BEST FIT PRACTICE MANUAL FOR SWEET LUPIN (*Lupinus angustifolius* L.) PRODUCTION

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

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NOVEMBER, 2015

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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Abbreviations

ACSI	Amhara Credit and Savings Institution
ADG	Average daily gain
ARARI	Amhara Regional Agricultural Research Institute
BDU	Bahir Dar University
BoA	Bureau of Agriculture
BW	Body Weight
CP	Crude Protein
CSA	Central Statistics Agency
DA	Development Agent
DAP	Di-Ammonium Phosphate
DM	Dry matter
DoA	District Office of Agriculture
DOM	Digestibility of Organic Matter
FTC	Farmers Training Center
ha	hectare
kg	kilo gram
masl	meters above sea level
M& E	Monitoring and Evaluation
ME	Metabolizable energy
mm	millimeter
NGO	Non-governmental Organization
SD	Standard Deviation
SMS	Subject Matter Specialist
t	ton
ToT	Training of trainers
ZoA	Zone Office of Agriculture

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1. Introduction

Ethiopia has a huge livestock population. Currently, it is estimated that the country has 53.4 million heads of cattle, 25.5 million heads of sheep, 22.8 million heads of goats, 2 million heads of horses, 6.2 million heads of donkeys, 0.4 million heads of mules and 1.1 million heads of camels (CSA, 2011). According to CSA (2011), about 99.3% of the cattle population of the country is indigenous breed. In addition, the livestock population in Ethiopia is also genetically diverse. It is estimated that about one-third of the national livestock population is found in Amhara National Regional State.

The livestock productivity in Ethiopia and Amhara National Regional State is low. There are several constraints that contribute to the low productivity of livestock in the country. These include poor genetic potential of indigenous breeds, feed shortage (both in quantity and quality), livestock diseases and parasites, lack of adequate livestock extension service, poor infrastructure and others. The livestock production constraints in CASCAPE project intervention areas include feed shortage, livestock diseases and degradation of grazing lands. Currently, among the livestock production constraints feed shortage is the main one.

Natural pasture and crop residues are the main feed resources in the region. The nutritive value of crop residues is inherently low. In addition, the quality and productivity of natural pasture especially during the dry season is low. Especially these feed resources are low in crude protein (CP), vitamin and metabolisable energy (ME) content. As a result livestock productivity and reproductive efficiency in the region is low.

Agro-industrial by-products are high in nutritive value. But they are expensive and less accessible to the small-holder farmers in rural areas. Therefore, looking for other alternative home grown protein supplements is crucial to improve livestock production and productivity. Growing and using legume crops like sweet lupin that have high nutritive value is one option to solve this problem. Therefore, introduction and demonstration of sweet lupin was conducted by CASCAPE Project in CASCAPE intervention Districts in North Western Ethiopia.

Lupin production is about 2000 years old. It began in the Mediterranean basin. Lupin like other legumes fixes atmospheric nitrogen and improves soil fertility. The grain has a high protein content. There are about over 300 species of the genus *Lupinus* (L.), but many have high levels of alkaloids (bitter tasting compounds) that make the seed unpalatable and sometimes toxic. Historically, lupin alkaloids have been removed from the seed by soaking in water for a longer time. Plant breeders in the 1920's in Germany produced the first selections of alkaloid-free or sweet lupin, which can be directly consumed by humans and livestock. Currently sweet lupin is produced in many countries as a forage or grain legume. Although bitter white lupin is a traditional pulse crop in Ethiopia, sweet lupin is a new crop to the country.

Sweet blue lupin has a relatively high CP content and a high digestibility. In addition, it has low alkaloid content. It has a CP content of 34.35% and a digestible organic matter (DOM) content of 86.28%. A study conducted for 69 days using sweet lupin grain as a supplement at 290 g/ head per day on Washera sheep shows that the animals can gain 74 g/ head per day and 5.1 kg/ head per 69 days (Yeheyis *et al*., 2012). The same study shows that sweet lupin (cultivar Sanabor) has a potential to substitute commercial concentrate feed supplement in Ethiopia.

