BEST FIT PRACTICE MANUAL FOR FOOD BARLEY PRODUCTION

Applicable for Mid-Altitude Areas Including Dera, South Achefer, Burie and Jabi Tehenan Districts of North-western Ethiopia

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Capacity building for scaling up
of evidence-based best practices
in agricultural production in Ethiopia

The CASCAPE project is designed to assist the activities deployed under the Agricultural Growth Programme (AGP) by further strengthening the capacity of AGP stakeholders in identifying, documenting and disseminating best practices in agricultural production. CASCAPE is jointly executed by Ethiopian researchers from Jimma University, Haramaya University, Bahir Dar University, Hawassa University, Mekelle University, Addis Ababa University and Dutch researchers from Wageningen University and Research Centre. In each site researchers from the universities and from the RARIs from different disciplines work on the CASCAPE project. The CASCAPE project is financed by the Dutch Ministry of Foreign Affairs through the Embassy of the Kingdom of The Netherlands.

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Acronyms/Abbreviations

ACSI	Amhara Credit and Saving Institute
AGP	Agricultural Growth Program
ANRS	Amhara National Research State
BoA	Bureau of Agriculture
CASCAPE	Capacity building for scaling up of evidence-based best practices in agricultural production in Ethiopia
CSA	Central Statistics Agency
DAs	Development Agents
DoA	District Office of Agriculture
FTC	Farmer Training Centre
Ha	Hectare
Kg	Kilogram
MoARD	Ministry of Agriculture and Rural Development
NGOs	Non –government organizations
PRA	Participatory Rural Appraisal
Qt	Quintals
SMS	Subject matter specialists
ToT	Training of Trainers
ZOA	Zone Office of Agriculture

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Improved Food Barley Production

1. Introduction

Barley is one of the commonly grown food security crops in high altitude areas of CASCAPE intervention areas. The total number of households cultivating barley in the Amhara Region was estimated to be 1,391,000, while the total number of households cultivating barley at national level was estimated to be 4,148,000 (CSA, 2010/2011). Similarly, the total number of households cultivating barley in South Gonder (in which Dera District is found) was estimated to be 182,750, while the total number of households cultivating barley in West Gojjam (in which Burie and Jabitehenan are found) was estimated to be 103,450 (CSA, 2010/2011). Its grain is used for the preparation of different foodstuffs, such as *Injera, Kolo,* and local alcoholic drinks, such as *Tela*. The straw is used as animal feed, especially during the dry season.

The national area coverage of barley was estimated to be 1,047,000 ha with productivity of 1.63 tons ha^{-1} while the regional area coverage and average productivity was estimated to be 328,000 ha and 1.3 tons ha^{-1}, respectively (CSA, 2010/2011). Similarly, the total area coverage for South Gonder was estimated to be 35,861 ha with productivity of 1.3 tons ha^{-1}, while for West Gojjam 24,649 ha with productivity of 1.1 tons ha^{-1}. Among other factors contributing for the low productivity of the crop, the low yielding ability of farmers' cultivars and soil acidity problems are the major bottlenecks.

However, recommendation packages from different agricultural research centers indicated the presence of a number of improved varieties released with the potential productivity of about 5 tons ha^{-1} and 3 tons ha^{-1} at research station and at farmers' field, respectively. According to MoARD crop variety registry (2009), 25 improved food barley varieties have been released till 2009.

Given the above mentioned potential productivity and current productivity, most of the farmers in the intervention areas obtained low yield that could have been enhanced from the use of improved technologies.

The PRA and scoping study of CASCAPE project revealed that there were limited improved practices in barley farming system in the intervention areas including improved varieties and liming. Thus, validation of improved food barley varieties was conducted during the previous cropping seasons. The result from this validation trial was found promising to narrow the huge production gaps at farm level. Besides, amendment of acidic soils using lime was tested in food barley production system and was found very promising with 50% grain yield improvement.

This manual describes the tested and validated innovation and best practices that have been tested by CASCAPE in Dera, Burie and Jabitehenan Districts. The practices described here are deemed proven enough to be handed over. Thus, these can be scaled out to many more farmers. This manual is written for extension workers working at district level and other development actors.

Generally, the best practices tested by the project was found very promising to boost food barley production and productivity and also highly demanded by farmers. For wide spread dissemination of this innovation writing of this best fit practice manual based on the project practical experiences is essential.

2. Testing of improved food barley technologies

Before recommendation of improved varieties to a certain area participatory evaluation of improved varieties against the local variety is essential to select the best fit variety among the improved varieties.

Consequently, in 2012/2013 cropping season, four improved food barley varieties (*HB-1307, HB-42, Shege and cross-4198*) were evaluated against local check. Testing of this innovation was carried out at *Shime, Mana* and *Woynma Ambaye Kebeles* in Dera, Jabitehenan and Burie Districts, respectively. These sites were selected based on their agroecological suitability for food barley production. The demonstration trial was conducted on nine farmers' fields and two FTCs with a plot size of 10m x 10m for each variety. The improved variety (*HB-1307*) was found superior over all other varieties tested including the local variety for its grain yield. Thus, the demand for this improved variety (*HB-1307*) has been very substantial to promote further and to scale it.

In 2013/2014, pre-scaling up of improved food barley variety (*HB-1307*) was carried out on selected 12 farmers' fields and one FTC on a plot size of 0.125ha. The pre-scaling up activity was undertaken at four intervention kebeles of *Mana, Shime, Gelawdewos* and *Woynma Ambaye* on two to four farmers and on one FTC at *Woynma Ambaye Kebele*. Besides, to evaluate strong positive yield synergies between improved crop varieties (*HB-1307*) and liming of acid affected soils, field trial with application of lime and without lime was conducted in 2013/2014 cropping season.

In 2014/2015, scaling up of improved food barley variety (*HB-1307*) was carried out in Dera (*Sheme Kebele*), Burie (*Woynma Ambaye Kebele*) and Jabitehenan (*Mana Kebele*) Districts. A total of 97 farmers were participated in the scaling up of *HB-1307*. Besides, scaling up activities were also done on three FTCs. Starting from 2012/2013 to 2014/2015 farmers were the major actors to participate the evaluation of the food barley innovation (Figure 1).

