this area, there is a need to use adapted and improved chickpea varieties with higher productivity and disease tolerance. Thus, enhancing chickpea seed production in the irrigated production system in the lowlands of North Wollo was initiated with the objectives of increasing production and productivity of chickpea and livelihood of farmers in the target areas.

Approaches

Study area description

Kobo district lies between 10°8'21"N latitude and 39°18'21"E longitude with altitude of 1450 masl. Average annual rainfall is about 637 mm. The minimum and maximum, respectively are 15.8°C and 29.1°C. The soil type is Eutric Fluvisol.

The seed production was conducted in the lowlands of Kobo district at Kobo-Girana Valley Irrigation Project (KGVIP) in North Wollo zone, Amhara region. At Kobo, the major crops grown under rainfed production are sorghum, tef, and chickpea whereas onion, chickpea and tef are the major crops grown under irrigation sequentially as triple-crop production per year. The irrigation water source is deep well ground water, which is managed and scheduled by KGVIP being governed by regional office of agricultural development. Out of the total 57 projects, 30 of them produce chickpea. Kobo-Girana valley represents the major chickpea growing areas in the irrigation production system of North Wollo zone. Table 1 provides additional description of the target location.

Description of chickpea variety

Habru variety is Kabuli chickpea released by Debre Zeit Agricultural Research Center (DZARC). Habru, released in 2004, is recommended for altitude range from 1450-2600 masl and matures within the range of 91-150 days. On-station grain yield ranges from 1.4-5.0 tons ha^{-1} whereas on-farm yield with farmers management ranges from 2.0–4.0 tons ha^{-1}. Sirinka Agricultural Research Center (SnARC) evaluated its adaptability during 2010 through participatory variety selection and recommended it for production in the study area based on its performance and farmers' preference. Harbu variety is bold seeded, which is preferable for export market; its 100 seed- weight is more than export standard size (100 seed weight > 35 g). In addition, it is also resistant to ascochyta blight disease which is a common threat in the chickpea producing lowlands.

Sites and farmers selection

KGVIP site was selected based on irrigation schedule and chickpea production experience in the district. Similarly, farmers with chickpea production experience were selected. These farmers have rich experience of triple cropping of tef-chickpea–onion production in a single year.

Crop management

Farmers, through supervision by responsible staff of KGVIS and SnARC, implemented most of the farm activities. The period between planting up to harvesting was from mid-November up to end of February. All agronomic practices such as row planting, irrigation frequency, and weeding were applied by the farmers with the supervision of staff of KGVIP and SnARC. There is no fertilizer application for chickpea production.

Training and field days

Training was given to farmers, district agricultural development experts, kebele agricultural development agents, KGVIP leaders, and researchers to create awareness and bridge knowledge gap in improved chickpea seed production, pre- and post-harvest crop management, its food value and utilization.

During maturity stage of chickpea, field days were organized to create awareness and experience sharing, marketing, and enhancing demand for further promotion of improved chickpea production at wider scale in KGVIP areas.

Achievements

Training

A two-days training was provided to 152 farmers (31 females), 12 development agents (4 females) of kebele agricultural development office, 2 experts of district agricultural development office, 2 coordinators/leaders of KGVIP, and 6 researchers of SrARC (Table 3). The training topics covered irrigation production system, chickpea seed production, export value of the large seeded kabuli-type chickpeas, pre- and post-harvest crop management, and its food value and utilization. Before the training, most of the farmers were not aware of kabuli-type chickpea and its food value. Therefore, different food types were prepared from grain of Kabuli chickpea variety, Habru and served to training participants (Figure 1). This approach significantly improved the acceptance of the kabuli-type chickpea by the producers.

Figure 1. Different food types prepared from Kabuli-chickpea var. Habru

Source seed provision

After training, the 7.56 tons seed of Habru variety, which were purchased from seed producer cooperatives in the mandate areas of DZARC, were distributed to 189 farmers (52 female) that covered 54 ha of irrigated land (Table 3). The seed distribution was done based on the agreement that each farmer who received the improved seed for multiplication should return after harvesting equal quantity in kind for revolving seed scheme and should also disseminate the seed at least to five interested farmers through seed exchange, in kind or sale.

Field days and media promotions

Field days were organized at maturity stage of the chickpea seed production fields; 251 farmers (4 female), 3 researchers, 15 development agents (3 female) of kebele agricultural development office, 2 leaders and experts of Kobo district agricultural development office, and 2 coordinators/leaders of KGVIP participated (Figure 2, Table 3). After observing the performance of Habru variety in terms of higher yield and disease tolerance, farmers promised to popularize the variety for non-participant farmers. They also suggested to enhance and popularize Kabuli chickpea marketing and utilization as the crop not yet well known in the surrounding markets and users. SrARC and KGVIP took the responsibility of popularizing the market and food use of the Kabuli chickpea to the surrounding markets and consumers.

In addition to the field days, the Amhara Mass Media Agency through its Television and Radio Programs promoted the performance of the irrigated chickpea seed production (Figure 3). The mass media broadcast news coverage was for 3.29 and 3.20 minutes on television and radio, respectively.

Figure 2. Participant farmers and stakeholders during field day visits and discussions at KGVIP in 2017

Figure 3. Media broadcast of irrigated chickpea seed production in KGVIP by Amhara Television (picture from video in 2017)

Seed production and dissemination

A total of 189 seed producer farmers planted Habru variety on 54 ha of land and produced 108 tons of seed (Table 1). Figure 4 shows the field performance of one of the seed production clusters of Habru variety in KGVIP. The seed production activity increased not only the productivity and production of chickpea in the area but also enhanced farmers' experience and awareness through training, field days, seed revolving scheme and farmer-to-farmer seed exchanges. Introducing chickpea served as a break crop to improve soil fertility and soil health that improves production system productivity and sustainability.

Seed producer farmers served as seed source for neighboring farmers, and served the offices of agricultural development from the region to kebele level to facilitate seed dissemination among kebeles, districts and zones, NGOs and investors. The awareness created demand from farmers where the price of seed of improved variety was 25 ETB kg^{-1} compared to that of the local chickpea which was 12 ETB kg^{-1}. In 2018 cropping season there was high demand for chickpea due to high incidence of stalk borer on sorghum compared to the previous years. Thus, chickpea became replacement crop for sorghum which failed due to damage by stalk borer. Farmer-to-farmer seed exchange benefited 945 farmers although it was not fully tracked and recorded (Table 1).