Adaptability and productivity of forage legumes differs from place to place depending on several environmental and socio-economic factors. To alleviate the feed quality problem, demonstration and scaling up of sweet lupin have been practiced previously by CSACAPE Project in Dera, South Achefer, Burie and Jabi Tehenan districts of Amhara Region. The productivity of sweet lupin in these districts was promising. Farmers were interested to adopt this multi-purpose legume crop as it has higher yield and its potential as livestock feed. Sweet lupin yields better than the local one and is highly palatable by livestock. In addition, sweet lupin is gaining more attention by small-holder farmers due to its value as human food. On average, the productivity of sweet lupin on farmers' fields was from 2.2 to 3.2 tons grain ha^{-1}. Based on an on-farm trial by CASCAPE Project, the average daily gain of local male sheep that were fed sweet lupin at 290 g per head per day ranges from 64 to 67g per head per day. In addition, it can be used for the preparation of a traditional stew called *shiro wot* for human food. Generally, it is believed that production and utilization of more quality feed enhances livestock productivity. This manual is intended to be used as a reference for extension staff, researchers, academicians, commercial producers, SMS and DAs that are involved in scaling

up of sweet lupin production in the mixed crop-livestock production system in Dera, South Achefer, Burie, Jabi Tehenan and other agro-ecologically similar districts in Amhara National Regional State. The manual is useful and applicable in the mid and highland (particularly Tepid moist mid highlands /M_3/) areas where lupin can grow.

2. Testing of sweet blue lupin

a. First year (2012)

Sweet lupin introduction and evaluation study was conducted at two CASCAPE project districts in Dera (Shimie and Gelawodios Kebele) and Jabi Tehnan (Mana kebele). The experimental treatments include three narrow-leafed lupin cultivars (*Sanabor, Probor* and *Bora*). Randomized complete block design (RCBD) with three replicates was employed. The plot size was 4 m x 5 m. Spacing was 7 cm between plants and 30 cm between rows. Sowing was by hand into a well prepared seed bed and 100 kg ha^{-1} DAP fertilizer was applied at planting. Weeding was done by hand at seedling and just before the flowering stages.

The grain yield of sweet annual lupins ranged from 3.15 to 3.36 ton ha^{-1} with mean of 3.36t/ha; 3.07 to 3.33t ha^{-1} with mean 3.22 t ha^{-1}; and 1.94 to 2.16 with mean of 2.04 t ha^{-1} at Mana, Shimie and Gelawodios kebeles, respectively (Table 1). The grain yield of sweet narrow-leafed annual lupins in this study is comparable with the yield reported by Yeheyis *et al* (2012) who reported a mean grain yield of 3.2 t ha^{-1}, 2.0 t ha^{-1} and 2.8 t ha^{-1}, for Sanabor, Probor and Bora , respectively, at Merawi site in mid-altitude of Mecha district. In addition, the same authors reported that gain yield of the different lupin entries was greater at the high-altitude locations than at the mid-altitude locations.

Table 1. Grain yield (t/ha) of three narrow-leafed (NL), annual lupin accessions at Mana, Shimie and Gelawudios kebeles

Treatments	Grain yield Mana kebele	Grain yield Shimie kebele	Grain yield Gelawudios kebele
Sanabor	3.15	3.07	2.16

Probor	3.60	3.33	1.94
Bora	3.32	3.27	2.01
Mean	3.36	3.22	2.04
LSD (0.05)	6.65	11.33	6.49
CV (%)	9.91	17.60	15.97

b. Second year (2013)

Demonstration of sweet lupin was conducted in lupin growing areas of CASCAPE project districts at South Achefer (Abichikeli kebele), Burie (Woyenema Ambaye kebele) and Jabi Tehenan (Mana kebele). Twenty farmers that were willing to produce sweet lupin and use it for sheep fattening from these districts were selected. The selected farmers grew sweet lupin on their own lands.

Narrow-leafed annual sweet lupin cultivar *Sanabor* was used. A plot size of 0.125 ha was allocated for sweet lupin production from each participating farmer. Seed rate was 80 kg ha^{-1} and 100 kg ha^{-1} DAP was applied at planting. Planting was done in the main rainy season. Weeding was done by hand. Weeding and other management practices were conducted by farmers' themselves. Field day was conducted involving different stakeholders at the end of the rainy season.

On average, sweet lupin (Sanabor) gave grain and straw DM yield of 1.3 and 3.3 ton per hectare, respectively. The grain and straw yield of sweet lupin in different districts is given in Table 2 and Figure 1.

Table 2. Mean grain and straw DM yield of sweet lupin planted on farmers' fields in different districts

Name of district	Grain yield (ton/ha)	Straw DM yield (ton/ha)
South Achefer	2.2±1.32	4.2±2.91
Burie	0.5±0.31	2.6±1.36
Jabi Tehenan	0.8±0.60	2.5±1.72

Overall mean	1.3±1.21	3.3±2.28

Previous study showed that the grain yield of sweet lupin (*Sanabor*) ranges from 2.2 t ha^{-1} to 4.8 t ha^{-1} depending on the area (Yeheyis *et al*., 2012). Sweet lupin (cultivar *Sanabor*) has the lowest alkaloid content and has a potential to be used as a protein supplement for livestock feeding.