Figure 1: Farmers and experts evaluating (*HB-1307* variety) during field day

3. Best fit production practices

3.1 Development pathways

The promotion of best practices should be designed in the context of the broader development pathway for a selected location and the factors that shape the nature of particular development pathways. What are the comparative advantages for a specific geographic area and its household groups (target groups) and what best practices help develop such opportunities? What are the factors influencing the spread or inhibition of uptake of the best practices in each path? Farmers adopt best practices that help them exploit the comparative advantages provided by the development path and therefore transform their livelihoods. For example, opportunities for development of high value perishable commodities, such as horticultural crops or dairy, are likely to be greatest in areas with relatively high market access and agricultural potential (Pender et al, 2001). Scaling up/out of best practices in horticulture or dairy may be targeted to such areas.

HB-1307 food barley variety was introduced and promoted for the last three consecutive years at Dera, Burie and Jabitehenan Districts. Based on data collected from the base line survey of the project and current observation, the innovation development pathway was analysed based on agricultural potential, population pressure and market access. The results are presented in Table 1.

As indicated in Table 1, the development pathway analysis revealed that, the agricultural potential of the intervention areas are characterized by high rain fall, availability of irrigation and well drained and fertile soils.

The presence of good road networks in these areas provided opportunities to have access to high local and regional market. The development pathways analysis showed that areas with similar agro-potential, market, infrastructure and well adopted culture of the community feeding barley should be considered in scaling up of this practice. In these areas and similar agro-ecologies, therefore, the innovation would contribute to achieve sustainable production, productivity and food security.

Table 1: Development pathway analysis for scaling up of *HB-1307* food barley

Agricultural potential	Market and infrastructure access	Population pressure
• High rainfall • Availability of irrigation • Availability well drained suitable soil	• Potential local and Regional markets • Accessibility of high way and all weather roads • Accessibility of finance for input supply	• High population density (land shortage) • Production diversification • Nutrition gap filling • Culture of consumption and production • Availability of labour

3.2. Drivers for adoption

Drivers for adoption of five crops were studied in 2013. The study includes improved seed use intensity, fertilizer use intensity, row planting and chemical (insecticide, fungicide, and herbicide) application technologies adoption. Except district differences, no variable was found to be significantly affecting the adoption levels of these technologies. The reason is simply because no improved seeds and pesticide chemicals in these areas. Row planting is not practiced in barley yet, though currently there is a strong start in this respect. As the result of the tobit model analysis indicated, barley technology adoption decreases significantly in Jabitehenan woreda when compared with Dera. But there was no significant difference in the levels of barley technology adoption among Dera, South Achefer and Mecha woredas. Thus, the result of the study showed the combined intake level. It does not focus particularly on the adoption level of improved seed and lime application.

However, the result of the qualitative studies, group discussion and key informant interview, indicated that shortage in the supply of improved seed is the primary problem in the process

of adopting barley improved variety. Hence, improving the supply of improved barley variety seed is the major task for any stakeholder involved in the scaling up process of barley.

3.3. Recommendation domains for HB-1307 food barley variety

Recommendation domains are defined as a group of farmers whose circumstances are similar enough that the same recommendation can be given. In other words, places and sets of conditions for which a particular target technology is considered feasible and therefore good to promote. Below these specific conditions for this practice are given.

The recommended domain for barley best practice are areas with altitude ranging from 2000 to 3500 m above sea level, 15-20 ^{O}c temperature, with an annual rainfall of 500 mm to 1200 mm and well drained fertile soil can be taken as suitable. There should be a market for barley within a reasonable distance (Table 2). The farmer should have access to capital or credit to purchase inputs, such as improved seed, fertilizers and other inputs as well as transportation means either by his own or by payment. Culturally, barley should be used for various forms of consumption and social services (Table 2).

Table 2: Recommendation domain for *HB-1307* food barley production

Identifier	Specific Identifier	Remarks
Agro-ecology	**Highland to midland**	Altitude 2000 to 3500 m asl.
	High rainfall area	15 to 20 ^{o}C
Resource endowment	**Capital (purchasing power for improved seed and other inputs) or credit access**	About Birr 1,500/ha is required for the purchase of fertilizer. When the costs of seed and labour are added it is not as higher for any ordinary small holder farmer.
	Transportation facility such as carts, donkey or any other (own or pay)	Near in the farmers plots
	Labour availability (for row planting, weeding and trashing)	Not beyond family labour
Location	**Input suppliers (Improved seed and fertilizers)**	Maximum 2 hour away by foot
	Market for barley	
	Presence of local processors (*Tela*, *Areke*, etc)	Within 50 km distance
	Sufficient numbers of wholesalers and retailers	Within 10 km distance
Cultural	**Consumption pattern of the community**	
	Own food consumption (*Injera*, bread, *Kolo*, and other forms)	
	Communities utilizing for social services	

Identifiers in **bold** are deemed more important

3.3.1 Suitable agro-ecology

Barley is a cool weather crop grown in the highlands of Ethiopia with an optimum altitude range of 2000 to 3500 meters above sea level. The optimum rainfall for barley production is from 500 to 1200 mm. Agro-ecologically the areas in which this practice was tested/validated are suitable for their barley farming system (Table 3).

Table 3: Altitude, mean annual rainfall and temperature of the study districts

Ecological Attributes	Districts		
	Dera	Burie	Jabitehenan
Altitude(m)	1500 - 2600	700 - 2300	1500 – 2300
Rainfall (mm)	1250	900 - 1400	1250
Temperature (^{o}C)	-	17 - 25	14 – 32

Source: District Office of Agriculture

3.3.2 Compatibility to the cropping system

Barley can be mixed cropped with wheat and relay cropping of barley with lupin and grass pea also possible (as some farmers practice these cropping systems). Besides, double cropping can be practiced. Generally, food barley is one of the common crops grown in these areas, thus changing the variety does not have trade-offs on the existing cropping system. Similarly, liming of acid affected soils does not have any negative impact to the existing barley farming system.

3.3.3 Resource endowment

Resource is not a limitation to adopt improved barley variety of *HB-1307*. It does not require much capital, labour and land. It can be handled in the way farmers are handling the local variety.

3.3.4 Location

Proximity to input suppliers: For the timely supply of chemical fertilizers, pesticides, lime and certified seed cooperatives, private traders and seed enterprises should be available close to farmer's village.