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Table 1. Summary of improved chickpea seed production activities in KGVIP

Activities	Amount	Participants		Remarks
		Male	Female	
Total planted land area (ha)	54	137	52	Farmers directly participated in seed production
Total planted seed (tons)	7.56			Planted in mid-November as part of triple cropping system per year
Trainees	**174**	**139**	**35**	**Total participants**
• Farmers	152	121	31	Kabuli chickpea seed production under irrigation and food preparation
• Experts and extension agents	16	12	4	
• Researchers	6	6	0	Participated as trainers and organizers
Field day participants	**273**	**266**	**7**	**Total number of participants**
• Farmers	251	247	4	Farmers shared their experience and increased demand to produce variety under irrigation
• Experts and extension agents	19	16	3	Took responsibility to popularize Habru variety in other irrigated areas
• Researchers	3	3	0	Participated as organizers
Seed produced (tons)	108			All 189 farmers seed production
Minimum number of farmers received seed through farmer-to-farmer exchange	945			Each seed producer exchange seed to 5 other non-participant farmers through barter or sale
Media coverage	3.29 (TV) & 3.20 (Radio)			Amhara Mass Media Agency coverage on TV and Radio program

Figure 4. Seed production cluster of Habru variety in KGVIP in 2017

Conclusion and Recommendation

The chickpea seed production in KGVIP in Kobo district of North Wollo zone was conducted to increase the productivity and production of chickpea in the cereal (tef/sorghum)-legume (chickpea)-vegetable (onion) triple production system. Habru variety performed best, and it was accepted by farmers in the triple cropping system. Therefore, the results suggest that further seed production and scaling up of Harbu should be continued to increase productivity and production of chickpea in KGVIP and similar irrigable areas.

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CHAPTER 4

CHICKPEA TECHNOLOGY MULTIPLICATION AND SCALING

Pre-scaling of Improved Chickpea Technologies through Community-Based Seed Production in Western Amhara Region

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Chickpea seed system is mostly informal that does not satisfy farmers' needs. The system needs to become more market oriented, starting with better adoption rates of improved varieties (Asfaw *et al*., 2010). In addition, the parastatal seed system produces insufficient amounts and quality of seed, and there are problems with timely delivery. A revolving seed scheme could improve seed accessibility for farmers. Another constraint for growing chickpea is that large-seeded Kabuli-type varieties are popular for their green pod consumption that additional labor is required for guarding the fields (Asfaw *et al*., 2010).

Traditional varieties, grown for national use are the desi-type chickpea varieties. Kabuli-type chickpea varieties are both for national use and for export. EIAR in cooperation with ICRISAT and ICARDA has led to the release of improved desi- and Kabuli- chickpea varieties (Shiferaw and Teklewold, 2007). Moreover, Adet Agricultural Research Center (AdARC) made effort on chickpea research and released improved chickpea varieties in collaboration with the national agricultural research system and international organizations.

Demonstration and promotion of improved chickpea varieties including Arerti, Shasho, Mariye and local was conducted; Arerti variety was most preferred by farmers and gave the highest yield. Based on the demonstration and promotion result, pre-scaling up activity through community-based seed production system was conducted for three consecutive years (2015/16 to 2017/18 cropping seasons) through the support of ICARDA-USAID seed production and scaling project. The objectives were to:

- Create wider demand with the pre-scaling up chickpea technologies
- Create and strengthen linkage among potential actors of chickpea production
- Enhance chickpea technology multiplication and dissemination

Materials and Methods

Description of the study areas

Chickpea pre-scaling was carried out for three consecutive years (2015/16 to 2017/18 cropping seasons) at Enemay (Bichena Debir, Banja-Sherer, Mankorkoya, Denssa Enekora, Sekele and Endeshignit kebeles) and Yilmana-Densa (Goshiye, Kililit, Debremawi and Adet-Hana kebeles), and for one year (2017/18) at Enarj Enawuga (Dayateba, Tamodewaro and Dejagimana kebeles) district in Amhara Region (Figure 1).

Enemay woreda: The major crops grown in the district are tef, barley, wheat, maize, sorghum, chickpea, grass pea, faba bean, and field pea (EWOA, 2016). Chickpea is grown in the mid-highlands, using the residual soil moisture and planting is usually practiced in September to October (mostly in mid-September) depending on the time the rain ceases,

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and harvested in January. Most farmers' practice barley-chickpea double cropping system; they plant barley at the end of May or first week of June that is harvested in September when chickpea is planted on the same piece of land.

Yilmana-Densa district: Mixed crop-livestock agriculture is the main agricultural system and major crops grown include teff, bread wheat, maize, barley, potato, chickpea, faba bean, field pea, and finger millet. Chickpea is being produced in the residual soil moisture system in which plating is practiced in September to November (mostly end of September) and harvested in January. Farmers do practice haricot bean-chickpea, tef-chickpea and barley-chickpea double cropping system depending on the rainy season.

Enarj Enawuga district: Major crops grown include tef, barley, wheat, chickpea, grass pea, faba bean, and field pea. Chickpea production is widely practiced by farmers using small seeded desi-type local varieties on the residual soil moisture production system in which tef-chickpea double cropping is common.

Table 1. Description of Enemay, Yilmana-Densa and Enarj Enawuga disitrcts

Description	Enemay	Yilmana-Densa	Enarj Enawuga
Geographic location	East Gojam	West Gojam	East Gojam
Total area and cropping pattern (ha) • Annual crops • Perennial crops • Grazing lands • Forest land and shrubs • Other uses	76,265 • 51,652 ha • 2,521 ha • 5,446 ha • 3,045 ha • 13,583 ha	99,180 ha • 46,097 ha • 109.09 ha	
Altitude (masl)	1600-3600	1800-3200	1100-3200
Annual rainfall (mm)	900-1150	1051.8-1488.2	700-2000
Rainfall pattern	Unimodal	Unimodal	
Temperature (^{0}C)	21	8.8-25.2	8 – 25
Soil type	Vertisol (75%)	65% red, 20% black and 15%	30% black, 24% brown, 25% red and 21% grey (sandy)

Source: EWOA, 2016; YDWOA, 2016; and EEWOA, 2016

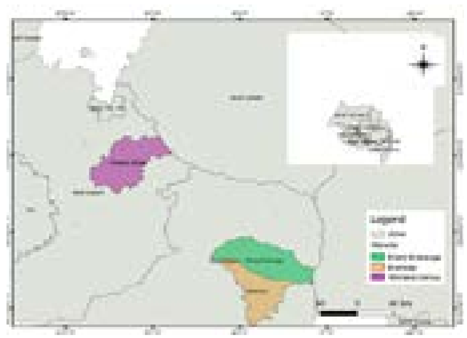

Figure 1. Maps showing the relative position of chickpea pre-scaling up intervention districts in Amhara region

Farmers' selection and site clustering

Host-farmers selection and land clustering was done in collaboration with agricultural extension agents and farmers themselves. A total of 650 host farmers, each allocating land size of 0.125 to 0.75 ha for chickpea, were selected based on their willingness and interest to participate in the pre-scaling up activity. These farmers were selected after awareness was created and mobilization was made by agricultural experts and researchers. As much as possible, host farmers' lands were clustered for facilitating operations such as monitoring and evaluation, exchange of feedbacks, and seed inspection.

Agronomic practices

Chickpea variety, Arerti, was used for the pre-scaling up activity in all locations. A seed rate of 125 kg ha^{-1} with fertilizer rate of 121 kg ha^{-1} DAP and/or NPS (nitrogen, phosphorous and sulphur) was used. All DAP or NPS was applied at planting time. The biofertilizer (inoculants) used was MBI-CP EAL-029 strain, bought from Menagesha BioTech Private Limited Company.