Figure 1. Sweet lupin grown in Mana kebele, Jabi Tehenan district

The sweet lupin planted in different districts performed better in all areas. The farmers were highly interested on it due to its grain yield and shorter maturity time. Farmers are willing to grow and use sweet lupin for their animal feeding. Field day was conducted to create

awareness and demand for the adoption and wider dissemination of the technology. In addition, attempts were made to publicize the results of CASCAPE project interventions to a wider community through Bahir Dar University (BDU) newspaper .

Animal Evaluation of sweet lupin

Farmers in South Achefer and Burie districts who produced sweet lupin for sheep fattening have conducted sheep fattening trial. Each farmer allocated two sheep for this purpose. The sheep were dewormed and vaccinated at the beginning of the trial. The animals were vaccinated against pasteurellosis and dewormed for internal parasites. The initial and final body weight (BW) of the animals is presented in Table 3.

The average daily gain of the sheep fed sweet lupin ranges from 64 to 67g per head per day. The average daily gain (ADG) of the sheep in the current study is lower when it is compared with other studies (Yeheyis *et al*., 2012). This may be due to variations in management of the experimental animals by the farmers.

Table 3. Initial and final body weight of sheep in South Achefer and Burie districts

District	Kebele	Initial BW (kg) (Mean±SD)	Final BW (kg) (Mean±SD)
S/Achefer	Abichikeli	26.1±3.70	30.2±2.84
Burie	Woyenema Ambaye	23.8±5.00	29.3±6.09
Average		25.0±4.31	29.8±4.44

Sweet lupin grain has a great potential to be used as a supplement to sheep fattening (Figure 2). It is highly palatable. The performance of animals that were fed sweet lupin is promising. The performance of old animals that were fed sweet lupin was less than young animals. As there is poor availability and high price of agro-industrial by-products to the smallholder farmers, growing and feeding sweet lupin to fattening sheep is one alternative to solve the current problem. Sweet lupin is adaptable in most areas of CASCAPE intervention districts. The productivity of sweet lupin is high. Growing sweet lupin increases the fertility of the soil. In addition, sweet lupin can be used as human food. Farmers can use sweet lupin either for animal feed or human food based on their preferences. So, scaling up of sweet lupin should be given a great emphasis in CASCAPE intervention districts in the future.

Figure 2. Sweet lupin (cultivar *Sanabor*) grain that can be used for sheep fattening

b. Third year (2014)

Scaling up of sweet lupin was conducted in 2014 in South Achefer, Burie, and Jabi Tehenan districts. The objectives of the scaling pilot were the following.

- To scale up sweet lupin for livestock feeding
- To identify and document challenges and lessons to design an effective scaling up/out strategy

Sweet lupin scaling was conducted in Abichikeli, Lalibella, Woyenema Ambaye, Arebisi and Mana kebeles. The seed rate used for sweet lupin production was 80 kg ha^{-1}. Sweet lupin seed was offered to farmers by CASCAPE project free of charge. Fertilizer and other management practices were provided by each participating farmer. The participating farmers were selected

together with kebele development agents in each kebele. The total number of farmers participating in sweet lupin scaling up was 67 farmers.
Stakeholder's workshop and field day were conducted in August at South Achefer District. Several stakeholders were involved in the workshop and field day. The stakeholders stressed that CASCAPE is working based on the problems identified in each districts and considered as a great advantage to the districts. It was suggested by the stakeholders to prepare manuals and leaflet on sweet lupin production. Sweet lupin can be used as a livestock feed as well as human food. There is no problem on human health if sweet lupin is used as human food.

Field days were organized in South Achefer (Abichikeli and Lalibela *kebeles*), Jabi Tehenan (Mana *kebele*), Burie (Woynma Ambaye kebele) and Dera (Korata kebele) districts during the vegetative growth stage of sweet lupin. There were different stakeholders participating in the field days. These include kebele, district and regional level experts. At regional level field days were organized at South Achefer, Burie and Jabi Tehenan districts. The field days were organized at the seed setting (ripening) stage of sweet lupin. A total of 1,056 participants attended the field days.

Farmers' were well aware of the use of sweet lupin. Sweet lupin is not only used as animal feed but also used as human food. Farmers showed interest to grow sweet lupin both for animal feed and human food. Sweet lupin was found to be susceptible to water lodging. Farmers were informed that appropriate site selection is an important step in sweet lupin production to assure an optimum grain and quality of the product.