Extension services: Kebele DAs should be present close to farmers' village for effective and efficient supervision and management of food barley innovation production. Moreover, higher level agricultural experts and other relevant stakeholders should support farmers with frequent supervisions.

Credit service: In the project areas the source of credit institutions are mainly ACSI and cooperatives for chemical fertilizers, pesticides, lime and barley seed. The presence of credit institutions at close distance from farmer's village help farmers easily accessed credit from the institutions.

Market access: Market is crucial for the product of improved barley production. The crop is usually attacked by storage pests. Therefore to avoid the damage of the crop from storage pests the as well as to encourage farmers to produce the variety, the surplus grain should be

marketed soon after harvesting/threshing. Thus, local markets should be available close to farmer's village.

3.3.5 Consumption and production culture

Communities are well aware of producing of barley. In addition to that barley crop is one of the main staple crops in the area and consumed in different forms such as, *Kolo*, *Injera*, bread, Local beer, *Besso* and source of cash.

3.4 Variety

Six-rowed food type barley, *HB-1307*, was developed by Holetta Agricultural Research Center from a cross between a landrace line and exotic germplasm (Awra gebs-1 x IBON93/91) and released in 2006 for mid and high altitude areas. This variety has been released for mid and high altitude barley growing areas due to its superiority in grain yield performance, stability, and wide adaptation. It has good physical grain quality (Figure 2), resistance to leaf rust and scald, moderate resistance to net and spot blotch, lodging tolerance, and good biomass yield. Some agronomic characteristic and agro-ecological requirements of *HB-1307* food barley is presented in Table 4.

Table 4: Some agronomic characteristics of HB-1307 and ecological requirement

Parameters	Descriptions
Year of release	2006 G.C
Maturity time	137 days
Rain fall requirement	700-1000 mm
Altitude range	2000-3000 meter above sea level
Grain yield	3.5-5.0 tons ha^{-1}

Figure 2: *HB-1307* food barley improved variety seed/grain

3.5 Land preparation

For timely and uniform germination of food barley and to avoid early weed infestation barley fields should be well prepared. Barley field should be ploughed 2-3 times. Ploughing should be done in such a way that make the seed bed/field suitable for germination and growth, to control weeds and to drain excessive water as it is highly affected by water logging.

3.6 Planting time

Planting time depends on the onset and distribution of the rainfall. It also varies from location to location and based on the type of variety. It is also important to consider indigenous/farmers knowledge. For *HB-1307* variety in CASCAPE intervention areas planting was carried out starting mid-June to mid-July depending to the locality. But, according to the feedback from farmers cultivating this improved variety with the help of CASCAPE project, planting of this variety around mid-July was reported to be suitable. This was also confirmed by district office of experts.

3.7 Seed rate and planting methods

Seed rate and planting methods are among the key agronomic attributes to determine barley productivity. Barley can be planted in broadcasting and in rows. However, it is recommended to plant in rows, 100 kg ha^{-1}seed rate at spacing of 20 cm between rows. Row planting helps

to maintain optimum plant density, better resource utilization of the plant, suitable for pest assessment and management, efficient application and utilization of commercial fertilizer and suitable for harvesting and weeding practices. Barley should be planted at 3-4 cm soil depth, if the depth of planting is shallow (less than 3-4 cm) it will reduced tillering and the plant will be easily lodged. Similarly, if the depth of planting is more than 3-4 cm, it will have poor germination and population density. Seeds for planting should be pure (free from seeds of weeds, insect pests and diseases) and it should also have good germination percentage (greater than 85 %), and particularly free from Covered Smut (*Ustilago horde*), Strip Blotch (*Helimentho sporium graminum*) and Loos Smut (*Ustilago nigra, Ustilago nuda*).

3.8 Fertilizers and lime application

Fertilizer: Rate of fertilizer depends on locality (soil type and fertility status), precursor crop and type of the variety to be used. Location specific fertilizer recommendation has been developed by different research centers. Thus, application these fertilizer rate recommended by research institutes should be practiced for barley production. For those areas where there is no fertilizer recommendation, application of 100 kg DAP /ha and 100 urea/ha, all DAP and 1/3 of urea at planting while 2/3 of urea should be applied at the initiation of tillering (35-45 days after germination), after weeding practice. For the implementation this practice 100 kg/ha DAP and 100 kg/ha urea were used.

Liming: Soil pH is an excellent chemical properties indicator of soil quality. As soils become increasingly acidic (decreasing pH), important nutrients like phosphorus become less available to plants (Figure 3). Other elements, like aluminium, become more available and may actually become toxic to the plant, resulting in reduced crop yields. Liming to optimum pH not only increases the availability of essential nutrients, but also supplies additional calcium and magnesium, improves soil conditions for microorganisms and improves soil structure.

