Towards up scaling integrated faba bean gall disease management in South Gondar Zone, Western Amhara Region, Ethiopia

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ABSTRACT

Faba bean (*Vicia faba* L.) is a major staple food and an important pulse crop in terms of area coverage and volume of annual production in Ethiopia. However, its productivity is declining due to the newly emerged faba bean gall disease. The disease also occurs under smallholder farmers' conditions in the Amhara region, although the information regarding its status and management practices is limited. Therefore, this pre-scaling up activity was conducted in 2020 and 2021 in South Gonder Zone of the Amhara Region with the objectives promoting improved management of faba bean gall disease, creating and strengthening linkage among stakeholders involved in faba bean production, and enhancing the availability of Wolki and Hachalu improved faba bean varieties with other components of the package. Host farmers were selected in collaboration with development agents and experts of the *woreda* (district) based on their interest in engaging with diligence and vigor. Training was provided to host farmers, development agents, and agricultural experts. A partial budget analysis was used to compare the benefit of integrated faba bean gall disease management with that of the local variety with local practices. The result shows that the Marginal Rate of Return (MRR) of Wolki was 464% in Ebenat and 435% in Libokemkem, while Hachalu variety has given a MRR of 560 in Farta and 386% in Libokemkem. As the result of the intervention, demand for faba bean gall disease management technology package was created, and linkage among the main actors was established and farmers acquired some amounts of improved seeds for future use. Therefore, as the MRR for the package in the study area is above 100%, it is worthwhile to upscale the packages to ensure the income, food, and nutrition security of rural households in the Amhara region and beyond where the crop is important.

Keywords: Gall disease management package; Host farmers; Linkage; Marginal rate of return; Pre-scaling up
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INTRODUCTION

Faba bean (*Vicia faba* L.) is a cool-season, annual grain legume crop, traditionally used as a significant, and cheap plant protein sources for human and livestock diets (Bon-Jae *et al*., 2020). Although it originated in the Middle East during prehistoric times (Multari *et al*., 2015), it is now cultivated worldwide (Prabhu and Rajeswari, 2018) and ranked as the third most important grain legume (Bon-Jae *et al*., 2020). The Mediterranean and East African countries account for nearly 32% of the global faba bean production (Abou *et al*., 2022). Globally, the production area of faba bean is 2,511,813 ha, with a crop

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production yield of 4,923,154 tons/year and an average annual yield of 1,960 kg ha^{-1}. China is the leading fab bean producer with 36.7% of the global output, followed by Ethiopia (20.1%), the United Kingdom (8.2%), and Australia (7.7%) (FAO, 2018). Compared to the year 1961, the area cultivated for faba bean production globally decreased from 5.4 to 2.46 million ha in 2017. However, the total production quantity of faba bean remained at a similar amount of 4.84 million tons between 1991 and 2017 (Bulti *et al*., 2019).

Faba bean is a major staple food and an important crop among pulses in terms of area coverage and volume of annual production mainly grown in the mid and high-altitude areas of Ethiopia with an elevation ranging from 1800 to 3000 meters above sea level (Gemechu *et al*., 2006; Leulseged *et al*., 2017). The crop takes the largest share (31%) of the area under pulse production. At a national level, faba bean covered about 520,551.7 ha of land where 4,309,978 smallholder farmers engaged in growing the crop with a total production of 1.09 million tons and a productivity of 2.1 t ha^{-1} (CSA, 2022). According to the Central Statistical Agency (2021/2022) report, faba bean accounts for 4.27% of the land area allotted to grain crops and for 3.33% of the total grain production in Ethiopia.

The crop has substantial nutritional and environmental advantages in Ethiopia; it is a valuable source of cheap protein for the poor who cannot afford to buy animal protein. The upper parts of faba bean are rich in protein that can nourish humans with almost all essential elements required for life (Etemadi *et al*., 2019). Faba bean is also a crop of considerable importance as a low-cost food rich in carbohydrates (Rasul, 2018). Despite its huge importance and area coverage, the productivity of faba bean is about 2.11 t ha^{-1} (CSA, 2018a), far below the potential of the crop which was 5.2 t ha^{-1} (MoARD, 2008). In addition, the productivity of the crop under smallholder farmers is less than 1.89 t ha^{-1} (Hizkel *et al*., 2018). Some limiting factors of faba bean production are climatic conditions, edaphic factors, disease problems, and agronomic practices (National Plan Commission, 2016). Furthermore, the low yield of faba bean was attributed to the susceptibility of the crop to biotic and abiotic stresses, declining soil fertility and acidity (Chilot *et al*., 2002; Samuel *et al*., 2008), use of old and low-yielding local landraces and unavailability of the high yielder improved varieties (Zewdie and Van Gastel, 2008; Rashid *et al*., 2010; Ademe *et al*., 2018). The use of certified improved seeds by farmers is also very low. Only 0.8% of the total pulse-cropped areas were covered by improved seed in the 2017/18 growing season (CSA, 2018b).

Moreover, the most important constraints that affect the production and productivity of faba bean include limited or no use of inorganic fertilizers (Solomon *et al*., 2011), the newly emerged faba bean gall disease (Endale *et al*., 2014; Beyene, 2015; Beyene and Abero, 2016; Challa *et al*., 2017; Ademe *et al*., 2018), chocolate spot, rust, ascochyta blight, zonate leaf spot, and black root rot diseases (Solomon *et al*., 2019). Declining

production and productivity results in less income, aggravation of poverty, and nutritional insecurity of smallholder farmers and thereby impedes the GDP of the country at large.

In the Amhara region, faba bean production is limited and it is unable to meet the increasing demand for local consumption due to a gradual decrease in productivity far below its potential. This is mainly because of the new faba bean gall disease locally called "*Kormid"* and Orobanche parasitic weed that significantly affects the yield of faba bean in the region (Mulugeta *et al*., 2015; Mekonnen, 2016; Beyene and Abero, 2016). To mitigate the adverse effects of the disease, different research activities have been carried out by agricultural research centers. For example, Debre Birhan Research Center confirmed that all foliar fungicides applied at seedling, flowering, and podding growth stages of faba bean with Bayleton, chlorothalonil, and mancozeb gave low disease scores. Among the fungicides sprayed better grain yields were recorded on baylton (2.124 t ha^{-1}), mancozeb (1.7023 t ha^{-1}), ridomil gold (1.4717 t ha^{-1}), and chlorothalonil (1.4709 t ha^{-1}) (Beyene and Abero, 2016).