Sweet lupin was found to be used for both animal feed and human food. So, the supply of this seed should be given a great attention. Therefore, office of agriculture should make a linkage with the national and regional seed producer enterprises and private seed producing institutions like that of food crops so as to make sweet lupin seed easily accessible by the smallholder farmers.

Figure 3. Field day on sweet lupin in South Achefer District Abichikeli kebele

3. Development pathways

3.1. Introduction

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.

3.2. Possible development pathways for sweet lupin in Amhara Region

For the last three consecutive years, sweet lupin innovation was introduced at South Achefer, Jabi Tehenan, Burie and Dera districts. Based on data collected from the base line survey of the project and field observation, the innovation development pathway analysis result has been summarized according to three main factors namely, agricultural potential, population pressure and market access. The results are presented below (Table 4).

Based on the development pathway analysis of sweet lupin innovation in the project areas the agricultural potential of the area is characterized by high rain fall, availability of irrigation, land and well drained moderately acidic soil.

Table 4. Development pathway analysis for scaling up sweet lupin innovation

Agricultural potential	Market and infrastructure access	Population pressure
.Relatively high rainfall .Availability of land .Well-drained moderately acidic soil .Availability of irrigation	.High potential of local and regional markets for livestock and livestock products .Demand for sweet lupin . Road access . Accessibility of finance for input supply	. High population density (shortage of grazing land and cut and carry system, crop residue based livestock feeding system) .High cattle and small ruminant (intensive and semi-intensive agriculture). . Availability of improved breeds of livestock .Availability of labour vs ease of cultivation . High intensification of cereal crop production (Rotation purpose and crop residue utilization) .Scarcity of food legume crops (food for human in different forms) .Resource scarce area (land) multi-purpose nature

The presence of road access in the area is an opportunity for better local and regional market access for livestock and livestock products. In addition, demand for sweet lupin and access to input are important issues for adoption of sweet lupin. Moreover, in densely populated areas of intensified cereal based crop production and high livestock population, scarcity of food legume crops (food for human in different forms) and resource scarce area (land) multi-purpose nature of the crop are found to be important.

The seed of sweet lupin is being used as source of food for humans in different forms. Therefore, the experience of the project showed that the innovation can be scaled up in a wider scale in areas of similar agricultural-potential, market and infrastructure access and population pressure in the region as well as in the country.

4. Drivers of adoption for Amhara Region (Dera, South Achefer, Burie and Jabi Tehenan districts)

According to the results of drivers for adoption study conducted in 2013, district differences, education level of head of the household and average distance to FTC are the variables significantly affecting the adoption levels of forage technology. The rate of adoption for forage varieties increases when we go from *Dera* to *Burie* and *Jabi Tehenan* districts. This is true in reality because Burie and Jabi Tehenan district farmers are familiar with growing improved forages like Rhodes grass and other varieties. But there is no significant difference between *Dera* and *South Achefer* farmers in adopting forage technologies. Level of education has a positive significant effect in improved forage technology adoption. The rate of improved forage technology adoption increases significantly for educated farmers in comparison to the illiterate ones.

But the result cannot be readily taken as the study was focusing on forage technologies in general which includes Rhodes grass, oat and vetch, sweet lupin and Napier grass. When farmers are asked about forage technologies, they usually talk about Rhodes grass, oat and vetch as well as other legume forages but not about sweet lupin. This is because sweet lupin is a newly introduced crop to the area. A farmer who wants to plant other forage species can

easily take sweet lupin as it has multipurpose function such as its use for livestock feed, human food and for soil fertility improvement.

During the focus group discussion and key informant interview, adopters of sweet lupin and their neighboring farmers were telling us focusing only on sweet lupin and its important aspects. They said that sweet lupin is a high yielding crop per unit area and is important sources of feed for livestock and food for human beings. This important crop can grow in all CASCAPE districts (*Dera, South Achefer, Burie* and *Jabi Tehenan*). Hence, it can be widely adopted by a range of farming households if the extension system works hard to promote its multipurpose uses.

5. Recommendation domains for sweet blue lupin

Recommendation domains are defined as a group of farmers whose circumstances are similar enough that the same recommendation can be given (Harrington and Tripp, 1984). In other words, places and sets of conditions for which a particular target technology is considered feasible and therefore good to promote. These specific conditions for this practice are given below (Table 5).