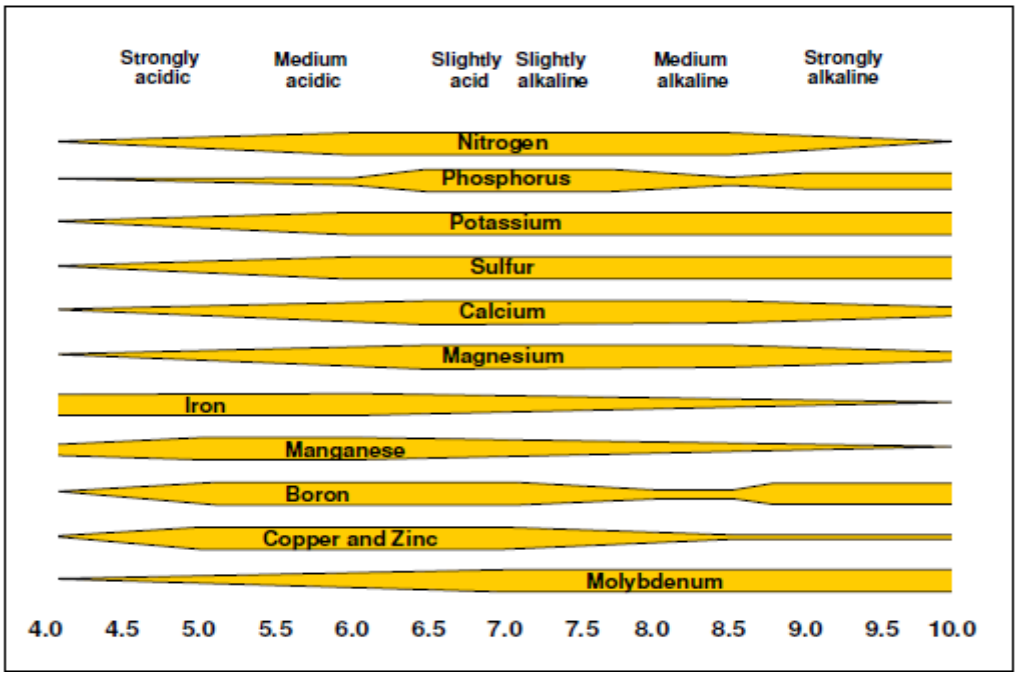

Figure 3: Effect of soil pH on nutrient availability (*Source: www.nmsp.css.cornell.edu)*

Farmers can improve the quality of acidic soils by liming to adjust pH to the levels needed for optimum barley production. Benefits of liming include:

- Increased nutrient availability;
- Improves physical condition (better structure);
- Liming will reduces the possibility of Mn^{2+} and Al^{3+} toxicity;
- Improves microbial activity;
- Source for Ca^{++} and Mg^{++} when these nutrients are deficient at lower pH;

Thus, understanding soil pH is essential for the proper management and optimum soil and crop (barley) productivity. Lime should be applied to amend acid affected soils, especially, soils having less than 5.5 soil pH should be treated with lime.

According to CASCAPE project experiences, liming of acid affected soils at Dera (*Sheme kebele*) and Jabitehenan (*Mana kebele*) based on soil laboratory recommendation (Regional soil laboratory) increased food barley productivity. Consequently, food barley productivity has been improved by 50% with application of 2 tons ha^{-1} lime (3.65 tons ha^{-1} grain yield with liming and 2.43 tons ha^{-1} grain yield without liming). Rate of lime will be determined either by buffer method or exchangeable acidity method. Both methods were used to identify the best method of lime rate determination. In this case, the rate of lime application was found comparable, 2.05 tons ha^{-1} on average for buffer method and 1.93 tons ha^{-1} on average for exchangeable acidity method. The lime should be applied at least one month before planting barley, thus site selection, soil sample collection and laboratory analysis should be accomplished taking in to account the time of lime application and barley planting.

3.9 Crop protection

Pest management refers to the management of a species defined as a pest, usually because it is perceived to be detrimental to crop production. Pest management is therefore a means to reduce pest numbers to an acceptable threshold. An acceptable threshold, in most cases, refers to an economically justifiable threshold where application of pest control measures reduces pest numbers to a level below which additional applications would not be profitable.

3.9.1 Barley Weed management

Weed infestation is one of important biotic factor that is responsible for low barley grain yield. Generally weeds reduce crop yields by competing for light, nutrients, water and carbon dioxide as well as interfering with harvesting and increasing the cost involved in crop production. Weeding frequency of barley field depends of the infestation level, two times of hand weeding is recommended at 25-30 days after sowing and 45-55 days after sowing. Besides, post-emergence application of 2, 4-D 1 L/ha controls broad leaf weeds.

3.9.2 Barley Insect pest management

Russian wheat aphids (*Diuraphis noxia*), barley shoot fly (*Delia arambourgi*) and mendi termite (*Macrotermes subhyalinus*) are among the major insect pest of barley in the intervention areas (figure 4, 5 and 6).

Russian wheat aphids *(Diuraphis noxia)*
Russian wheat aphids prefer to feed on foliage and grain spikes of actively growing plants. While feeding, these aphids can secrete fluid and injected to dissolve and neutralize the plant sap then suck the sap. These piercing and sucking action causes discoloration and distortion of the plant leaf and stem. These insect also transmit various types of plant diseases such as virus.

Symptoms

- Infected plants show yellow streaks along the veins
- The leaves curl in wards and the plants remains stunted
- This insect is known to be a vector of virus diseases
- Very serious in dry weather conditions

Management options

- Use of tolerant varieties
- Seed dressing (Gaucho 70% WS 126g for 100 kg seed)
- Spraying Diazinon 60% EC 0.5 l/ha
- Spraying Dimethoate 40% EC 1 l/ha
- Actalic 50 % EC 1l/ha

Figure4: Russian wheat aphids (RWA)

Barley shoot fly (*Delia arambourgi*)

Symptom

- As larva feeds on the stem of the central shoot, it turns brown, dies and may be easily pulled out of the plant
- One larva may destroy 3-4 shoots

Management options

- Planting of crops when there is enough moisture
- Use of tolerant variety
- Field sanitation
- Soil tillage
- Crop rotation
- Seed dressing (Gaucho 70% WS 88g for 100 kg seed)
- Spraying of Diptrex 1 kg/ha mixing by 200-300 l water

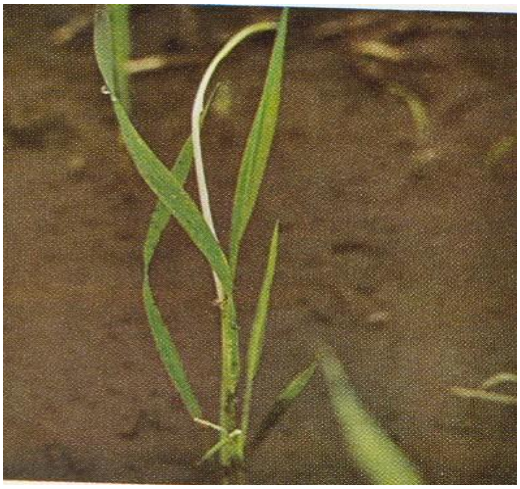

Figure 5: Barley seedling damaged due to Barley Shoot fly

Mendi Termite (*Macrotermes subhyalinus*) (Rambur)

The species is found throughout the country but it is specially a problem in the western regions of Ethiopia

Symptoms

- Damage stems and roots which is especially serious in seedlings
- Often they cut the base of the plant at ground level

Management options

- Early planting practice to avoid severe damage.
- Ploughing practice immediately after harvest.
- Remove stubbles immediately after harvest.
- Crop rotation.