Moreover, the research results of Getnet and Yehizbalem (2017) indicated that the combined use of baylton foliar spray with varieties significantly reduced the maximum percent severity index (PSI) of faba bean gall disease. The severity of faba bean gall disease was reduced on plots that were sprayed (with improved varieties as well as the local varieties) compared to the unsprayed plots. Baylton foliar spray significantly reduced the severity of faba bean gall disease. Therefore, foliar spray using baylton at the rate of 1.5 a.i/ha with varieties *Adet-Hana*, Bulga70 and CS20DK, Nc58, and Kasa gave better yield and therefore these could be recommended as the best management options for the control of faba bean gall disease.

Considering the effectiveness of foliar chemical application and the productivity of improved faba bean varieties, pre-scaling of the integrated faba bean gall disease management package was conducted in 2020 and 2021. It was carried out using Noble-25, which is the currently available pesticide similar to that of Baylton, in areas where faba bean production has been declining because of the disease with the objectives to create wider awareness and demand for an integrated faba bean gall disease management package. Despite the disease's prevalence under smallholder farmers' conditions in the Amhara region, there is limited information regarding its status and management practices. And also to create and strengthen linkage among stakeholders to upscale the technology package; strengthen the seed production and dissemination systems of the varieties; and enhance farmers' access to the improved varieties and integrated gall disease management options in the intervention areas.

MATERIALS AND METHODS

Description of the study areas

Ebenat woreda is one of the 10 woredas of South Gondar Zone, Amhara region with a latitude and longitude of 12°7′N 38°3′E / 12.117°N 38.050°E. Its elevation ranges from 1800 to 2150 meters above sea level. Its capital Ebenat is 698 km from Addis Ababa, 122 km from Bahir Dar the regional capital, and 109 km from the zonal capital Debre Tabor. The woreda is bordered by Belesa to the north, Farta to the south, Bugna and Dahena to the east, and Laigaint and Libokemkem to the west. Topographically, 45% of the woreda is mountainous, 35% hilly, 15% plain, and 5% valley (Ebenat Woreda Agriculture Office, 2013, unpublished report). The woreda encompasses three distinctive agroecological zones namely lowland, mid-altitude, and highland. Moreover, the average annual rainfall of the woreda is between 500-1300 mm and the average minimum temperatures is 23 °C and the maximum is 30 °C. The total land area of the woreda is estimated to be about 24,942,700 hectares of which 16,978,410 ha can be cultivated; 3,784,600 ha is grazing area, 1,122,440 ha is covered by forests, and the remaining hectares are covered by bushes, water bodies, housing and other infrastructure. Although many types of crops are grown in the woreda, the most commonly grown ones are wheat, *teff*, barley, maize, and peas. These crops are grown as staple and cash crops in the woreda. The types of animals reared are cattle, sheep, goats, chickens, and donkeys (Agegnehu, 2015).

Farta is located in the south Gonder Zone of the Amhara Region, Ethiopia. It is located between 11° 32′ to 12° 03′ latitude and 37° 31′ to 38° 43′ longitude. The woreda is bordered by Misraq Este in the south, Fogera in the west, Ebenat in the north, and Lay Gaint in the east (PEDD, 2007). It lies in an altitude range of 1920 - 4135 m.a.s.l. It receives an average annual rainfall of 900 - 1099 mm and a mean range temperature of 9 – 25 °C. The rainy season ranges from May to September (Abebaw and Melaku, 2009). In terms of topography, 45% of the total area is a gentle slope, flat lands account for 29%, and steep slopes for 26. In terms of land use pattern, an estimated 65% of the area is cultivated and planted with annual and perennial crops, while the area under grazing and browsing, forests and shrubs, settlements, and wastelands account for about 10, 0.6, 8, and 17% respectively. About 50% of the soils are brown, 30% red, and 20% black.

Libokemekem, one of the woredas of South Gondar Zone, is bordered by Ebenat in the North, Fogera in the south, Gondar Zuria in the west, and Farta in the east. It is located at 37°15’36” E to 38°06’36” E longitude and 11°54’36” N to 12°22’48” N latitude and has an altitude of 1975 meters above sea level (Endesew, 2019). Addis Zemen is its administrative center. It is situated 645 km from Addis Ababa and 82 km from the regional capital, Bahir Dar and has 29 rural and 6 urban *kebeles* (lowest administrative unit in Ethiopia equivalent to commune). About 95% falls under the midland

agroecology, 4.1% highland, and 0.9% lowland. The maximum average temperature is 27.9 °C and the minimum 11.1 °C. The cropping systems are mainly dependent on *meher* rains with 75% production contribution and with supplementary irrigation 25% of major crops. The woreda is characterized by rain-fed subsistence farming of crops (maize, millet, "teff" and sorghum), animal husbandry, and irrigated paddy rice cultivation; and these remain the principal agricultural activities despite poor soil fertility and highly variable rainfall in most areas (Addisie *et al*., 2012). Figure 1 shows the map of study area.