Technology dissemination

The technology dissemination and promotion pathways used, and procedures followed for this chickpea pre-scaling up activity include establishment of Innovation Platforms (IPs); capacity building (training); partnership arrangement and sharing of responsibilities; joint planning, implementation, and monitoring and evaluation; enhance community-based seed production system; and creation of market linkage with farmers' cooperatives (unions).

On-station and/or early generation seed production of improved chickpea varieties was part of the pre-scaling up activity to enhance sustainable seed supply and delivery.

Multidisciplinary team establishment

A multidisciplinary team of researchers that consists of economists, research-extensionist, seed experts, breeders, agronomists, and crop protection specialists was established; these represented research staff of the implementing research center, AdARC, for providing training, field monitoring and evaluation, feedback collection, and organizing and facilitating events such as field days and workshops.

Innovation platforms (IPs) and linkage

Innovation platforms (IPs) that comprise AdARC, office of agriculture from region to kebele level, farmer's primary cooperatives and unions and seed agencies were established and functional in planning, implementing, and evaluating the whole process of the activity through regular meetings, field days, and workshops. The IP members discuss on achievements, planning, problems encountered, and suggest future directions. Based on this, it was tried to create linkages among partners for sustainability in production and marketing.

Partnership arrangement

The role and responsibility of different stakeholders in technology pre-scaling up and modality for partnership was properly designed and agreed before the implementation of the activity and the detail roles and responsibilities of each actor was defined. Thus, memorandum of understanding was signed among research, office of agriculture and farmers' cooperatives

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union. Focal persons from offices of agriculture were assigned in each intervention site at district and kebele levels.

Adet Agricultural Research Center (AdARC): AdARC was responsible for coordination and facilitation; delivery of initial seed of improved variety; provide training and organizing field days and IPs meetings/workshops; organizing and facilitating joint monitoring and evaluation events with stakeholders. This approach helped AdARC to build effective and efficient coordination and collaboration among stakeholders to ensure a smooth flow of information and knowledge about the technologies among stakeholders for future wider dissemination and sustainability.

Farmers: Farmers are the ultimate users of any technology generated and transferred and are core and primary stakeholders particularly in pre-scaling up activity. The major role of farmers in the process of pre-scaling up was providing their own labor and land for the implementation of the activity. Moreover, they were participating in planning, implementation, and evaluation of activities.

Office of Agriculture (regional, zonal, district, and kebele level): They are the main responsible government organization for implementing technology dissemination and transfer and were facilitating site (host farmers) selection, and mobilizing farmers for technology evaluation, training, and field day events. The agricultural office also participated in the joint monitoring and evaluation events, and closely monitored the implementation process of the activity by each hosting farmer.

Ghion Farmers' Cooperatives Union: Its main roles included serving as input (seed and mainly fertilizer) source for farmers and facilitating grain and seed marketing through agreements reached and signed. It collected and purchased seed produced by farmers that passed inspection for seed quality certification.

ICARDA: Apart from overall coordination in implementing the project it provides funds and initial technologies (seeds, inoculants), participated in joint monitoring and evaluation events, and organized training of trainers and annual review and planning workshops.

Training and field days

Multidisciplinary team of researchers from AdARC gave theoretical and practical (on-field training) trainings to farmers and experts (zone, district and kebele experts of agricultural development offices, and experts from cooperatives) on chickpea production and marketing, and extension approaches. Field days were organized towards the maturity stage of the crop by inviting different stakeholders.

Joint planning, imlementation, and monitoring and evaluation

Team of researchers, agricultural development extension staff (regional, zonal, district, and kebele level), farmers' cooperatives/union experts, and farmers jointly monitored and evaluated the implementation of the planned pre-scaling up activity at least two times per production season for each year. Forums were organized for joint planning and review of progress. During monitoring and evaluation (M&E), implementation in terms of application of agronomic packages by farmers and any challenges and constraints were assessed and solutions were suggested according to each actor's roles and responsibilities. Moreover, ICARDA-USAID project arranged travelling workshop on chickpea pre-scaling up achievements and experiences across each implementing research institutions/centers in the country so that researchers, experts and farmers were able to exchange ideas from different perspectives.

Community based seed production schemes

In addition to the pre-scaling up activity, it was attempted to produce and make quality seed available locally for own use and/or sell for surrounding farmers' or beyond. Farmers were organized into groups as seed producers and marketing cooperatives to produce seed that can be cleaned, bagged, and prepared for sale to the formal sector or for local exchange. This was facilitated by the already available farmers' cooperative offices in most cases.

Seed quality inspection: The AdARC usually worked with quarantine offices for seed quality control and certification of the pre-scaling up and community-based seed production activities. AdARC requested formally for the plant quarantine and inspection office of each zone of Amhara region for inspection and certification of seed produced. The request letter provides information on the area planted under each variety, seed class, number of participant farmers producing the seed of each variety, cropping history of land and crop management practices. Plant quarantine and inspection office, after the final stage of evaluation, formally notify the inspection result and certification.

Market linkage: AdARC in collaboration with office of agriculture, made farmers to sign agreement with Ghion Union prior to harvest so that famers could sell chickpea seed that was certified by quarantine office.

Tracking farmer to farmer seed exchange: Farmer-to–farmer seed exchange was promoted and recorded by development agents in each kebele every year to enhance technology dissemination, and to assess technology demand of farmers for future research and development.

Data collection and analysis

Qualitative and quantitative yield-related and social data were collected. Yield data were collected after harvesting by taking quadrant plot sampling technique and using survey checklists. Number of farmers participated in training, field visits and field days were collected by disaggregating by gender. Social data like role of farmers and other stakeholders in technology promotion, change in level of knowledge and skill of farmers, and farmers' opinion/perception of the technology promoted were collected. Additional social data on opinions/feedbacks of farmers and experts were collected during monitoring and evaluation, experience sharing and field day events as well as during innovation platform and joint planning meetings.

Direct field observation; individual host farmer interview using checklists; participatory data collection using focused group discussion (FGD), key informant interview (KII) of elders and experts, and knowledge and attitude test using Liker scale were some of the methods of data collection.

Data analysis was done using simple descriptive statistics such as mean, maximum, and minimum values of quantitative data. Social data (opinions/feedbacks of farmers and experts were simply qualitatively described and classified by themes and contents. Some social data were also analysed using Likert scale.

Results and Discussions

Early generation seed production

Early Generation Seed of different seed class was multiplied and used for variety maintenance and seed multiplication as well as for the pre-scaling up activity. The seed production was carried out on-station with close follow up of researchers. A total of 10.6 tons of EGS of five improved chickpea varieties was produced on 8.74 ha of land and used for seed maintenance and pre-scaling up purposes (Table 2).