Table 5. Recommendation domains for sweet lupin innovation

Identifier	**Specific Identifier**	**Remarks**
Agro-ecology	**Mid to highland**	Altitude, 1800 to 2600 masl
	Sufficient rainfall	1100 to 2300 mm/annum
Resource endowment	**Well drained moderately acidic soil**	
	Availability of labour	
	Presence of livestock	Cattle and small ruminants
Location	**Input suppliers (*seed*)**	
	Access to road	For input and output market
	Access to livestock products	

	market	
Cultural	**Use pattern of the community**	
	Community aware of feeding improved forage for livestock	Since there is lack of awareness on sweet lupin there should be adequate extension support
	Community aware of using local lupin as human food	
	Community where attitudes developed towards sharing the limited land for livestock feed production	
	Community where there is crop rotation practice	

Note: Identifiers in bold/italics are deemed more important

An area in the mid to highlands which has a reliable input supply (sweet lupin seed) within a reasonable distance and the farmer should have good number of livestock. There should be a market for livestock products nearby, the location of the farmer from roads need not be too far. The farmer should have access to capital or credit to purchase improved seed and other inputs as well as transportation means either by his own or by payment.

Sweet lupin can be scaled up in the highland areas of the North Western part of Amhara Region. The highland areas that are Tepid moist mid highlands /M_3/ are suitable for this crop production. The soil should not be water-logging. Those farmers who have more land and have more number of small ruminants are preferable. Sweet lupin production is suitable in densely populated areas. This is because labour is an important input for planting and managing the crop. Those areas that have adequate extension service and markets access are best areas. As sweet lupin production will be new to most rural areas awareness creation and

provision of technical advice in sweet lupin production and utilization to the farmers by extension staff will be crucial. Sweet lupin will be best scaled out in areas where there is experience in improved forage production and animal products marketing such as fattened sheep.

6. Best fit production for sweet blue lupin

6.1. Recommendation domain for sweet blue lupin

6.1.1. Suitable agro-ecology

Sweet lupin grows in the highland (≥ 1500 masl) areas. The suitable altitude ranges from 1800 to 2600 masl and the mean annual rainfall ranges from 1100 to 2300 mm. The yield of sweet lupin is much higher as the altitude of the area increases.

6.1.2. Compatibility to the cropping system

Sweet lupin is suitable for crop rotation. Sweet lupin can be intercropped with maize and this practice will alleviate the land shortage for sweet lupin production. In addition, this practice increases the fertility of the soil.

6.1.3. Resource endowment

Compared to other crops, sweet lupin technology adoption does not require many resources. The seed of sweet lupin is not expensive to the level that challenges the farmers' capacity to purchase. Adopting sweet lupin innovation does not require much labour when compared to adopting other forage species. Presence of livestock enhances sweet lupin adoption.The whole production cycle (from land preparation to harvesting and transporting) can be handled by family labour. The fertilizer and other inputs requirements are minimal as it is a legume crop. But there is shortage in the supply of sweet lupin seed. Land is not as such a problem as far as the farmer is convinced in adopting any sort of forage varieties, though there is high competition for land between crop and livestock production. Hence, sweet lupin can be cultivated and adopted with the resources farmers already own as far as there is no shortage in sweet lupin seed supply.

6.1.4. Location

Proximity to input suppliers: For the timely supply of chemical fertilizers, herbicides and certified seed for farmers, input suppliers such as cooperatives, private traders and seed enterprises should be available near to farmers' village.

Extension services: Kebele DAs should be available near to farmers' village for effective and efficient supervision and management of the sweet lupin innovation. Moreover, higher level agricultural experts should support farmers with frequent supervisions.

Credit service: Even though sweet lupin production is not widely adopted currently, in the future ACSI and cooperatives are the potential sources of credit for input supply. Therefore, these institutions should be accessible for farmers.

Market access: Market is crucial for sweet lupin adoption (for human and livestock nutrition). Farmers can also sell sweet lupin grain in local markets for food for human. Therefore local markets should be available near to farmers' village.

6.1.5. Consumption and production culture

Production of sweet lupin has got high acceptance by farmers and has showed, a potential to alleviate the shortage of livestock feed in the study area. It has also a potential to be used as human food.

6.2. Sweet blue lupin varieties

There are two sweet blue lupin varieties (Sanabor and Vitabor) released by the regional research institute (ARARI). The released variety (Sanabor) is described below.

- Name of the variety: Sanabor
- Year of release: 2014
- Days to maturity: 140 days
- Rain fall requirement: 1189 - 2348 mm
- Altitude range: 1935 - 2610 masl
- Grain yield:
    - Research field: 3.7 t/ha
    - Farmer field: 3.1 t/ha

6.3. Land preparation

The land that should be used for sweet lupin production should be well-drained. Sweet lupin requires a well prepared seed-bed. The land should be ploughed two to three times before planting sweet lupin. The land should be free from weeds and clumps. If the land is not tilled or if sweet lupin is planted in less prepared seed-beds it will not grow well and will not give adequate grain yield.