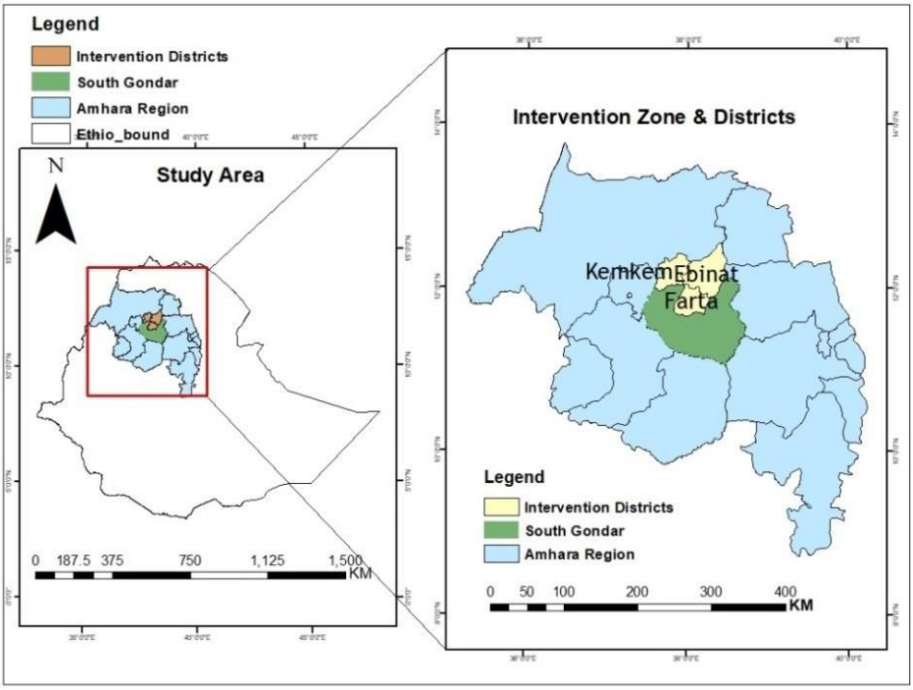

Figure 1. Map of Ebenat, Farta, and Libokemkem woredas (Own source)

Selection of woredas **and the rationale for conducting the trial**

Faba bean gall incited by the pathogen *Olpidium viciae* Kusano infection has led to complete crop failure over wide areas within a short period and aggravated the diminution of yield to maximum nationwide (Mastewal *et al*., 2018). Production has declined in the Norwegian Forestry Group/Forest Landscape Restoration Program (NFG/FLRP) intervention area. To address the constraints of production and to meet farmers' demand for improved varieties and gall disease management technology/package, an integrated faba bean gall disease management pre-scaling-up activity (varieties, agronomic practices such as use of row planting, fertilizer, and bio-

fertilizer, weeding, and crop protection practices such as foliar chemical application) was undertaken in Ebenat and Farta in 2020 and in Libokemkem in 2021.

The Amhara Agricultural Research Institute (ARARI), as a stakeholder of the NFG/FLRP, which deals mainly with the restoration of degraded landscapes and protection of exclosures, purposively selected the woredas for they are intervention areas of the program and the resident farmers' demand for faba bean gall disease management technology was communicated to the institute through the program. Consequently, ARARI through its Adet Agricultural Research Center executed the research activity to address farmers' technology needs and help farmers get additional income and food until they start to benefit from the fruits of natural resources conservation works they undertook on their farm plots and/or communal lands. The trial was conducted to improve the income and livelihoods of farmers in the program's intervention areas as a trade-off for the natural resources conservation works whose outcomes are very slow and are not rewarding within short periods.

Discussion with stakeholders

Before conducting the pre-scaling up, a discussion forum was organized with the heads and experts of Ebenat, Farta, and Libokemkem and kebele Offices of Agriculture, seed producers' cooperatives, unions, Norwegian Forestry Group/Forest Landscape Restoration Program (NFG/FLRP) and zone quarantine office on the objectives of the pre-scaling up activity and on how faba bean production can be reinstated in the project area through the use of improved varieties, agronomic practices and chemical application against gall disease, and how they could contribute in doing so. Moreover, a discourse was made with heads and experts of the woreda Offices of Agriculture and Development Agents (DAs) of the kebeles about the selection of clustered farms (5 ha each in Ebenat and Libokemkem, and 5.65 ha in Farta) and participant farmers.

Signing of agreement

Researchers from Adet Agricultural Research Center (AARC) who were originally responsible for creating and strengthening linkage with extension, quarantine office, cooperatives promotion office, farmers' union, and farmers' cooperatives signed an agreement following the discussion and the consensus between them and the stakeholders. The agreement was signed to accomplish the pre-scaling up research undertaking and other successive activities. Therefore, researchers were responsible for the formation of clustered farms; provision of couples training, establishing a committee, provision of inputs such as improved seeds, bio-fertilizers, and pesticides; and organizing field days. Experts and development agents from the woreda and kebele agricultural offices were responsible for the formation of a representative cluster, selection of participant farmers, participating in the training, distributing inputs,

guiding/assisting farmers at planting, conducting joint M & E with researchers, and organizing field visits to resident farmers and attending field days.

Moreover, experts of the woredas had the duty to organize field days jointly with researchers, and DAs to arrange other (additional) field days for those who missed the opportunity to participate in the field visits and field days. The Quarantine Office is responsible for the inspection and approval of the two faba bean varieties tested as one of the packages of faba bean gall disease management to be used as quality declared seeds (QDS). The cooperatives' promotion office, farmers' union, and farmers' cooperatives had the duty of facilitating the purchase of faba bean seeds from the producers. These seeds were used as a seed source for further scaling-ups. Experts of the NFG/FLRP had the responsibility to participate in the selection of farmers, store inputs in warehouses that are to be distributed to participant farmers, and grain samples after harvesting in the warehouses. Moreover, they had the duty to provide transport services (motorbike) to DAs whenever necessary and make periodic inspections of the trial.

Selection of farmers, clustering farmlands, and committee establishment

Eighty-five host/participant farmers (24 in Ebenat, 43 in Farta, and 18 in Libokemkem, of which 7 were females) having 15.65 ha of land were selected to participate in the integrated faba bean gall disease management pre-scaling up. The host farmers with adjacent farmlands were selected collaboratively by extension workers, researchers, and experts of the NFG/FLRP and clustered forthwith. They were selected purposively considering the suitability of their farmlands, their interest and willingness to grow faba bean and engage in the activity diligently and vigorously. Their farmlands were clustered for ease of timely planting, weeding, guarding, disease surveillance, increased visibility, and easiness of follow-up. For the success of the pre-scaling up, a committee consisting of a chairman, secretary, and controller was established which is responsible for the overall activities of the trial. It had to coordinate and ensure timely sowing, flood control, weeding, chemical application, and guarding of the cluster from livestock damage. Furthermore, the committee was entrusted with the tasks of summoning host farmers/participants and non-participants of the pre-scaling up for field visits, field days, and harvesting.