Table 2. Early generation seed production of chickpea varieties during 2015-2017

Seed class	Varieties	Area (ha)				Seed produced seed (tons)			
		2015	2016	2017	Total	2015	2016	2017	Total
Breeder seed	Teketay, Dalota, Ejeri, Habru and Arerti	0.09	0.06	0.34	0.49	0.08	0.12	0.20	0.40
Pre-basic seed	Arerti, Ejeri and Habru	2	1	5.25	8.25	4.20	2.00	4.00	10.20
Total		**2.09**	**1.06**	**5.59**	**8.74**	**4.28**	**2.12**	**4.20**	**10.60**

Note: AdARC is the initial pre-basic seed source whereas basic seed was usually produced on farmers' fields who are members of cooperatives union, or seed enterprises

Training and sensitization workshops

Theoretical and practical trainings were given to 978 farmers (109 female) and 212 experts (28 female) to improve and fill the gap on knowledge, skills, and attitude (Table 3). Training topics addressed chickpea seed production packages (agronomy, fertilizer, bio-fertilizer, disease and/or pests control options, and post-harvest handling techniques); extension approaches like land clustering, monitoring and follow up and data collection; and seed marketing. Power point presentations in Amharic language, leaflets, posters, and audio visuals were used as training materials during training sessions. Based on the simple evaluation of the training event, 80%, 75%, and 80% of participants said the training was good in methodology, logistics, and contents, respectively. The positive effect of the training was also observed on farmers' field management during monitoring and evaluation events.

Table 2. Early generation seed production of chickpea varieties during 2015-2017

Year	District	Farmers			Experts			Overall total
		Male	Female	Total	Male	Female	Total	
2016	Enemay and Yilmana-Densa	410	29	439	62	14	76	515
2017	Enemay	459	80	539	122	14	136	675
Total		**869**	**109**	**978**	**184**	**28**	**212**	**1190**

Note: Experts include development agents at kebele, agricultural experts at district and zone level who work in extension, input delivery, agronomy and crop protection; and experts from cooperative offices and experts from seed enterprises/agencies

Input delivery and seed production

Biofertilizers/Inoculants: In addition to DAP fertilizer, farmers were advised to add nitrogen fixing rhizobium inoculants at the rate of 500 g ha^{-1} (4 sachets, each containing 125 g) for improving the productivity of chickpea and soil health. Thus, 3009 sachets of inoculants were delivered to 3003 farmers in the intervention districts (Table 4). Farmers also witnessed that inoculants make chickpea plant vigorous, relatively tolerant to disease and produce higher yield.

Table 3. Number of rhizobium inoculant sachets distributed for direct beneficiary farmers for chickpea during 2015-2017

2015/16			2016/17			2017/18			Total		
Sachets	Farmers		Sachets	Farmers		Sachets	Farmers		Sachets	Farmers	
	M	F		M	F		M	F		M	F
480	455	25	1296	1250	40	1233	1201	32	3009	2906	97

Note: M= male; F= female

Seed provision and production: 19.43 tons of basic and/or certified seed of improved chickpea variety, Arerti, was provided to 650 smallholder farmers that planted on 180 ha of land and produced 139 tons of seed during the project period (Table 5). The seed delivered/provided to the farmers for production was collected after harvest by kebele and district agriculture offices in consultation with the research center for re-distribution to other farmers in the next production season [as a revolving seed scheme].

Table 5. Source seed delivery of chickpea at Enemay, Enarj Enawuga, and Yilmana-Densa districts during 2015/16 – 2017/18

Year	Planted area (ha)	Seed provided (tons)	Number of direct beneficiary farmers	Quantity of seed produced (tons)
2015	9	0.90	25	14
2016	57	7.125	205	45
2017	114	11.4	400	80
Total	**180**	**19.425**	**650**	**139**

Field days

Twelve field days were organized towards the maturity stage of the chickpea crop, in collaboration with district and kebele level agriculture offices and representatives of participant farmers. The major objectives were to show the performance of improved technologies for experience sharing, obtain participants' reflections and feedbacks about the improved technologies being promoted and create wider awareness and demand. Participants of the field days were farmers, agricultural experts and officials/administrators, and other stakeholders (seed agencies, universities, quarantine offices, and research institutions). Accordingly, 586 farmers (17 female), and 169 experts (18 female) attended the field day events in the intervention districts (Table 6, Figure 2). The field day event was broadcasted by Amhara Media Agency's Television and Radio programs so that large audience was reached for awareness and demand creation.

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Table 6. Number of participants on the field day events of chickpea technology pre-scaling up intervention districts during 2016-2017

Year	Farmers			Experts			Total		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
2016	384	7	391	69	8	77	453	15	468
2017	185	10	195	82	10	92	267	20	287
Total	569	17	586	151	18	169	720	35	755

Figure 2. Field day on chickpea pre-scaling up and community-based seed production at Enemay district during 2016/17-2017/18

Yield performance

Arerti variety gave a mean yield of 2.5, 1.9 and 2.3 tons ha^{-1} at Enemay, Yilmana-Densa and Enarj Enawuga districts, respectively (Table 7.1). The yield obtained at Enemay and Enarj-Enawuga districts are higher than the national and West Gojam zone average, and by far better than the regional and East Gojam zone chickpea productivity (Table 7.2).

Table 7.1. Mean seed yield of Arerti chickpea variety on pre-scaling up participant farmers' fields during 2015 – 2017

Districts	Seed yield (tons ha^{-1})		
	Minimum	Maximum	Mean
Enemay	1.24	3.45	2.542
Yilmana-Densa	0.9	2.8	1.881
Enarj Enawuga	1.3	2.8	2.3

Table 7.2. National, regional, and zonal productivity of chickpea (tons ha^{-1}) during 2015/16 – 2016/17

Year	Ethiopia	Amhara region	East Gojam zone	West Gojam zone
2015/16	1.828	1.632	1.400	1.885
2016/17	1.969	1.828	1.460	1.814
Mean	1.899	1.730	1.430	1.850

Source: CSA, 2015 and 2016

Farmer-to-farmer seed exchange

Tracking the diffusion of chickpea seed produced by the participant farmers in the pre-scaling up revealed that large quantity of seed was transferred to the surrounding farmers through farmer-to-farmer seed exchange mostly in sale while some was used for home consumption and sold as grain. Although not fully tracked, about 122 tons of Arerti seed was revolved and exchanged in farmer-to-farmers seed exchange that directly benefited 1562 farmers in the intervention areas (Table 8).

Table 8. Seed dissemination through farmer-to farmer seed exchange and revolving seed schemes of chickpea pre-scaling up activities during 2015-2017

Method of seed dissemination	Area planted (ha)				Seed exchanged (tons)				Farmers benefited			
	2015	2016	2017	Total	2015	2016	2017	Total	2015	2016	2017	Total
Revolving seed scheme	0	40	91	131	0	70	9.1	79.1	0	210	535	535
Farmer to farmer exchange	-	-	-	-	0	18	25.0	43.0	0	527	500	1027
Total	**0**	**40**	**91**	**131**	**0**	**88**	**34.1**	**122.1**	**0**	**737**	**1035**	**1562**

Feedbacks from field days

Farmers: Unavailability of clean seed, and disease (root rot) and pest (ball worm) are still major problems in chickpea production. "We [farmers] are producing grass pea instead of chickpea due to lack of improved varieties; even our local varieties are also susceptible to root rot disease; therefore, we are abandoning chickpea production", said a field day participant farmer. Farmers added that, Arerti variety is well adapted and performed well in our locality (it is vigorous, good in pod setting potential, has more branches and relatively tolerant to disease) and they can generate income in addition to meeting home consumption needs.