Figure 6: Nymphs of Termites

3.9.3 Barely Disease management

Many diseases challenge the yield, quality and market profitability of barley. Therefore, barley disease in the target areas need to be manage effectively. The major barley diseases in the intervention areas are presented below.

A: Barley covered smut (Ustilago hordei)

Symptoms

- The disease is not obvious until ear emergence when infected grains are replaced by a mass of black fungal spores (Figure 7).
- Kernels of infected plants are replaced by masses of dark brown smut spores.

Management options

- Tolerant varieties and seed treatment

B: Barley loose smut (Ustilago nuda)

Symptoms

- Loose smut is easily recognized as the ear is usually completely replaced by black fungal spores (Figure 7).
- The spores completely replace the grain head so that there is no grain to be harvested on infected plants

Management options

- Use of tolerant varieties
- seed treatment practice using Tilt and Bayleton fungicides
- Seed washing before sowing
- Roughing at time of heading and maturity
- Rotation with other crop species like pulse and oil crops
- Field sanitation

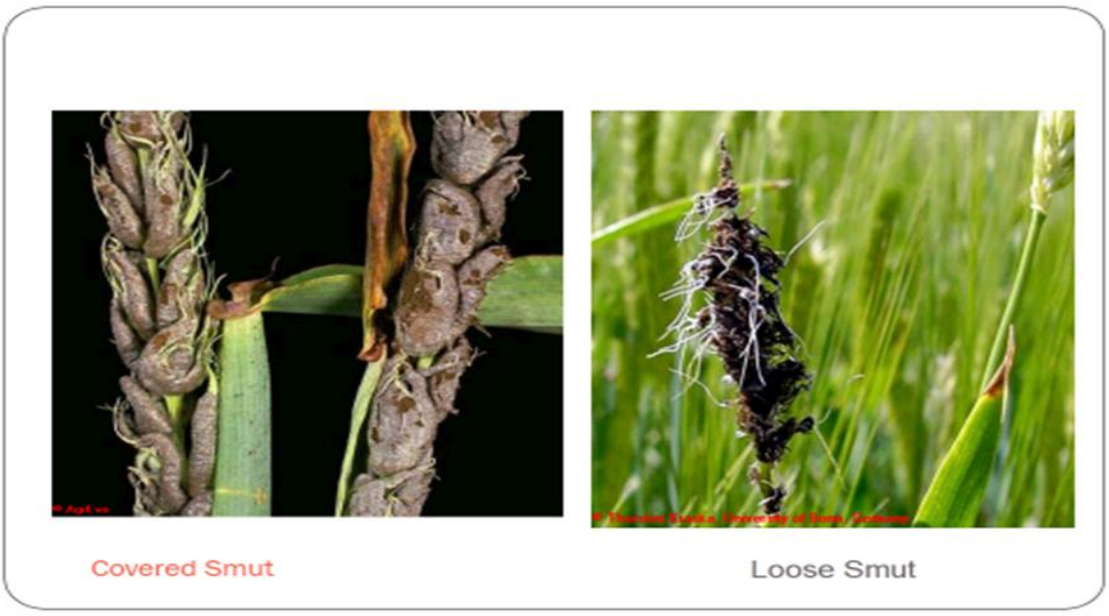

Figure 7. Barley covered and loose smut damage symptom

C: Barley leaf rust (*Puccinia hordei*)

Symptoms

- Orange-red pustules erupting from the leaf surface (Figure 8).
- Heavily infected leaves die prematurely

Management options

- Use of tolerant varieties
- Fungicide spray such as Tilt 250 EC 0.5-1 L/ha, mixing with 400-600 L water, Bayleton 0.5-1 L/ha, mixing with 400-600 L water and Bravo 1.5 kg/ha, mixing with 400-600 L water

Figure 8: Barley leaf rust damage symptom

D: Barley stem rust (*Puccinia graminis*)

Symptoms

- Masses of brick-red spores (pustules) erupt primarily on stems and leaf sheaths (Figure 9).

Management options

- Use of tolerant varieties and
- Fungicide spray such as
  - Tilt 250 EC 0.5-1 L/ha, mixing 400-600 L water
  - Bayleton 0.5-1 L/ha, mixing 400-600 L water
  - Bravo 1.5 kg/ha, mixing 400-600 L water

Figure 9: Barley stem rust damage symptom

E: Barley net blotch (*Pyrenophora teres*)

Symptoms

- Infections appear as dark, chocolate-colored blotches (Figure 10).
- The spots merge, eventually forming irregular dead patches on the leaves.

Management options

- Use of tolerant varieties
- Fungicide pray such as Tilt 250 EC 0.5-1 L/ha, mixing with 400-600 L water)
- Crop rotation

Figure 10: Barley net blotch damage symptom

F: Barley scald disease (*Rhynchosporium secalis*)

Symptoms

- The spots are oval shaped and the margins of the spots change from bluish-green to zonated brown or tan rings, with bleached straw-colored centers (Figure 11).

Management

- Use of tolerant varieties
- Fungicide spray such as;
  - Tilt 250 EC 0.5-1 L/ha, mixing with 400-600 L water
  - Bayleton 0.5-1 L/ha, mixing with 400-600 L water
- Crop rotation
- Field sanitation (removing crop residue in the field)

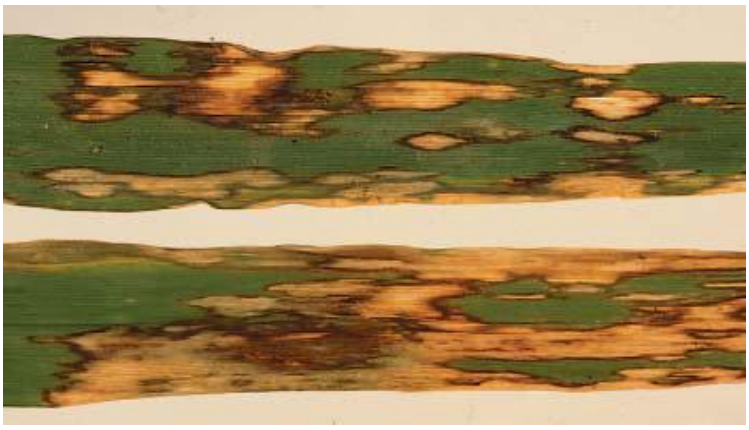

Figure11: Barley scaled disease damage symptom

3.10 Harvesting, threshing and post-harvest handling

Timely harvesting of barley is important to prevent shattering and reduction of grain and seed quality. Barley field should be harvested when it turns to yellow and when grain moisture is about 16- 18 %. Barley should store at 12.5% grain moisture level. If barley grain is intended to store more than three month, it should be treated with Acetelic Supe or Malathion 5% dust and should be stored in storage free from moisture.