6.4. Planting time

Sweet lupin should be planted at the beginning of July when there is sufficient moisture. If it is planted late there will be yield reduction. It should be planted in dry and sunny days to avoid muddy conditions of the soil.

6.5. Seed rate and planting method

The seed rate for sweet lupin production is 80 kg ha^{-1}. The seed rate will vary depending on the seed quality. If the seed quality is low it is advisable to adjust the seed rate according to germination percentage/viability of the seed. The planting method can be row planting or broadcasting. When planting is in rows spacing should be 7 cm between plants and 30 cm between rows. Sweet lupin should not be planted in areas where there are forests nearby as the crop will be damaged by wild animals. As the leaves of sweet lupin are not bitter they will be easily eaten by wild animals. It should be expected that there will be no grain yield if the crop is damaged by wild animals during the early stages of plant growth.

6.6. Fertilizer application

If the soil is fertile application of DAP fertilizer is not necessary. However, if the soil is not fertile application of DAP fertilizer as a starter at the rate of 100 kg ha^{-1} is necessary. Urea is not necessary as the crop is legume and can fix nitrogen. There is a problem of lodging when sweet lupin is planted in very fertile soils. This occurs if planting is conducted near backyards. So, planting sweet lupin in very fertile soils is not recommended.

6.7. Plant protection

6.7.1. Weed control

Weeding should be conducted two times; once at seedling stage and the other just before flowering stage. This depends on the infestation of the crop by weeds. Weeding at the seedling stage is very crucial as sweet lupin seeding is weak at this stage. Weeding should be conducted by hand.

6.7.2. Insect pest control

Sweet lupin can be damaged by cut worms. Cut worms damage sweet lupin at the seedling stage. Compared to the bitter cultivars, sweet lupin cultivars are sensitive to biotic and abiotic factors because of their low alkaloid content which serves as one of their defense mechanisms.

6.7.3. Disease control

Diseases caused by *Fusarium spp* are the most important ones in sweet lupin production. To control sweet lupin diseases, site selection is very important. The site that should be used for sweet lupin production should be non-water logging and non-alkaline area. The land should be moderately fertile and the soil should be moderately acidic. Generally, to avoid diseases site selection is very important..

Sweet lupin can be damaged by hail that can cause yield reduction. Sweet lupin can be easily damaged by livestock. So, it is advisable to fence the sweet lupin crop and prevent animals from damaging the crop. In addition, farmers can prevent sweet lupin damage by livestock by planting sweet lupin in the middle of other crops.

6.8. Harvesting, threshing and post harvest handling

Sweet lupin should be harvested when it is mature. Harvesting early after maturity is important to avoid grain loss by shattering. In addition, the harvest should also be threshed early so as to avoid seed loss by shattering. The crop can be threshed traditionally like other pulse crops in the region. The grain obtained after threshing should be air-dried before storage. The grain should be stored in a clean and dry place. If sweet lupin is stored for a long time there is a probability that the grain will be damaged by insects. The moisture content

should be from 15 to 20% for storage purposes. For storing for a long time seed treatment with chemicals is necessary.

6.9. Productivity

The grain yield of sweet lupin ranges from 2.2 to 4.8 ton per hectare depending on the agro-climatic zone and other environmental factors. The grain yield of sweet lupin is higher in cool highland areas when it is compared with mid-altitude areas.

A feeding trial was conducted for 69 days using sweet lupin seed supplementation at 290 g/ head per day on dry matter basis using yearling male sheep fed on natural pasture hay as a basal diet. Based on the feeding trial, the Average Daily Gain (ADG) and body weight change of the sheep was 74 g per day and 5.1 kg, respectively. In addition, supplementation of 400 g sweet lupin per head per day can be used. The sweet lupin should be fed to sheep twice per day; the first half in the morning and the other half in the evenings.

6.10. Farmers preferences

Data on farmer's preference on the demonstrated sweet lupin varieties of Sanabor, Prober and Bora is not available to make preference analysis. Compared to the local bitter white lupin the introduced sweet lupin cultivar has lower alkaloid content, is palatable to livestock and easy to process it as human food. Because of these advantages, farmers showed interest on sweet lupin production and utilization.

6.11. Sustainability assessment

No study on sustainability of sweet lupin production was conducted. As sweet lupin is a legume, it needs little fertilizer application for better productivity. As the crop is legume and fixes nitrogen, it increases the nitrogen content of the soil. So, growing sweet lupin on crop lands reduces the amount of fertilizer that should be applied in subsequent crops. It is a better crop in areas where there is high population pressure and land scarcity.