Experts: The chickpea root rot problem observed during the pre-scaling up in farmers' fields needs further breeding strategies and control options. There should be further technical backstopping and material support from the AdARC to make the activity more sustainable. Farmers' seed producer and marketing cooperative should be established and strengthened. Development and promotion of varieties that are suitable for barley-chickpea, and tef-chickpea double cropping, disease and pest tolerance, and market demand is necessary.

Market linkages

Agreement was signed among farmers and Ghion Union through primary farmers' cooperatives at Enemay district for seed and grain marketing of chickpea during 2015/16 and 2016/17 cropping season. Accordingly, about 80 tons seed of Arerti variety that passed the inspection and quality control was purchased from farmers and sold by the Union.

Chickpea production and area expansion

The area coverage of chickpea was almost non-existent in Enemay district before the intervention of the chickpea seed production and scaling project of ICARDA. It is a great achievement that more than 800 ha of land was covered with improved variety for chickpea production and farmers met their home consumption needs besides supplying the surplus to the market.

On the other hand, as confirmed from field visits and interviews of farmers and experts although Enarj Enawuga district is potential for chickpea production, there was no improved chickpea variety introduced before the intervention of this pre-scaling up activity of the ICARDA-USAID project.

Farmers' awareness for seed business

Farmers' awareness on seed production as a business was highly enhanced due to the intervention of chickpea pre-scaling up activity through community-based seed production at Enemay district. The AdARC and Debre Markos University agreed to strengthen the seed system of chickpea in collaboration with Ghion Union and district offices of agriculture.

Enhanced institutional linkages

The whole process of the pre-scaling up activity ensured that there was greater improvement in institutional linkages through joint planning and implementation, monitoring and evaluation, trainings, field day events, experience sharing, and sensitization workshops that should be maintained for enhancing chickpea production and marketing in the future. The strong linkages created made the chickpea pre-scaling up activity so successful that it should be scaled out.

Challenges

- Initial seed multiplication; control of diseases and pests; difficulty in clustering fields; running innovation platforms; and maintaining strong linkages among stakeholders demanded considerable time and cost.
- Human consumption, green pod consumption while the crop is in the field, was a major problem for Kabuli chickpea pre-scaling up activities at Enemay district, especially at the beginning when chickpea area was small. Initially it was managed through discussion with community and setting by-laws; and later the problem declined when the area under chickpea increased over years.

Conclusions

Arerti variety with full recommended package performed well on farmers' fields. The pre-scaling up of chickpea technologies required concerted efforts of different stakeholders across the value chain. Trainings, creating awareness, experience sharing, monitoring and evaluations, sensitization workshops, and field days improved the capacity of farmers and experts of agricultural development. Lack of initial source seed and occurrence of diseases (root rot) and pests (ball worm) are the major challenges observed in chickpea production.

Recommendations

- Community-based seed production and the pre-scaling up results suggest that Arerti chickpea variety with full package should be promoted on a wider scale to reach more farmers (vertical and horizontal scaling out) by office of agriculture in collaboration with farmers' cooperative unions and/or universities;
- Develop integrated disease management options for chickpea production specially for chickpea root rot;
- Develop and strengthen chickpea seed system including EGS (breeder, pre-basic and basic) production;
- Introduce Vertisols management options at Enemay district using Broad Bed and Furrow (BBF) method to enhance productivity through soil management and double cropping.

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II CHICKPEA: Chapter 4: Chickpea Technology Multiplication and Scaling

Pre-Scaling of Improved Chickpea Technologies in North Shewa Zone

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In the chickpea growing predominantly Vertisols area of North Shewa zone more than 26.24% of the area is covered by local chickpea varieties and traditional management practices (late planting, broadcasting and no inoculants) with a productivity of less than 1.3 t ha^{-1} (North Shewa Zone, Office of Agriculture Report, 2016).

However, during 2015-2017, promotion of both improved varieties and agronomic practices, using participatory evaluation methods were undertaken at four districts of North Shewa zone with the budgetary support of ICARDA-USAID chickpea scaling project. Therefore, this activity was conducted to create wider awareness and demand of improved technologies, strengthen linkages among possible actors, and enhance technology multiplication and dissemination for improving the productivity and production of chickpea.

Methodology

Area description

The activities were conducted at Ensaro, Merhabete, Moretina-Jiru, Siyadebrina-Wayu, and Basona-Worena districts of North Shewa zone of Amhara region during 2015-2017. The altitude of the districts where the scaling up of improved chickpea technologies was carried out is between 2200 to 2800 masl. The districts are characterized by a unimodal rainfall pattern and receive an average of 929 mm. The annual average maximum and minimum temperatures are 21.4 and 9.0°C, respectively. Vertisols are the dominant soil types in the chickpea production areas. The crops widely grown include wheat, tef, faba bean, barely, and lentil, whereas chickpea and grass pea have relatively low area coverage compared to cereals and mostly grown on residual soil moisture at the end of the rainy season. Geographical map of the four target districts that have high potential for chickpea production due to large coverage of Vertisols is given in Figure 1.

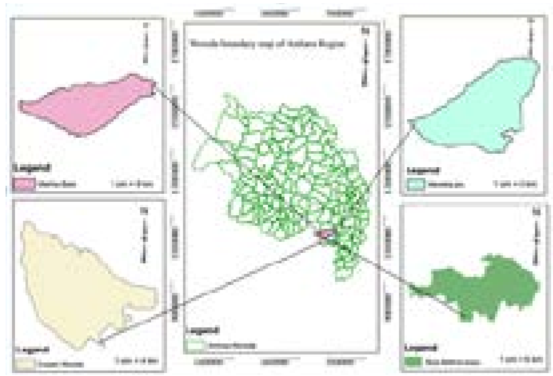

Figure 1. Maps showing target study districts in Amhara region

Implementation of activities

Zonal workshops were conducted for planning and sharing responsibility with the participation of zone and district experts and leaders, seed union and NGOs before starting to implement each year plan. The workshops were led by Head of the Zone Agriculture Office where the researchers present previous year and next year activities in each district. Each district which participated in the workshop will identify and present the target kebeles and plans for training, seed distribution and planting. After all districts presented their implementation plan, a memorandum of understanding were signed between DBARC and each implementing district for sharing responsibility facilitated by the zonal agriculture officer. The major responsibility of each district included farmer selection and land clustering, seed distribution in revolving repayment modality, planting, and follow-up of implementation of activities. The improved management practices such as early planting on broad bed and furrows to drain out excess soil moisture of Vertisols, application of recommended seed and fertilizer rates, and weed and pest management were applied.