3.11 Productivity

Improved food barley variety *HB-1307* gave 32 % grain yield advantage as compared to local variety with improved management, while it gave 86 % grain yield advantage as compared to regional average of the same production season (Table 5). Similarly, it was also observed that the synergy from improved variety and liming (maintaining other improved practices like row planting and fertilization) gave 50% grain yield advantage as compared to improved practices without lime and 140 % as compared to the regional average of the same production season (Table 5).

Table 5: Grain yield of HB-1307 against the local check and average yield

Year	Treatment	Grain yield (q/ha)	Grain yield advantage (%) over the check/ regional average/control
2012/2013	*HB-1307*	26.4	--
	Local variety with improved practices	20.0	32
	Regional average yield (CSA 2012)	14.2	86
2013/2014	*HB-1307* with lime application	36.5	--
	HB-1307 without lime application on acid affected soils	24.3	50
	Regional average yield (CSA 2013)	15.2	140

3.12 Profitability

In order to run the economic analysis results effectively, some basic data are required as indicated below on tables 6-9. On liming information, time required for liming (30 minutes to apply 100kg of lime), field price of labour is about 45 birr/man day, field price of lime 2.6 birr/kg, field price of barley 6.2 birr/kg and single one time application of lime can serve at least for three years.

Table 6: Rate of lime application for different treatments

No	Treatment	Lime application rate (kg/ha)
1	Buffer method	1925
2	Exchangeable acidity method	2050
3	Control	0

Here treatments are mentioned in the column and the cost items which vary from treatment to treatment are located in rows (table 7, 8).

Table 7: Total cost that incured in different treatment

	Treatment		
Item cost	**1**	**2**	**3**
Cost of lime (Birr)	1668	1777	0
Cost of labour to apply lime (Birr)	54	58	0
Total costs that vary	1722	1835	0

Table: 8 the Partial Budget

	Treatment		
Yield obtained and Item costs	1	2	3
Average yield (kg/ha)	3648	3643	2432
Adjusted yield (kg/ha)	3283	3279	2189
Residues (kg/ha)	5503	5415	3953
Gross field benefits (Birr/ha)	23106	23037	15548
Cost of lime (Birr)	1668	1777	0
Cost of labour to apply lime (Birr)	54	58	0
Total costs that vary (Birr)	1722	1835	0
Net benefits (Birr)	21384	21202	15548

As indicated in table 9, a farmer who was cultivating barely without adding lime would benefit if he added lime in a buffer method (1925kg/ha). The benefit can be expressed as for one additional Birr he spent in adding lime in a buffer method; he will collect three Birr benefit after recovering his one birr of initial investment. However, the buffer application method (1925 kg/ha) and the exchangeable acidity application method (2050kg/ha) has almost equal rates of application. Hence, using either method will not lead to a great mistake.

Table: 9 Marginal analysis

No	Treatment	Total costs that vary (Birr/ha)	Net benefits (Birr/ha)	Marginal rate of return (%)
3	Farmers practice (control)	0	15548	
1	Buffer method	1722	21384	338.9

Minimum rate of return = 100%

Sensitivity analysis

Prices of inputs and outputs are often changed through time. The best ways to test a recommendation for its ability to withstand these changes is through sensitivity analysis. Sensitivity analysis is to mean redoing the marginal analysis with alternative prices. Our conclusion from the marginal analysis is to use exchangeable acidity rate of application of lime. But, if the price of lime gets increasing, to what level would it be feasible?

$\Delta Y = \Delta TCV\ (1+M)/P$

$\Delta TCV = P*\Delta Y/\ (1+M)$

ΔY = Change in adjusted yield

ΔTCV = Change in total costs that vary

M = Minimum rate of return

P = Field price of product

Using this formula;

$1925p + 54 = 6.2*1094/2$

P = Birr 1.7

When it is multiplied by 3 years

P = Birr 5.2

The interpretation is that keeping other things constant, the current price of lime Birr 2.6/kg can rise to Birr 5.2/kg without affecting the feasibility of using lime.

3.13 Farmers preferences

Data on the demonstrated varieties such as HB-1307, HB-42, Shege, and cross-4198 and local varieties was not available to make preference and set in the order of rank. As general criteria farmers preferred HB-1307 food barley variety on yield, grain quality , high tillering capacity and vegetative growth, resistance to lodging and high volume of straw for livestock feed compared to the local variety.

3.14 Sustainability assessment

Sustainability of a technology can be favoured or constrained by many factors among others the economic, social and environmental (people, profit and planet) are the main ones. Thus, it will be important to examine the sustainability of a technology by setting indicator for the three parameter and analyse the short term and long-term effects of the technology.

The sustainability indicators for the three parameters were selected with the farmers and development agents for the systemic comparison of the conventional (benchmark) that is, the landrace or local variety which is dominantly in use with the newly introduced food barley innovation that has the following elements

- high yielding food barley variety HB-1307
- liming at the rate of 20 qt/ha

Summary of the results are presented in table 10 and figure 12.

Table 10: Summary of sustainability indicators for food barley innovation

Sustainability parameters/indicators	Conventional method	Barley innovation	Remarks
People			
Labour	±	-	Liming is considered as additional activity that has labour implication for the family. Thus it demand higher labour
Profit			
Revenue	±	+	Yield has nearly increased by 50 %, accordingly the revenues increased
Resource efficiency	±	+	The increase in yield has the implication of land use efficiency. Farmers gain 50% more yield from the same land because of this technology. This is a good quality in area where land is scare.
Input supply	±	-	Accessibility and affordability of inputs mainly limes will be the limiting factor
Net Income	±	+	Even if the new technology uses higher additional input of lime. The overall net income from the new technology showed higher result.
Planet			
Soil erosion	±	±	The new technology neither trigger nor reduce soil erosion
Soil nutrient	±	-	Interms of soil erosion the two methods are similar. However, the new technology seemed to deplete more K form high biomass harvest
Biodiversity	±	±	Both the conventional method and new food barley innovation production didn't use any pesticide and /or insecticides the damage to biodiversity loss in the vicinity is less.
Reduce soil acidity	±	+	Reduce soil acidity

Once the indicators are set and their relative magnitude is evaluated then spider graph will simplify the comparison of indicator through visualization (figure 12).