6.12. Contribution of sweet lupin to nutrition and gender aspects

As feed shortage is the main problem in livestock production, alleviating feed shortage will increase animal productivity. This in turn results in more meat and milk production. This will contribute for better nutrition of the household. As there is malnutrition problem in the region, better nutrition of animals will result in better nutrition of humans.

Though lupin productivity is relatively high, the crop is underestimated and underutilized legume in Amhara Region. Lupins are highly valued as animal feed but have been underutilized as human food yet the seeds are reported to be a rich source of protein with a range value of 33 - 47% and oil 6 - 13% (William P, 2000). Sweet lupin variety was initially introduced to Ethiopia as livestock feed and this was the driving force to see the potential use of its flour for *wot* or *shiro* making for human consumption. Foods based on sweet lupin protein are gaining attention from industry and consumers because of their possible role in the prevention of cardiovascular disease as well as in reduction of blood glucose and cholesterol levels (Duranti, 2006). Sweet lupin in the region is the most candidate legume for protein source to reduce protein malnutrition of children in the community. The stunting rate of under five children in the region is 42%. One of the advantages of sweet lupin is its low level of alkaloid content which is 0.003% (Wasche et al., 2001), so there is no risk of toxicity for human consumption (Martínez-Villaluenga et al., 2006a), and this made the sweet lupin variety more acceptable than the local one.

Utilization of sweet lupin as human food

Sweet lupin grain was pre-cleaned to avoid foreign materials, then slightly roasted. After cooled the roasted grain was splinted to remove the hull. Then the necessary spices which are normaly added to field pea *shiro* were mixed with the splinted sweet lupin and milled together in miller to get fine flour for the traditional stew, *shiro wot*, making. Flour from field pea was prepared following the same procedure that sweet lupin was prepared. Then using the flour from the two crops five different blend proportion (BP) with 25% range including field pea and sweet lupin alone were formulated for the *shiro wot* making.

The sensory test was conducted in Bahir Dar University (BDU), following the procedure of Watts *et al. (*1989). A thirty semi-trained but inexperienced panelists consisting of students, researchers and faculty staff of the University were selected to rate the quality attributes.

Following the procedure of Yost *et al.* (2006) appearance, color, texture, flavor and overall acceptability were evaluated according to the 1 – 9 hedonic scale. The scale had verbally anchored with nine categories, as follows: like extremely, like very much, like moderately, like slightly, neither like nor dislike, dislike slightly, dislike moderately, dislike very much, and dislike extremely. Coded samples were served for each panelist separately in similar plastic trays. The evaluation was repeated in the field by the farmers for each five sample.

The result showed that substituting up to 75% of field pea with sweet lupin for *shiro* making has no significance difference in appearance, texture, aroma and overall acceptability when it is compared with 100% field pea. For taste it has no significance difference up to 25% portion sweet lupin blend with field pea. In all the parameters except taste, the blending proportion 0 - 75% sweet lupin had no significant difference with that of 100% sweet lupin made *shiro*. This indicates that there is an opportunity to substitute other legumes with sweet lupin for both economic and nutritional benefit.

The bitter lupin is known in the area but its use as food is only as snack after long processing procedure to get rid of the alkaloid. However, after farmers got these sweet lupin cultivars in addition to snack they are using sweet lupin for the preparation of different types of food like the traditional stews, *shiro wot* and splinted *wot.* According to farmer panelists from the five samples delivered they preferred a blending ratio of 50% sweet lupin with 50% field pea. So, this shows that blending sweet lupin with field pea for *shiro* making up to 50% is very acceptable.

Farmers' opinion about sweet lupin

According to the participant farmers the crop’s important values are absence of bitter taste, palatability for livestock and its higher productivity. As a result farmers mentioned that the crop is being used for human food, livestock feed and as rotational crop for soil fertility maintenance. Thus, sweet lupin is becoming an important multipurpose crop in the mixed crop livestock farming system of the area. From the sensory evaluation and animal evaluation trials it is possible to conclude that sweet lupin seed can be used for both traditional stew preparation and as protein supplement in the diets of cereal dominant areas. Hence, compared to the local bitter lupin cultivar the newly introduced sweet lupin crop has higher value in the area and its acceptance by local smallholder farmers is very high.

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

7.1. Identification and involvement of relevant stakeholders

Identifying and participating the key stakeholders is the priority task to share responsibility and maximize the effort of each stakeholder for the successful scaling up of sweet lupin production in a wider scale. The key stakeholders and their roles are listed in table 6.