Major responsibilities of DBARC included training and seed provision, organizing field days and workshops, data collection and reporting. Monitoring and evaluation was the responsibility of both DBARC and offices of agriculture at different administrative levels. DBARC provided seed and biofertilizer to district or kebele experts for distribution to farmers. A team of researchers from DBARC, experts from district and kebele agricultural development offices did monitoring and evaluation for ensuring the appropriate implementation of the pre-scaling up activities. Experts from Dessie seed laboratory inspection office did the field inspection to ensure seed quality.

Farmers' feedback and yield data collection through mini survey were done. Revolving seed collections were done each production year for redistribution to the interested and new farmers. Seed production and marketing cooperatives were established at Ensaro district while strengthening the already established SPCs and unions were carried out at Moretina-Jiru and Siyadebrina-Wayu districts through training, seed and material support. DBARC research team assessed the opportunities and challenges of chickpea production during the implementation of the scaling up activities.

Results and Discussion

Capacity building

Training was organized for farmers and experts on chickpea production packages, and establishment and functions of seed producer cooperatives (SPCs). About 1006 farmers (89 female) and 74 experts (20 female) from all districts were trained during 2015-2017. The training mainly focused on chickpea production packages, post-harvest storage, concept of seed business, value addition and market linkages for both seed and grain. In addition, field level practical training and field visits were carried out during the vegetative stage of the crop.

Experience sharing and training of seed experts and leaders of cooperatives were done twice on seed production, seed quality control, seed marketing, seed business establishment and management, chickpea value addition, and internal control mechanism and management of cooperatives. During the experience sharing and training events, six experts and four cooperative leaders participated at Kulumsa and Debre Birhan ARCs.

Monitoring and evaluation was carried out at different crop growth stages with the participation of farmers, district experts and researchers to review the progresses and achievements, and to identify major constraints and potential opportunities. A national level chickpea travelling workshop was also organized by ICARDA team for experience sharing in which one of the best experiences visited by the participants was the practice of early planting of chickpea by using broad beds and furrows to drain excess moisture of Vertisols in Ensaro district.

Extension folders/leaflets were important tools used to present agricultural information to farmers and extension agents. This approach helped to address those farmers who can read and write. Each of these briefs and concise extension folders contained full production packages of chickpea. Accordingly, about 1,184 sheets were distributed to farmers and other stakeholders during training and field day events.

Input distribution

Improved chickpea varieties of Naatolii, Kutaye, Mastewal, Habru and Arerti were used for pre-scaling up according to farmers' preferences. About 38.83 tons seed of these varieties were distributed to 826 farmers (69 female) who planted on 302 ha of land.

To implement the activities in best possible way and increase chickpea productivity, a complementary production package like biofertilizer was used. Therefore, about 4027 chickpea rhizobia (strain EAL-029) inoculant packs were distributed. Each pack contains 125 g of inoculant enough for dressing seed that covers a quarter of a hectare. To create awareness and demand on wider scale, rhizobium inoculants were also provided to interested chickpea farmers that were not part of the planned pre-scaling up activities.

Field days

Seven field days were organized by inviting participants from zone and district agricultural development experts and authorities, farmers' cooperatives unions, kebele agricultural development agents, farmers, DBARC, ARARI, ICARDA-USAID project, Africa Rising project, Debre Birhan University, communication experts from zone and districts, and mass media experts from Fana FM, EBC, and Amhara Radio. A total of 1134 (149 female) participants attended the field days. The field day program included field visits, reflections on the performance of the varieties by farmers and stakeholders, and open discussions and feedback on the field visits. Challenging issues and future directions on seed collection, seed marketing and seed exchange were also discussed.

Feedbacks

Farmers' feedbacks: Farmers said that even though each improved chickpea variety was affected by wilt and root rot (abriq in Amharic), their performance was impressive; hence they promised to continue to adopt and expand production of these varieties. Farmers also stated that the improved varieties were relatively better tolerant to insect pests and showed a productivity as high as 3.5 tons ha^{-1} compared to the local varieties that gave 1.13 tons ha^{-1}. Previous limitations such as lack of sufficient market and human consumption of green pod would be addressed with expanding production and market promotions through the established cooperatives and unions. Early planting of improved varieties on broad beds and furrows helped the crop to mature early and escape frost and moisture deficit stress at later stage, which have combined effect of significantly improving productivity.

Experts and authorities: They witnessed and impressed with the performance of improved varieties compared to local varieties and the improved planting methods in increasing the productivity of chickpea on Vertisols. They noted that Kabuli chickpea have high demand for export market hence the need to meet demand for both seed and grain production. They are convinced and promised to take responsibilities to expand the improved technologies to other potential districts and kebeles.

Introducing new innovations

Early planting: The unworkable nature of Vertisols when saturated with water, obliged farmers to usually plant chickpea at the end of the rainy season on the residual soil moisture. Late planting is a major yield-limiting factor as it causes the crop to experience terminal drought (Rashid *et al*., 2010) and expose the crop to frost as noted by farmers.

There are two main options for maximizing chickpea productivity under these conditions: (i) Advance chickpea planting time towards the rainy season to give the crop sufficient moisture for all growth stages. This approach requires availability of farm implements that can operate under waterlogging conditions and drain excess water from the field, and disease resistant varieties that can adapt to and germinate under high-moisture condition; and (ii) maximize yield following the conventional late planting by using early maturing or drought tolerant varieties. Bejiga *et al*. (1997) reported that 30-50% yield increase from early planting (August) compared to late planting (September) in Debre Zeit and Akaki areas in East Shewa zone.

Improved soil drainage method: Given that major chickpea-producing areas in Ethiopia are prone to waterlogging, and the crop's sensitivity to waterlogged conditions, drainage of excess water is of particular importance in seedbed preparation. The broad bed maker (BBM), adapted from the dual oxen-drawn plough in the 1990's to address this issue, forms raised broad beds around 0.3 m high and 0.8 m in width, alternating with furrows each having 0.4 m width to facilitate water drainage (Astatke and Kelemu, 1993). Draining water through the furrows, the raised beds are not saturated with excess water allowing early planting while still in the rainy months. Field trials have shown average yield increase of up to 45% from planting on BBF over the flat bed in Ginchi areas of West Shewa zone (Agegnehu and Sinebo, 2012).

The major problem encountered in using BBM was that it is difficult to use it in saturated soil moisture conditions for example in August. Therefore, we introduced the widely practiced traditional soil drainage method of broad bed and furrows prepared manually, called mekerbet locally which is the common practice in Moretina-Jiru and Siyadebrina-Wayu districts. Therefore, we organized for target farmers from Ensaro district to visit the traditional broad bed and furrow making practice during planting at Moretina-Jiru and Siyadebirna-Wayu districts and learn the experience from their fellow farmers. With this practical experience sharing and learning visit, our pre-scaling up target farmers in Ensaro district introduced and practiced early planting in mid to late August on broad beds and furrows to drain excess soil moisture of Vertisols that significantly improved productivity and production of chickpea. This is a big success story in the area.