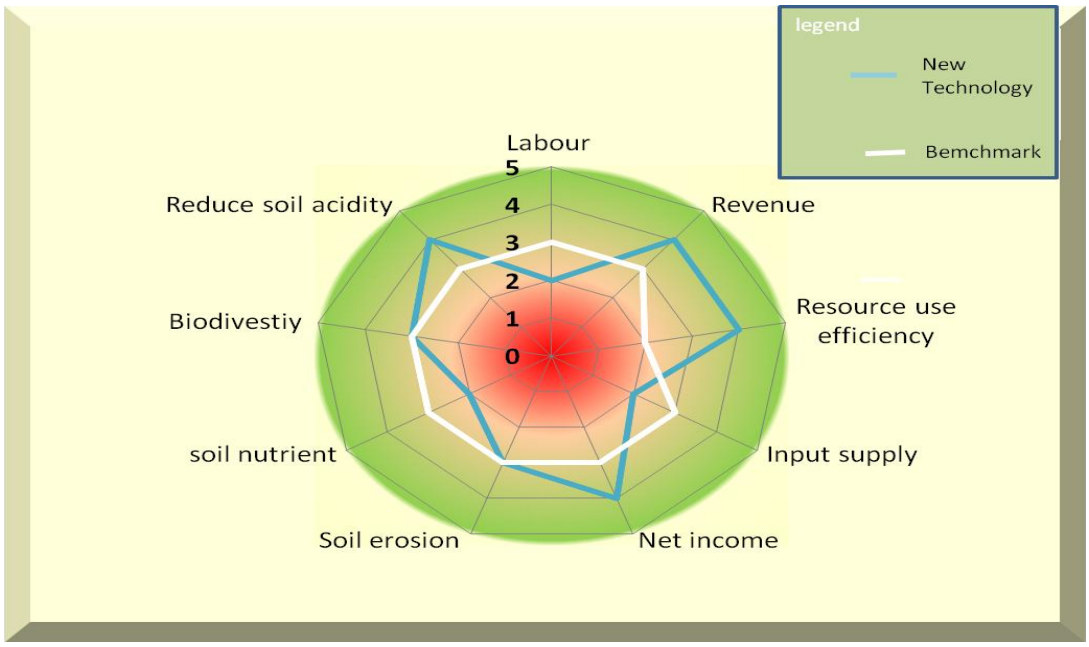

Figure: 12 Spider graph of barley production technology versus benchmark

3.15 Contribution of the best fit practice to nutrition and gender aspects

Barley is actually one of the oldest consumed grains in the area. It is included in the diet of many farmers in the form of *Kolo, Injera*, porridge, local alcohol (*Tela*) and bread.

Barley provides a range of important vitamins and minerals such as fiber, B vitamins, niacin, and more. When we compared to many other grains, barley is lower in fat and calories, but higher in dietary fiber and certain trace minerals. To get the necessary benefits from barley nutrition, it's recommended that, it should soak and sprout hulled uncooked barley grains, then preparing different foods from sprouted barley flour is nutritious and the bioavailability is become very high. Soaking and sprouting grains, including hulled uncooked barley, can help to lower the level of anti-nutrients significantly, making grains more beneficial and also easier to digest. Fiber's found in barely is also important for maintaining a healthy balance of bacteria within the digestive tract. So, barely production increment in the area might have a positive impact in the health and nutrition improvement of the farmers.

Though, processing of barely needs labour to use at the household level or for local market, it is also a source of income generation for women. Women can process and sale different products from barely such as *Kolo, Tela* and complementary food to get income and fulfill their needs in the household.

4. Suggestions for points of attention for BoA and extension officers

4.1. Identification and involvement of relevant stakeholders

Identifying and participating the key stakeholders is the prior task, to share responsibility and mitigate the effort of each stakeholder, for the successful, scaling up innovation of improved food barley production, in a wider scale. All key stakeholders have their own specified roles and responsibilities. Joint planning, monitoring and evaluation should be done by the cooperation of the relevant stakeholders based on their specified role listed in Table 11.

Table 11: Key stakeholders and their roles

Identified stakeholders	Stakeholders role
Model farmers	• Joint planning and execution of scaling up • Seed multiplication • Share their improved barley production, handling and utilization best experience to other farmers
Kebele office of agriculture	• Assist farmers in site selection • Provide training and technical backstopping to farmers • Facilitate credit service
Kebele Administration	• Mass mobilization • Facilitate inputs supply to farmers
District office of agriculture	• Participate in joint planning • Provide training and technical backstopping to farmers and Das • Facilitate timely availability of input • Arranging market availability to farmers
District office of administration	• Participate in joint planning and mobilizing the community
BoA	• Provide training and technical backstopping to ZoA and DoA • Facilitate timely availability of inputs
Quarantine Agency	• Seed quality inspection, control and certification
Seed enterprises	• Multiply and supply certified seed of maize seed to farmers
Research institution and centers	• Provide training to BoA, DoA, ZoA and DAs • Technology demonstration and evaluation • Supply basic and pre-basic seeds for farmers and seed enterprises
Cooperatives	• Organized local seed producer cooperative and provide training at different levels • Supplying chemical fertilizers and herbicides to farmers
Traders	• Supply herbicides to farmers
Universities	• Provide training and advisory services • Technology demonstration and evaluation
Credit institutions	• Provide credit to farmers for purchasing input
Projects and NGOs	• Support logistics and participating in capacity building • Participate in input supply and technology transfer

4.2. Joint planning

Joint planning, monitoring and evaluation should be done by the cooperation of the relevant stakeholders based on their specified role listed in Table 11.