Table 6. Main stakeholders and their involvement for sweet lupin innovation

Identified stakeholders	Stakeholders' role
Model farmers	• Joint planning and execution of scaling up • Seed multiplication • Applying recommended practices • Share their best experience to other farmers on sweet lupin production, handling and utilization
Kebele office of agriculture	• Assist farmers in site selection • Provide training and technical backstopping to farmers • Facilitate credit service
Kebele Administration	• Mass mobilization
District office of agriculture	• Facilitate inputs supply to farmers • Participate in joint planning • Provide training and technical backstopping to farmers and linking the research output with farmers and DAs
	• Facilitate timely availability of input

	• Arranging market access to farmers
District office of administration	• .Participate in joint planning and mobilizing the community
BoA and livestock Agency	• Provide training and technical backstopping to ZoA and DoA • Facilitate timely availability of inputs • Linking the research output with farmers and DAs • Policy direction
Quarantine Agency	• Seed quality inspection, control and certification
Seed enterprises	• Multiply and supply certified seed of sweet lupin 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 to farmers and seed enterprises • Conduct research
Cooperatives	• Organize 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 • Conduct research

Credit institutions	• Provide credit to farmers for purchasing input
Projects and NGOs	• Support logistics and participate in capacity building • Participate in input supply and technology transfer • Dissemination of technologies

7.2. 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 6 above.

7.3. Training at different levels

Experts from BoA, research centers, universities and NGOs should provide both theoretical and practical training of trainees (ToT) for ZoA and DoA. Similarly, ZoA and DoA should train development agents. Finally, development agents should provide training to farmers.

7.4. Availability of inputs

The main input in the sweet lupin innovation system is the sweet lupin seed. It can easily be collected and stored by producer farmers as they are doing in other legume crops. But, currently there is no system established that can deliver seed reliably. Farmers are trying to exchange seed among each other. Therefore, immediate action is needed from stakeholders to secure a reliable seed system. Fertilizer is the other input required in the system. It is available in farmers' cooperatives in nearby areas to the farmers. Adoption of sweet lupin innovation does not require much labour and can be managed by family labour.

7.5. Market access

The growth rate of human population is very high which results in more demand for crop lands and a reduction in the size of the grazing land. This increment in the number of human population means an increase in the demands of livestock products. On the other hand, the

decrease in the sizes of grazing land limits livestock productivity. That means the gap in the demand and supply of livestock products is increasing. Hence, there is a reliable market for livestock products such as milk, meat and live animals.

Sweet lupin is produced mainly to feed animals in order to get better yields from them. Hence, market access is vital for sweet lupin production and utilization. But when we look at the market of sweet lupin, it is not a commercial crop yet, though the future looks bright as it can be used for both livestock and human beings. In the future, awareness creation on the importance of the crop and creation of a marketing system is necessary.

7.6. 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 or program.

Joint monitoring and evaluation is where all stakeholders are involved 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 district 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 can advice on the technique of planting, weed and disease control, 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, storytelling 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 include 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*, districts, zones and regions) ;
- Comparison between years;
- Compare the performance of different interventions; and
- The average performance at *kebele*, district, zone, region and at country level.

In most cases the above analysis relate to the quantitative data. However, if this is complemented with 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 M&E information collected through the established M&E 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 program. Communication can be done through periodical reports, stakeholders meetings and critical reflections, brochures, 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 M&E

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.

7.7. Sharing lesson learned and challenges faced

Sweet lupin is better adaptable and more productive in the highland (≥ 1500 masl) areas of the project intervention districts. It performs better if the soil fertility is good. Protecting the sweet lupin land from free grazing is better to protect the crop from damage by animals. Sweet lupin is very suitable for sheep and dairy producer farmers. Sweet lupin is a multi-purpose crop. It can be intercropped with other food and forage crops. It needs minimum input supply. It improves the fertility of the soil. It can be used as food for humans and feed for livestock.

Sharing lessons learned and challenges faced among stakeholders is crucial. After demonstration/implementation all stakeholders should be involved in the monitoring and evaluation process. Those challenges faced should be sorted out. Further scaling up should be

planned considering the lessons learned and the challenges faced. In some instances, farmers do not manage the crop as effectively as expected. Farmers also plant the crop on degraded lands and this results in low yield. Some farmers do not use the recommended seed rate. They do not weed the crop adequately. The seed should be provided to the farmers on time. In addition, early harvesting and monitoring is essential. These management aspects should be monitored and evaluated periodically. Sweet lupin needs a well-drained soil when it is compared with the local lupin. In addition, its seed shatters easily when it is compared with the local lupin. So, harvesting the sweet lupin on time is crucial.

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