Training couples

Apart from their involvement in livestock production and household chores, women in Ethiopia play central role in crop production right from the soil preparation to post-harvest activities (Fenet and Alemayehu, 2019). They are involved in land preparation, sowing, weeding, harvesting, threshing, winnowing, storing, and post-harvest handling (Mulugeta and Tilaye, 2021). With respect to faba bean production, women farmers in the study area cleaned seeds, conducted seed dressing (with biofertilizer), planted seeds

(drilling NPS fertilizer and seeds), removed weeds, and stacked grain together with their children. They also provided food to male household members involved in harvesting and threshing. Sometimes women were also involved in harvesting when labor was scarce and children were at school. Furthermore, women transported the harvested grain home when loaded on a pack animal (donkey), stored it, and practiced other post-harvest management activities. Their role in varietal evaluation and selection was very important; they knew which variety was good for boiling, roasting, *shiro*, or *kik* making.

Women are well familiar with the variety that is good for household use (consumption) or sale. They, for example like both small and large varieties depending on specific purposes; if it is for *shiro* for example in Banja area, they prefer small-size to large-size varieties, while if it is for sale in the market or pot-house/tavern, large-size faba beans are preferred for they can be consumed boiled (*nifro*), or as *bokelt*. This helps faba bean breeders and agricultural extension researchers to design new breeding strategies to develop a new variety that best suits the needs of women and introduce and promote a variety that is their choice.

Despite women's contribution to faba bean production, and in taking care (nurturing and feeding) of the household members, they are not represented in FREG, participating in trainings, field visits, field days, and experience-sharing visits that bolster their knowledge and skills. It is their male counterparts who are often at the forefront of events of agricultural knowledge and technology transfer (Mulugeta and Tilaye, 2021). Therefore, considering women's utmost contributions, couples trainings were arranged for both husbands and wives in the intervention areas to enhance their knowledge of faba bean production, and joint decision-making power related to the amount to be sold and consumed. Women's decision-making power plays a paramount importance in preventing the stunting and wasting of children as faba bean is rich in protein and is considered by farmers as the poor man's meat.

Therefore, trainings were offered to participant farmers, i.e., couples, kebele administrators, and extension workers in the three towns - Ebenat, Debre Tabor, and Addis Zemen (Table 1). The training was given by a multidisciplinary team of researchers comprising breeders, pathologists, agronomists, and agricultural research extensionists. The training focused on the importance of faba bean for food, and nutrition security, sowing, integrated gall disease management package (use of improved varieties, row planting, fertilizer, bio-fertilizer, weeding, and disease control), the crop's contribution to soil fertility, post-harvest handling, and seed system and dissemination. Subsequently, chemical application was demonstrated to farmers and development agents in case an incident happens after planting. On the other hand, couples trainings were arranged because researchers and extension workers primarily offered advice and training services to male members of the household with the

understanding that these individuals will then pass the information on to their spouses or other female household members.

Table 1. Training participants by occupation and woreda

Place of training	Participants/Trainees							
	Farmers in MHHs		Farmers in FHHs	Agricultural extension workers		Total		Total
	M	F	F	M	F	M	F	
Ebenat	21	21	8	8	3	29	32	61
Debre Tabor	38	38	10	10	2	48	50	98
Addis Zemen	30	30	6	9	2	39	38	77
Total	89	89	24	27	7	116	120	236

Key: MHH is a male headed household and FHH is a female headed household

In practice, agricultural knowledge and information are hardly transferred from husbands to wives and other female members of households. To solve this problem, couples' trainings were performed with the presumption that women exchanged information more effectively both inside the household and with neighbors so that information got absorbed more readily, household decisions were made collectively, trainings were applied better, and family labor better mobilized.

Input supply, planting, other agronomic and disease control practices

Wolki and *Hachalu*, adaptable and high-yielding varieties, were released by the Ministry of Agriculture and Rural Development in 2008 and 2010 respectively, for areas with altitude ranges of 1900-2800 masl (mid to high altitude) and rainfall ranges of 700-1000 mm (MoARD, 2008, 2010). Hachalu was recommended for Farta and Wolki for Ebenat, which are areas with water logging vertisols. Both varieties were recommended for Libokemkem with similar vertisols based on the information from the 2008 and 2010 crop variety registers and results of the pre-extension demonstration. The soil types, altitude, and rainfall ranges of the intervention areas were within the ranges of the altitude and rainfall ranges of the adaptation areas where the varieties were released.

These varieties, however, were not widely cultivated in the study areas, therefore, the two improved varieties, bio-fertilizer (FB-EAL-110), and pesticides (Noble-25 only upon occurrence) were distributed to participant farmers by AARC free of charge. Besides, row planting, fertilizer (NPS covered by beneficiary farmers) application at planting, hand weeding, and chemical spray upon the incidence of gall disease were recommended as a package/technology. Thus, a total of 0.6 tons of Wolki and 0.7 tons of Hachalu faba bean seeds were distributed to Ebenat and Farta, respectively, while 0.668 tons of the same varieties were distributed to participant/host farmers in Libokemkem . Planting was done at a seed rate of 150 kg ha^{-1} and a fertilizer rate of 121 kg ha^{-1} NPS in rows with a spacing of 40 cm between rows and 10 cm between plants.

The faba bean clusters in Farta and Ebenat were later sprayed with Noble-25 chemical at the rate of 500 gm ha^{-1} because the crop was attacked by gall disease. No such spray was done in Libokemkem because there was no disease. Planting was done in the presence of researchers from AARC, heads and experts of the woreda offices of agriculture and DAs of the kebele agriculture office, kebele administrators, and participants of the pre-scaling ups. Sowing was done according to native farmers practices.

Monitoring and evaluation

The team of researchers from Adet Agricultural Research Center and the Amhara Agricultural Research Institute, agricultural extension workers from the woreda and kebele Agricultural Offices, participant farmers, and experts of the Quarantine Office and NFG/FLRP, jointly monitored the pre-scaling ups. Successive joint M & Es (follow-up actions) were conducted at different growth stages of the crop, where technical advice to participant farmers was provided based on emerging knowledge and skills. During the M & E, the team was able to ensure the emergence of the seeds, proper drainage, weeding, and health of the crop. The joint team suggested corrective actions against constraints encountered in the process such as the use of chemicals against gall disease (upon the incidence of the disease), and the protection of the field trial from livestock damage.