4.3. Training at different levels

Experts from BoA, Research Centres, Universities and NGOs should provide both theoretical and practical training of trainers (ToT) for ZoA and DoA. Similarly, ZoA and DoA should train development agents. Finally, development agents should provide training to target farmers.

4.4. Availability of inputs

Fertilizer is available in sufficient quantity and timely through farmers' cooperatives, though some farmers complain about its high price. Lime is also available in every farmer's cooperatives with fair price. But seeds of improved barely variety are almost non-existent due to lack of focus from the regional seed multiplication enterprise. But, recently this organization is working to solve the problem. The other stakeholders should also focus in solving the shortage of improved barley seed supply.

4.5. Market access

Barely is used in our community to prepare a wide range of consumable items. It is used to prepare *Injera*, bread, *Kolo*, local alcohol such as local beer and *Areki*. That means it is demanded in almost every household in everyday life to prepare at least one of the above items. But the production and productivity are very limited which creates shortage in supply of this grain. This makes farmers and other consumers to use substitute crops to prepare the above consumable items. The reality is that the demand for barely grain is by far higher than the supply. So market problem is not an issue in order to produce barely in larger scales both in terms of area coverage and productivity.

4.6 Joint monitoring and evaluation

A. Definition

Monitoring is a management process that systematically seeks to supply to the stakeholders information on the progress of implementation of a program/project in order to facilitate timely decision making. Monitoring means keeping track of where you are with a project in relation to where you planned to be. Evaluation is a periodical review of the status of implementation and of achievement of a project / program.

Joint monitoring and evaluation is where all stakeholders involve in the monitoring and evaluation process either alone or together. Each stakeholder has a role to play in the process and need to participate to make the process effective by creating sense of ownership in the whole process of production, harvesting, processing, utilization and marketing. Farmers need

to follow the day to day events of the production process because they are the nearest stakeholders for each activity than anyone in the system. They can know what is happening in the planted seedlings, in the status of weeds, in the emergence of diseases, in the process of harvesting and marketing on a daily bases. They can also evaluate the efficiency and effectiveness of the system better periodically. In so doing farmers can deliver correct and fresh information for other stakeholders who are located relatively in far areas from the field, for instance for woreda and regional stakeholders and subject matter specialists.

The other stakeholders can follow up the process as timely as possible and can support technically as well as with resources. For instance, the technical people at district or region level can advice on the technique of ploughing, planting and pest management (weed insect pests, disease and vertebrate pests , harvesting processing, marketing and utilization based on their periodic follow up or information obtained from farmers.

B. Data collection

Qualitative and quantitative data should be collected regularly by stakeholders and should be centrally organized, analyzed and communicated again to stakeholders. The tools used to collect qualitative data are focus group discussion, key informant interview, story telling and attitude and perception measures. Similarly, there are a number of tools which we can use to collect quantitative data. To mention some structured formats developed and agreed up on stakeholders, reports, surveys, transect walks, field visits, etc.

C. Data analysis

All the data collected by different stakeholders should be brought into experts/department of the respective organization for reorganization and analysis. Some of the parameters considered during the analysis were included yield, productivity, environmental impact, profitability, income, land requirement, labour demand and so on. Summary tables can be produced focusing on:

- Different attributes/indicators;
- Comparison between planned and actual;
- Comparison between different areas (*kebeles*, *woredas*, zones and regions) ;
- Comparison between years;
- Compare the performance of different interventions; and
- The average performance at *kebele*, woreda, zone, region and at country level.

In most cases the above analysis relate to the quantitative data. However, if this is complemented with the qualitative data which will be generated by the qualitative surveys it will help to answer why the interventions are performing as observed in the quantitative data. For example, the quantitative data about training can be complemented with the trainee's feedback result on the same issue. This type of information can explain why things are

happening (or not happening) in a particular manner and provide significant insights for decision making purposes.

D. Communication

The Monitoring and Evaluation information collected through the established Monitoring and Evaluation process can only be used for accountability, learning and decision making, as well as input for re-planning of program/project if there is a clear plan for appropriately communicating it to the stakeholders of the programme. Communication can be done through periodical reports, stakeholders meetings and critical reflections, broachers, leaflets, using electronic means (telephone, e-mail, etc), vocal, workshop, field days, seminar, training and in so many other means. Communication should be done timely.

E. Capacity building for Monitoring and Evaluation

For the joint monitoring and evaluation process to be effective, capacity building need to be given intensively. Farmers should be given appropriate training on how to record information and on how to communicate it. They need also be supported by necessary materials. The other stakeholders in the process need to get the capacities which enable them to discharge the monitoring and evaluation process effectively. Moreover, need based training for other stakeholders have to be given on data collection analysis and communication.

In general, the monitoring and evaluation activities must be done jointly and in participatory ways. Otherwise, lack of sense of ownership and carelessness may appear in some stakeholders and will lead to total failure in implementing the innovation as a whole. This is usually appearing in most projects and programs.

4.7 Lesson learnt and challenges faced

Lessons learnt

- The combined effect of improved variety, recommended fertilizer application and liming enhanced food barley productivity up to 36.5 tons ha-^{1} which is more than double as compared to regional average 1.5 tons ha-^{1}(CSA, 2012).
- Participatory technology evaluation is important to identify the best technologies which fit the local conditions. This also help to have good adoption as the farmers are the key actors for selecting technologies based on their criteria.
- Start with identification of problems and potentials through PRA techniques scoping studies and regional workshops.
- Involvement of policy makers, development workers and farmers at all stages of development intervention.
- Farmers become convinced through demonstration and practice not by we telling and talking them but by what we show them.
- We need to take to farmers proven technologies and best practices.
- Start demonstration of best practices and technologies with model farmers.
- Training of farmers, DAs and experts will enhance adoption rate of new technologies.

Challenges faced

- Inadequate knowledge of farmers and development agents on full package practice of barely production
- Inadequate supply of improved seed, fertilizer and pesticides have been a great challenge during promotion of this innovation. Thus, ensuring the production and delivery of high quality barley seed and improve formal and farmer-based seed systems should be worked out.
- Most farmers did not practice the full packages of the innovation rather than using the improved variety. Thus, training and awareness creation about the full package, row planting, fertilization, liming and etc.) Should be considered.
- Inadequate use of modern farm machinery to produce barley starting from planting up to harvesting

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