Area coverage and production

During the pre-scaling up activities from 2015-2017, more than 38.8 tons of seed was provided and about 302 ha of land was covered by improved chickpea varieties and improved production packages producing 1,057 tons of seed. As the result of this intervention, the improved chickpea varieties with early planting on broad beds and furrows on Vertisols are expanding to cover more than 90% of the areas in the intervention districts, especially in Ensaro district (Unpublished report from Ensaro district office of agriculture, 2018). No doubt that increasing productivity and production of chickpea in the target districts significantly improves food and nutritional security of the farming and the surrounding urban community since the supply of chickpea increases in the market.

Major challenges

- Although farmers are interested to continue chickpea production, marketing of chickpea and continuous supply of quality seed and agrochemicals for disease management are uncertain (Figure 2).
- Root rot and wilt diseases associated with early planting still reduces productivity although this practice is by far higher yielding than the traditional late planting on the residual soil moisture.
- African bollworm and lack of recommended chemicals for managing its damage remain a constraint for chickpea production.
- The current green pod theft and consumption of Kabuli chickpea because of their big pod/seed size compared to the local ones is a major concern although this problem may reduce with the expansion of the production area

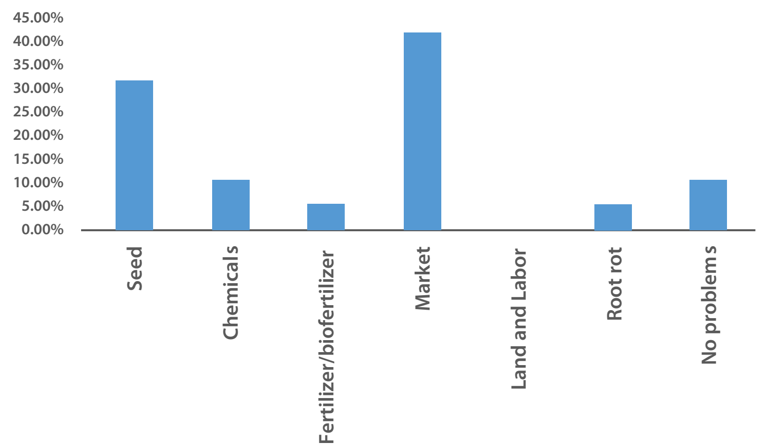

Figure 2. Major future chickpea production challenges rated by farmers

Conclusions

The productivity and production of chickpea increased in the intervention areas due to the introduction of improved varieties and improved production package such as fertilizer, inoculants and agrochemicals. The improved agronomic practices such as early planting on broad bed and furrows on Vertisols and weeding significantly increased yield. Consequently, farmers shifted the planting time from mid-September to mid-August in most target areas. Thus, the productivity of chickpea increased by three folds using all improved inputs and agronomic practices. The improved varieties of chickpea disseminated to a wider area through farmer-to-farmer seed exchange.

Recommendations

Based on the observations and feedbacks from farmers and different stakeholders, we can recommend the possible ways of enhancing productivity and production of chickpea and similar technologies.

- Integrated management option for chickpea root rot and wilt must be priority intervention area of research for development.
- Post-harvest handling and training on the preparation of different food types of chickpea is important to improve consumption that helps for improving food and nutrition security.

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Pre-Scaling of Improved Chickpea Technologies Through Farmer-Based Seed Production in North Gondar Zone

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In West Belesa district, where there is severe terminal moisture stress, chickpea is the major crop of choice by the famers who grow the local variety with traditional production practices. Gondar Agricultural Research Center (GARC) conducted participatory adaptation trials to test the suitability of different varieties to improve the productivity of Kabuli chickpea. Two Kabuli chickpea varieties, Habru and Ejeri, were selected by farmers and researchers. Following the recommendation, this pre-scaling up and farmer-based seed production of the Habru variety, together with the improved chickpea production package, was initiated to increase chickpea production and productivity by targeting and creating sustainable market outlets in the area.

Methodology

Area description

The study was conducted in West Belessa district during 2015-2017. According to the report by CSA (2007), the district had 28,046 households with total population of 142,791 (69,962 female). The altitude of the district ranges between 1,200 and 1,800 masl. It is one of drought prone and food insecure districts of North Gondar zone (Figure 1). Tef, sorghum and chickpea are the major crops being produced in the district. Rainy months extend from June until the end of August. However, most of the rainfall is received during the month of July. The soil type on which the pre-scaling up activity implemented is relatively light Vertisols.

Figure 1. Maps of the study target district in North Gondar zone

Selection of sites and farmers

The technology popularization was conducted for three years (2015-2017). Clustering by aggregating adjacent fields was an approach used to popularize the chickpea technologies. Selecting participating farmers and clustering fields were carried out in collaboration with the farmers and experts of the district office of agriculture and development agents at each kebele. Each participating farmer allocated at least 0.25 ha of land for the scaling up of improved technologies of chickpea. The technology package used was improved Kabuli chickpea variety (Habru), biofertilizer inoculant (EAL-029) and improved agronomic practices. The seed rate was 110 kg ha^{-1} and it was dressed with 500 g ha^{-1} rhizobia inoculant. Row planting was done by using 30 cm row and 10 cm between plant spacing. Each field weeded at least once during the production season. Since the area faces moisture stress, planting was done starting from the end of July to the mid-August.

Capacity building

Building trust of community members in the research process is so crucial in pre-scaling up activities which takes a lot of resources and time and patience. Sensitization workshop was carried out to let farmers know what was planned and how it is going to be implemented. Farmers' role and detailed plan of activities was jointly prepared, and memorandum of understanding was signed between the implementing parties. After farmers trust was obtained, training on improved chickpea production and management was organized for farmers and development agents.

To sustain improved chickpea seed production in the area, seed producer cooperatives were established with the collaboration of the district office of cooperative promotion. Farmers were assisted with appropriate technical guidance in different steps of seed production such as identification of varieties, removing of off-types, management of diseases and pests, harvesting and post-harvest handling. Every year on-farm seed quality inspection was made by inviting seed quality control and quarantine agency. Fields that did not fulfill the seed production standards were rejected.

Field days

Every year, field days were organized at grain filling stage of chickpea plots. The main aim of the field days was to create awareness and demand for the technology, engage different partners and collect feedbacks on the popularized technologies. During each field day, farmers and other stakeholders visited the fields and participated in experience sharing discussions.

Data collection and analysis

Both social and yield data were collected; social data were collected from participants of the field days while grain yield was recorded from each of sample fields to estimate the average productivity. The collected quantitative and qualitative data were analyzed using simple descriptive statistics and narration.

Result and Discussion

Training

During the three implementing years, different training sessions were organized (Table 1). The topics covered included improved agronomic practices, disease and pest management, bio-fertilizer inoculation, quality seed production, post-harvest handling and market linkages. Trainees included 355 farmers, 34 experts who are from zone and district office of agriculture and development agents at kebele level, and 23 researchers.