Field visits and field days

Field visits were arranged collaboratively by kebele Agricultural Offices and committees for participants and other resident farmers to enhance their awareness and augment their knowledge of integrated faba bean gall disease management package/technology and facilitate experience sharing among participant and non-participant farmers. Field visits are important extension methods for creating wider awareness and facilitating farmer-to-farmer information/experience sharing. Field visits were arranged 3 times (at emergence, in the middle, and at the maturity stages of the crop) in a production season to create an opportunity for the participant and non-participant farmers to learn from each other.

Field days were organized by AARC and the woreda Agriculture Offices jointly to collect ideas and opinions of farmers and stakeholders on the performances of the trial, seed system and dissemination, the linkage and synergy among the stakeholders, and wider scaling up of the technology, or integrated faba bean gall disease management package (improved varieties, row planting, fertilizer and bio-fertilizer application, weeding and disease control). To create opportunities for those farmers who were not able to attend field visits and field days for different reasons, additional field days were also organized by the kebele Agricultural Offices to facilitate wider knowledge and technology sharing and dissemination among kebele inhabitants.

Data collection and analysis

Data collection

Quantitative data on agronomic traits such as plant height, number of pods per plant, and number of seeds per pod were recorded from a total of five randomly taken plants from each cluster and averaged for data analysis. Besides, data on dry biomass yield (grain and straw yields) were taken to determine which variety has desirable traits (s) and is the highest yielder. To see the grain yield difference, samples of grain yield were taken from the clusters and the nearby farmers' plots after harvesting and threshing. Data on the current wage price of labor, input costs (bio-fertilizer, chemical fertilizer, and seed), and current farm gate price of the grain at harvest were collected. Besides, qualitative data (feedback opinion, and perception) from farmers, extension workers, and other stakeholders were gathered during M & E, field visits, and field days. On the other hand, sex-disaggregated data on the performance of the new faba bean production package, the number of participants in the pre-scaling up, couples training, field visits, and field days were also taken. In addition to this, issues that were raised and discussed during the field days about the roles of the stakeholders in the upcoming technology scaling-up were recorded.

Data analysis

Plant height was measured by the researchers taking the average height of five randomly taken plants from each cluster measured in centimeters from the ground surface to the tip of the main stem at maturity. The number of pods per plant was recorded by the extension workers taking the average number of pods counted on the five randomly selected plants from each cluster. Similarly, the number of seeds per pod was determined by taking the average number of seeds from three pods of five plants from each cluster. Moreover, dry biomass yield was measured by taking 3 samples along the diagonal line of each cluster above the ground with a 1m by 1m quadrant, sun-dried, weighed, and converted to a hectare to get the biological yield.

The quantitative grain yield data were analyzed using simple descriptive statistics such as mean, maximum, and minimum. Partial budget analysis was employed to analyze the economic benefits of the new technology option (IFBGDMTP) using data on current wage-price, input costs, and current farm gate price of the grain at harvest. The qualitative data were thematically described and used to further strengthen the best practices and tackle the shortcomings; sex-disaggregated data were also qualitatively narrated and used to rectify the flaws and show future directions for gender-inclusive pre-scaling up and up-scaling endeavors.

RESULTS AND DISCUSSION

Results of agronomic traits, yield, and yield advantage

For up scaling integrated faba bean gall disease management technology, participant farmers were allowed to compare the two improved faba varieties along with their agronomic and disease control components of the package. They compared them with the local variety and local practice based on their tradition or visual judgment. Thus, from Table 2, it can be understood that Hachalu is taller than the two faba bean varieties (Wolki and the local variety) with an average height of 177.6 cm across the three woredas. Farmers who observed the varieties visually have selected Hachalu to be the tallest over Wolki and the local faba bean varieties in all locations and this corroborates the results of the plant height analysis of the researchers. Since row planting was used as one of the production packages of faba bean, improved faba bean plants are assumed to have grown tall because of less nutrient competition compared to broadcasting where there is high competition among individual plants. The difference in plant height (and other agronomic traits such as pods per plant and seeds per pod, and yield such as dry biomass yield) between the two improved varieties, however, is purely attributed to their genetic makeup, while between the local and the improved ones is attributed to both the genetic makeup and methods of planting.

Pods per plant were counted to determine which variety has more pods per plant and is very productive; thus compared to Wolki (improved) and the local variety, Hachalu had on average 12.2 pods per plant (Table 2). By having a look at the varieties and counting the number of pods per plant, host farmers confirmed that Hachalu variety is the variety with more pods per plant. It is better than Wolki in the number of pods per plant because of its genetic makeup while it surpasses the local variety on the one hand because of its genetics on the other because of the planting method. Row planting for Hachalu and Wolki was one of the constituents of faba bean production package/technology in contrast to the local variety that was broadcasted.

Table 2. Agronomic traits and dry biomass yield performance of faba bean varieties

Varieties	PH Cm	PPP no	SPP no	DBM t ha^{-1}
Hachalu	177.6	12.2	4.4	7.03
	148.2	9.2	3.5	6.25
Local	125.6	5.0	2.0	3.83

Key: PH=Plant Height, PPP= Pod per Plant, SPP= Seed per Pod, and DBM=Dry Biomass. **Source:** Own data

Average number of seeds per pod was 4.4 for Hachalu, 3.5 for Wolki, and 2.0 for the local variety. By visual observation, farmers confirmed Hachalu to be better variety with more seeds per plant, and were more productive than the other two varieties (Table 2).

The highest average dry biomass yield (t ha^{-1}) was recorded from Hachalu at 7.03 t ha^{-1} followed by Wolki with a dry biomass yield of 6.25 t ha^{-1} in all woredas. The response of this trait to the sowing method (row planting) may be due to the efficient resource utilization of the plant when compared with the other methods (Table 2). More biomass means an advantage in limited animal feed settings. To this end, the highest biomass yield of Hachalu provides more feed (biomass yield) than the local variety.

In terms of grain yield, Wolki with all other elements of the technology package gave an average grain yield of 3.20 t ha^{-1} in Ebenat while Hachalu gave a mean grain yield of 3.64 t ha^{-1} in Farta. On the other hand, Wolki faba bean variety with all other components of the technology package gave a mean grain yield of 3.30 and Hacahlu 3.10 t ha^{-1} in Libokemkem. The local variety produced by farmers gave low grain yield due to its poor genetic potential, susceptibility to gall disease, and treatment with local production practices. In all three locations, the average grain yields of Wolki and Hachalu varieties were well above the national average productivity (2.1 t ha^{-1}) of faba bean with the yield advantage of 55.0% and 60.71% over the national average productivity, respectively.

The yield and yield advantage of integrated faba bean gall disease management package/technology is presented in Table 3 compared with local production practice which consists of the use of the local variety, broadcasting, no weeding, and no pesticide use against gall disease. Yield and partial budget analysis were used to compare the two (Wolki and Hachalu) varieties and their own production packages with that of the local faba bean variety and its local production practices. To compare the yield advantage and analyze the yield gap between the two practices, samples of grain yield were collected from 5 host/trial farmers' plots and 5 neighboring farms with the local practices. The highest yields were obtained from improved faba bean varieties with integrated faba bean gall disease management technology, i.e., Hachalu (3.90 t ha^{-1}) and Wolki (3.31 t ha^{-1}). The highest yield obtained from the local variety and practice was 1.20 t ha^{-1}. The overall sample mean yield of Wolki was 3.20 t ha^{-1} and that of Hachalu was 3.64 t ha^{-1} which is far better than the yield of the local variety (0.86 t ha^{-1} and 1.0 t ha^{-1}). The improved faba bean variety Wolki with the recommended production packages gave a yield advantage of 272.1% and Hachalu 264.0% over and above the local variety with local practices in Ebenat and Farta.

Similarly, in Libokemkem, the overall sample mean yield of Wolki was 3.30 t ha^{-1} and that of Hachalu was 3.10 t ha^{-1}. The two improved production packages gave more grain yield than that of the local variety (1.20 t ha^{-1}). Wolki with the recommended production packages gave a yield advantage of 175% and Hachalu) 158.3% over the local variety with its local practices. Across locations, Wolki with the recommended production packages gave a yield advantage of 218.6% and Hachalu 230.4% over the local variety with local practices (Table 3). Figure 2 shows the maximum, minimum and average

yields of the two improved and one local variety along with their corresponding production packages. The high yield variability of Hachalu is attributed to the observed difference in precursor crops among the farmlands of the clustered farmers.

Table 3. Average yield and yield advantage of faba bean technologies by different locations

Location	Variety	Average grain yield (t/ha)	Yield advantage (%)
Ebenat	Wolki	3.2	272.1
	Local	0.86	-
Farta	Hachalu	3.64	264
	Local	1	-
Libokemkem	Wolki	3.3	175
	Hachalu	3.1	158.3
	Local	1.2	-
Average	Wolki	3.25	218.6
	Hachalu	3.37	230.4
	Local	1.02	-

Source: Current study

Figure 3 shows the improved Wolki variety and the local one in Libokemkem. The local variety was affected by gall disease.

Partial budget analysis

Farmers adopt new agricultural technologies/packages only when they are convinced that they benefit from them. Hence, to help farmers adopt the integrated faba bean gall disease management technology package, a partial budget analysis was employed to compare the improved varieties with other elements of the technology package with that of the local variety with the local practice using CIMMYT (1988) manual. The yield obtained from the improved technology package was adjusted by 10% to more accurately reflect yields obtained under farmers' practices. See Appendix-1 which shows the data used for the partial budget analysis. The appendix also justifies the reason why the harvesting and threshing costs vary between the IFGDMTPs (Integrated Faba Bean Gall Disease Management Technology Package) and the local variety with local management.

As indicated in Table 4, Hachalu variety (with gall disease management technology package) gave a net benefit of 104,762 ETB ha^{-1} in Farta. The benefit of the technology is very high with a marginal rate of return (MRR) of 560%, i.e., for every additional Birr investment on the technology there is a return of 5.60 ETB ha^{-1} after covering the one Birr investment. Besides, Wolki variety (with gall disease management technology package) gave a net benefit of 88,850 ETB ha^{-1} in Ebenat with a MRR of 464%, i.e., for every Birr additional investment in the technology there is a return of 4.64 ETB ha^{-1} after covering the one Birr investment. In Libokemkem, Wolki gave a net benefit of

92,450 ETB ha^{-1} and Hachalu 85,250 ETB ha^{-1}. The MRR for Wolki was 435% and for Hachalu 386%, i.e., a return of 4.35 and 3.86 ETB ha^{-1}, respectively, after covering the one Birr investment. Therefore, as the MRR for Wolki and Hachalu are above 100%, it is worthwhile to adopt the technologies and ensure income, food, and nutrition security of rural households.

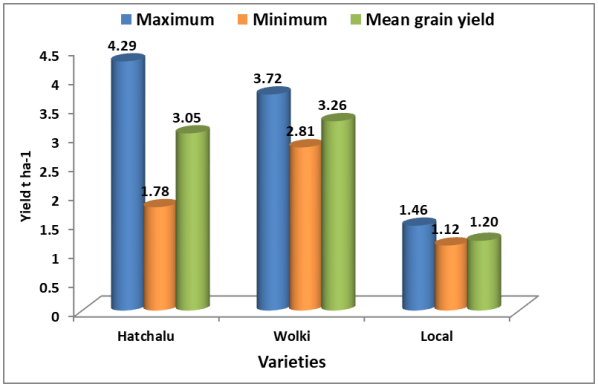

Figure 2. Grain yields of faba bean in Libokemkem woreda

Farmers' and stakeholders' feedback on the integrated gall disease management packages

Three field visits were organized by the kebele agricultural development offices in Ebenat and Farta, where over 80 (66 men and 14 women) and 120 farmers (101 men and 19 women) participated, respectively. In Libokemkem, *w* over 70 farmers (59 men and 11 women) participated in three similar field visits. Figure 4 shows one of the field visits in Farta and Ebenat.