Table 1. Number of training participants during 2015-2017 cropping seasons

Type of trainees	2015		2016		2017		2015 - 2017		
	Male	Female	Male	Female	Male	Female	Male	Female	Total
Farmers	103	5	103	5	126	13	332	23	355
District level experts and DAs	8	4	8	4	7	3	23	11	34
Researchers (excluding trainers)	3	0	10	0	8	2	21	2	23
Total	**114**	**9**	**121**	**9**	**141**	**18**	**376**	**36**	**412**

Note: DAs= development agents

Input distribution

The basic inputs used to enhance chickpea productivity and production were quality seed of improved variety Habru and recommended biofertilize inoculants (Table 2). Thus, 18.18 tons certified seed 1 of Habru variety was distributed to 8999 farmers (63 female) that planted 151.5 ha of land. A total of 2,750 sachets of biofertilizer inoculants were distributed to the participant farmers in the pre-scaling up of improved chickpea technologies, and other farmers interested to use biofertilizer for chickpea production.

Table 2. Seed of Habru variety and biofertilizer inoculants distribution across years

Year	Amount of seed distributed and area planted		Rhizobia inoculants distributed and area covered (ha)		Number of participant farmers		
	Seed (ton)	Area (ha)	Packets	Area (ha)	Male	Female	Total
2015	3.84	32	150	32	56	9	65
2016	9.3	77.5	1728	380	204	13	217
2017	5.04	42	872	218	576	41	617
Total	**18.18**	**151.5**	**2750**	**630**	**630**	**63**	**899**

Note: Each packet or sachet contains 125 g of rhizobia inoculants enough to dress chickpea seeds for planting 0.25 ha of land

Field days

The main purpose of organizing the field days were to create awareness and demand for chickpea technologies, create and strengthen linkages among stakeholders who work to improve chickpea value chain, and enhance technology multiplication and dissemination system. The field days were organized at Kalay and Dikouna clusters.

About 422 farmers and stakeholders from different organizations participated in the field days (Figure 2). At regional level, ARARI senior researchers from crop and socio-economics research directorates, and public communication staff participated. At zonal level, zonal office of agriculture, zonal office of cooperative promotion, Tsehay union, zonal office of seed inspection, North Gondar zone livelihood improvement and sustainable resource management program, GARC, and Ethiopian Television participated. At district level, district office of agriculture, cooperative and experts of agriculture, and development agents from both kebeles participated in the field days.

In both kebeles, Habru variety with its recommended technology packages compared with local ones were demonstrated to the participants. Briefings and explanations were given to the field day participants about chickpea technology packages, and how the scaling up activities can be continued sustainably. Interestingly the use of chcikpea by-products as feed source for goat keepers was also explained.

Duringn each field day, farmers' responses to Habru variety and the technology package were collected. Farmers suggested the main advantages of Habru variety, and its technology packages compared to the local variety and practices are as follows:

- Habru is resistant/tolerant to drought and disease; has large number of pods per plant; has large seed size preferred by market; and has good branching ability and the biomass is good source of feed to goats and other livestock;
- Row planting has brought vigorous growth, but it demands high labor cost
- Plowing 2-3 times reduces weed and diseases infestation

At the end of each field day, the participants had an intensive open discussion on how to sustain the expansion of the improved chickpea seed production without external support. Furthermore, issues of seed production and marketing, seed quality assurance, and the roles and responsibilities of the local institutions were also discussed.

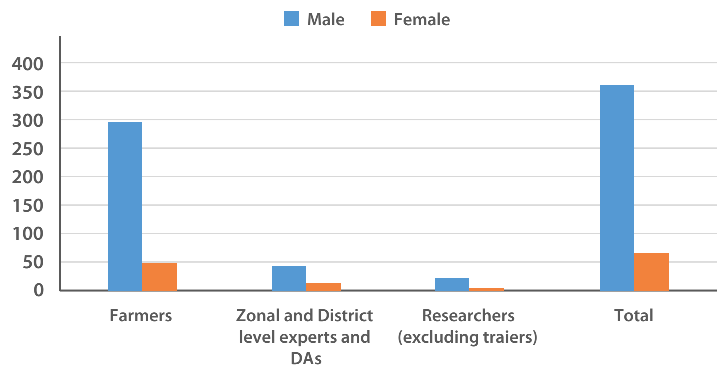

Figure 2. Chickpea field day participants: 2015-17

Productivity and seed production

Since Habru variety was introduced for the first time, there was no local Kabuli chickpea variety in the area to compare with. The local chcikpea varieties grown in the are desi chickpea. The highest yield recorded from the Habru variety was 2.7 tons ha^{-1} and the lowest was 1.65 tons ha^{-1}, the average being 2.24 tons ha^{-1}. According to the unpublished report of the district office of agriculture, the average productivity of chickpea was 1.60 tons ha^{-1}, indicating that Habru variety, had a yield advantage of 0.64 tons ha^{-1}.

The improved seed planted on 151.5 ha of land produced 275.6 tons of seed in the pre-scaling up of the improved chickpea technologies and seed production activities during 2015-2017 in the target district and kebeles (Figure 3). The total amount of seed obtained was below the expected yield since some of the seed production fields could not meet the seed quality standards and thus rejected. The produced seed of 26.54 tons, in addition to being used in the formal seed dissemination, it was informally exchanged with non-participant to 705 farmers that are interested to produce the improved chickpea variety in the target district and kebeles. The informal seed exchange is expected to be higher than the indicated figure since it was not possible to fully track all the dissemination paths.

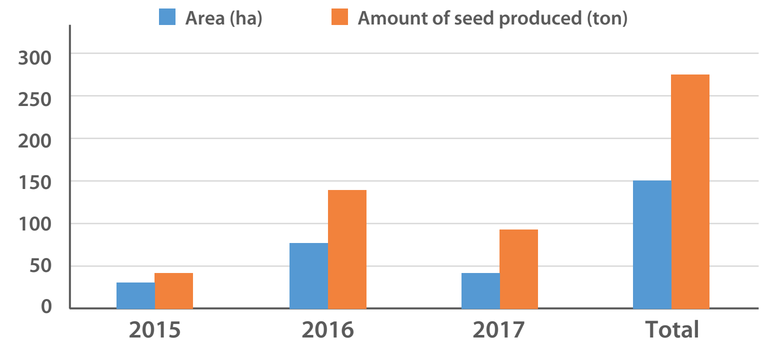

Figure 3. Area planted and seed produced during 2015-2017

Challenges

- Clustering fields was challenging unless all the neighboring farmers are included.
- Bollworm was difficult to control due to unavailability of pesticides.
- The established seed producer cooperative did not have enough capital to purchase the produced seed

Lessons

- Knowing seed production standards ahead and involving the inspectors starting from the beginning is very crucial.
- The established seed producer cooperatives should be strengthened in terms of facility and financial capacity if they are to serve their purpose.
- Involving seed buyers starting from the beginning and signing a memorandum of understanding played a key role in improving market linkages.

- Participant farmers should sign contractual agreement with the established cooperative and act accordingly to meet their obligations.

Conclusions and Recommendations

The pre-scaling up and seed production activities proved that the Kabuli chickpea variety, Habru, is high yielder, financially profitable and socially preferred by the farmers. The local institutions should further follow up the seed production and strengthen the capacities of the cooperatives and unions to make them competitive in the market and sustain the system. However, it would be good first to have sufficient time to create demand for the technology before converting it into business. This is because farmers prefer to check the performance of the technology before venturing into seed production and marketing.

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