Figure 3. Improved variety (left) and local variety (right) in Libokemkem

Field days were also organized by Adet Agricultural Research Center together with the respective Agriculture Offices to get feedback from farmers and other stakeholders. A total of 358 farmers (49 female) and 103 (6 females) agricultural experts, DAs, woreda administrators, regional office heads, researchers, representatives from farmers' unions, and NFG/FLRP attended the field days. Leaflets prepared on faba bean production packages were distributed to participants to familiarize farmers and other stakeholders with faba bean integrated gall disease management technology and thereby create wider demand for up scaling.

Table 4. Partial budget analysis for the different faba bean varieties tested at different locations

	Farta		Ebenat		Libokemekem		
	Hachalu	**Local**	**Wolki**	**Local**	**Wolki**	**Hachalu**	**Local**
			Grain yield (kg ha^{-1})				
Average GY*	3642	1000	3200	856	3300	3100	1200
Adjusted GY by 10%	3277.8	900	2880	770.4	2970	2790	1080
Gross field benefits	131,112	32,400	115,200	30,816	118,800	111,600	38,880
			Costs incurred (ETB ha^{-1})				
Seed	6750	7200	6750	7200	6750	6750	7200
Chemical fertilizer	1500	0	1500	0	1500	1500	0
Bio-fertilizer	100	0	100	0	100	100	0
Pesticides	6000	0	6000	0	6000	6000	0
Land preparation	4,800	1,200	4,800	1,200	4,800	4,800	1,200
Planting	400	200	400	200	400	400	200
Fertilizers	400	0	400	0	400	400	0
Weeding	1600	400	1600	400	1600	1600	400
Pesticide	1200	0	1200	0	1200	1200	0
Harvesting	2400	1800	2400	1800	2400	2400	1800
Threshing	1200	600	1200	600	1200	1200	600
Total costs	26,350	11,400	26,350	11,400	26,350	26,350	11,400
Net benefit (ETB/ha)	104,762	21,000	88,850	19,416	92,450	85,250	27,480
MRR* (%)	560		464		435	386	

*GY stands for grain yield and MRR for marginal rate of return.
Note that the 3 treatments were not replicated at the 3 locations because Wolki and Hachalu varieties were mainly recommended for Farta and Ebenat, respectively, whereas both varieties are recommended for Libokemkem. 1 USD is equivalent to 56.9721 ETB on April 23, 2024

At the scene of the field days participant farmers expressed their happiness since they had been made acquainted with the varieties, and the recommended agronomic and disease management options. They expected the trials to be seed source for them. They were happy because the two varieties were inspected by South Gonder Zone Plant Health, Other Inputs Quality Control, and Quarantine Authority and approved to be used as QDS (1st generation seed). Host and non-host farmers attending the field days were

excited by the performance of the improved faba bean varieties because they were tall, more prolific, and resistant to gall disease. According to them, the local and the improved varieties were incomparable. The local is out of production because of the disease. The new ones are taller, possess broader leaves, set more pods from bottom to top and give more yield.

According to farmers, the use of bio-fertilizers and chemical sprays such as Noble-25 against gall disease is inevitable for sustaining the production of faba bean. They are easy to apply and not very expensive given the yield advantage they offer. Non-host farmers who had the chance to visit this work wanted to get these technologies also for them.

Extension workers claimed that farmers have stopped producing faba bean for over 15 years because of the disease. Libokemkem woreda Office of Agriculture promised to facilitate the purchase of the seeds from participant farmers for the upcoming large scaling-up endeavors to speed up the dissemination of the varieties. Participant/host farmers in Ebenat and Farta affirmed their interest in exchanging the seeds in kind or selling out the extra seeds to other farmers for broader dissemination.

Participating women farmers claimed that this project was an effort to resurrect the long gone crop and was a success.

They said that the crop vanished because of *"kormit"* or *"kormid"*, i.e., the gall disease. Common traditional dishes such as *shiro, kik, elbet, nifro,* and *girgib* turned a luxury as a result. The crop used to be viewed as the poor's man meat. Women believed that this effort could help in curbing stunting and wasting of children, a common experience in the Amhara Region including the study area.

Women participants preferred Hachalu and Wolki over the local for the seeds are bigger and smoother. Participant women got involved in decision making efforts at all levels including the marketing of the beans.

Women were willing to adopt the technology but they feared that they may not get access to Noble-25 and the bio-fertilizer and they underpinned the need for a steady supply of these inputs (Table 5). They promised to convince nearby communities to exchange the technologies farmer to farmer.

The difference in plant height and other agronomic traits such as pods per plant, seeds per pod, and dry biomass yield between the two improved varieties, are purely attributed to their genetic makeup, while between the local and the improved ones is attributed to both the genetic makeup and methods of planting.

Figure 4**.** Faba bean cluster in Farta and Ebenat woredas

This is partly in agreement with Kissi and Tamiru (2016) who reported that the highest agronomic traits and dry biomass yield were recorded by the row planting method as compared to broadcast planting. The highest number of seeds per pod from Hachalu (4.4) coincided with farmers' speculation that Hachalu is the best variety with more seeds per plant, and is more productive than the other two varieties. This can be seen in harmony with the reports of Ashenafi and Mekuria (2015) and Degife and Kiya (2017) which portray that the number of seeds per pod had a considerable relationship with seed/grain yield.

Table 5. Farmers' response on the merits, access to external inputs, and the decision to adopt IFGDMTP

Variables	Response	Frequency	%
Are the IFGDMTPs generally better than the local variety with local management?	Yes	15	100
Are improved varieties disease-resistant?	Yes	10	67
Do IFGDMTPs increase productivity?	Yes	15	100
Are biomass yield of IFGDMTPs better than the local variety with local management?	Yes	15	100
Is the marketability of improved varieties better than the local variety?	Yes	15	100
Is the food quality of improved varieties better than the local variety?	Yes	15	100
Does Noble-25 pesticide control gall disease?	Yes	15	100
Will you have access to Noble-25 and bio-fertilizer?	No	15	100
Will you use IFGDMTP by next year?	Yes	15	100
Will you recommend others to adopt IFGDMTPs?	Yes	15	100

Note: IFGDMTP means Integrated Faba Bean Gall Disease Management Technology package

The highest mean dry biomass yield (t ha^{-1}) was obtained from Hachalu (7.03 t ha^{-1}) followed by Wolki with a dry biomass yield of (6.25 t ha^{-1}) in all the woredas. This also partly complies with the report of Kissi and Tamiru (2016) which reveals that the highest biomass yields were recorded by the row planting method compared to broadcasting. The response of this trait to the sowing method (row planting) may be due to the efficient resource utilization of the plant when compared with broadcasting. The highest dry biomass yield from Hachalu is more advantageous in areas where natural resource degradation is prevalent and feed for livestock is a scarce resource.

The mean grain yield obtained from Wolki variety with all other elements of the technology package in Ebenat (3.20 t ha^{-1}) and in Libokemkem (3.30 t ha^{-1}) agreed with a farmer field yield range of 2.0 - 4.20 t ha^{-1} as reported in MoARD crop variety register of 2008. On the other hand, Hachalu variety with all other components of the production gave a mean grain yield of 3.64 t ha^{-1} and 3.10 t ha^{-1} in Farta and Libokemkem, respectively. This complies with the farmer field yield range of 2,4 – 3.5 t ha^{-1} as indicated in the MoARD crop variety register of 2010. As Walli (2004) reported, straws of legume crops have generally better nutritive value, and forage quality and thus are nutritionally superior to cereal straws. This is because a straw of faba bean is richer in protein, calcium, and magnesium than cereal straws, and if properly harvested, it is a useful roughage feed for ruminant animals (McDonald *et al*., 2010). Generally, pulse straws contain 10 - 15% crude protein (CP) in DM and their energy content is higher compared to the respective cereals by-products and sugar cane, with satisfactory palatability (Yetimwork *et al*., 2011).

ONCLUSION AND RECOMMENDATIONS

Conclusion

The two improved varieties, Wolki and Hachalu, as components of the IFGDMTP were found to be highly productive with the yield advantage of 272 and 264%, respectively, over the local variety with local practice. The varieties with other recommended agronomic and disease control practices were very adaptable in the intervention areas and gave higher economic benefits with the MRR ranging from 386% to 560%. The IFGDMTP not only contributed to high grain yield but also contributed to high straw yield (dry biomass yield) that can be used as the source of feed for livestock.

The pre-scaling up was conducted by involving host farmers in the entire process, from planning to harvesting and creating awareness about the technology package and its economic benefits. This in turn has brought about increased demand for the IFGDMTP among the farming communities. Owing to such demand, in three years, an additional 933 farmers have adopted the production package that constituted 28 tons of the disseminated improved seeds through farmers-to-farmers seed exchange in 2023. In Ebenat alone, the varieties have been scaled up in 13 mid and high-altitude areas in 2020. This fast rate of diffusion of the production technology is attributed to creating strong linkage among key stakeholders where each stakeholder discharged its duties and responsibilities as per the agreement signed.

It is observed that about 25.7% of women have been participants in couples training and field days. However, their participation is very minimal; it is below what has been planned by ARARI (30%) over the past 15 years, and the target set by the Amhara Bureau of Agriculture, i.e., GTP II: 50% and 100% of the total extension service beneficiaries to be married women and female-headed households, respectively.

Recommendations

For wider up scaling of the IFGDMTP in the intervention and elsewhere in similar agroecologies of the region, seed multiplication of the improved faba bean varieties by the public, and the private sectors is indispensable. The provision of farmers with a bio-fertilizer, a pesticide (for gall disease), and seeds of the improved varieties is critical for scaling up the technology package so that research centers, agricultural offices, and other development partners in the Amhara region should be able to dress the seeds before planting and/or spraying the chemical immediately upon the occurrence of the disease. Thus, the offices of agriculture have to avail all the inputs (with quality assurance) ahead of time for the upcoming planting seasons as they are important for the success of faba bean gall disease management scaling-up efforts.

Farmers have the belief that excess water will percolate into the soil if a plot of land is weeded twice so that the surplus water will negatively affect the growth of the crop. This calls for biophysical researchers to research to prove the belief.

To make women farmers more active participants and beneficiaries of participatory research and extension such as the IFGDMTP pre-scaling up and scaling up, their participation has to be improved through community awareness creation and opening of more rooms (providing more opportunities) for their participation. Hence, more work is required to bring them to the forefront equally to their male counterparts to enhance their participation in research as their roles are very central.

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Appendix 1. Data used for the partial budget analysis

Field price of improved and local faba bean varieties (40 and 36 ETB/kg, respectively**)**
Seed rate of improved and local management (150 and 200 kg ha-^{1}, respectively)
Field price of improved and local seeds (45 and 36 ETB/kg, respectively)
Chemical fertilizer rate (100 kg ha-1)
Field price of chemical fertilizer (15 ETB/kg)
Bio-fertilizer rate (0.5 kg ha^{-1})
Field price of bio-fertilizer (200 ETB/kg)
Pesticide rate (2 Lit ha^{-1})
Field price of pesticide (3000 ETB/Lit)
Labor required for land preparation to the improved & local management (16 & 4 man-days/ha, respectively)
Wage rate of land preparation (300 ETB/man-day)
Labor required for planting to the improved & local management (4 & 2 man-days/ha, respectively)
Wage rate of planting, fertilizers application, and weeding (each 100 ETB/man-day)
Labor required for fertilizers application (4 man-days/ha)
Labor required for weeding to the improved and local management (16 and 4 man-days/ha, respectively)
Labor required for pesticide application (8 man-day/ha)
Wage rate of pesticide application, harvesting, and threshing (each 150 ETB/man-day)
Labor required for harvesting the improved & local management (16 & 12 man-day/ha, respectively)*
Labor required for threshing the improved & local management (8 & 4 man-days/ha, respectively)*

* Note that the difference in the required labor for harvesting and threshing of the improved & local management is attributed to the higher plant density and area coverage of IFGDMTPs per hectare at the maturity stage of the crop than the local variety with local management.