Exploring forgotten opportunity: White Lupin development for food, feed, cash, health, and soil fertility management in Ethiopia

Mulugeta Atnaf, Dagne Wegary, Kassahun Tesfaye, Kifle Dagne, Yalew Mazenga, Birhanu Ayalew, Adane Melak & Moti Jaleta |

To cite this article: Mulugeta Atnaf, Dagne Wegary, Kassahun Tesfaye, Kifle Dagne, Yalew Mazenga, Birhanu Ayalew, Adane Melak & Moti Jaleta | (2020) Exploring forgotten opportunity: White Lupin development for food, feed, cash, health, and soil fertility management in Ethiopia, Cogent Environmental Science, 6:1, 1813451, DOI: 10.1080/23311843.2020.1813451

To link to this article: https://doi.org/10.1080/23311843.2020.1813451

© 2020 The Author(s). This open access article is distributed under a Creative Commons Attribution (CC-BY) 4.0 license.

Published online: 21 Sep 2020.

Submit your article to this journal

Article views: 232

View related articles

View Crossmark data
Interview with a farmer during household survey

Exploring forgotten opportunity: White Lupin development for food, feed, cash, health, and soil fertility management in Ethiopia

Mulugeta Atnaf, Dagne Wegary, Kassahun Tesfaye, Kifle Dagne, Yalew Mazengia, Birhanu Ayalew, Adane Melak and Moti Jaleta

Cogent Environmental Science (2020), 6: 1813451
ECOLOGY | RESEARCH ARTICLE
Exploring forgotten opportunity: White Lupin development for food, feed, cash, health, and soil fertility management in Ethiopia

Mulgeta Atnaf¹, Dagne Wegary², Kassahun Tesfaye³, Kifle Dagne³, Yalaw Mazengia¹, Birhanu Ayalew¹, Adane Melak¹ and Moti Joleta²

Abstract: White lupin is an important grain legume in the Ethiopian farming system. However, farmers’ cultivars contain undesirable characters, such as high alkaloid level, are susceptible to diseases and low yielders. In order to ascertain the extent of these constraints with the farmers and document their experiences and practices on white lupin production and processing, detailed baseline survey was conducted in white lupin producing areas of north western Ethiopia. Household level survey data collected from 303 farmers is used for the analysis. The study showed that farmers have long experience in producing lupin on marginal lands for food, feed, soil fertility management, and to generate cash income from sale. It also indicated that majority of lupin farmers perform minimum crop management practices to grow lupin. High alkaloid level in traditional cultivars, prevalence of different lupin diseases and lack of improved varieties are among the top production constrains voiced by most surveyed farmers. The development of white lupin variety would help a lot in overcoming this undesirable feature and boosting grain productivity. Enhancing further research and development initiatives on lupin could help smallholder farmers living on marginal lands to generate better food for home consumption.

ABOUT THE AUTHOR
Mulgeta Atnaf joined the research system in Ethiopia at his early career in 2001. Since then, he has served as researcher and administrator with different positions and capabilities. He has worked as legume breeder from 2001 to 2017 in the Ethiopian Institute of Agricultural Research (EIAR). He did his PhD on the genetics and socioeconomics of neglected but multipurpose legume species in Ethiopia, white lupin. This particular manuscript is one output of his PhD research project. His involvement and significant contribution resulted in release of number of improved varieties of different food legumes (mainly common bean, soybean, and chickpea), and rice. He also authored several publications in journal articles, book chapters and conference proceedings. Mulgeta has been awarded for such outstanding accomplishment. Currently, he is served as senior rice breeder and coordinator of national rice research program of Ethiopia based at Fogera National Rice Research and Training Center of EIAR.

PUBLIC INTEREST STATEMENT
Ethiopia is endowed with diverse agro-ecologies that are suitable for different farming systems found in the country. Mixed crop-livestock production is the typical farming system in northwestern part of Ethiopia. Food legumes are among the various crops produced across the country. White lupin is among the legumes adapted and grown by farmers in the northwestern part of the country. However, despite its importance in improving the fertility of degraded farm land and providing economical sources of protein for poor families, only very limited research and development efforts have been made to improve its productivity and quality in Ethiopia. Ascertainment constraints along the value chain and documenting farmers’ experiences is important not only to use it as baseline information to setting up national lupin improvement programs, but also it ensures farmers participation to develop demand led lupin technologies. This paper assesses experiences and practices of Ethiopian white lupin farmers.
consumption, feed for their livestock, cash income from sale, fix nitrogen for better soil fertility, and rehabilitation of degraded lands.

Subjects: Agriculture & Environmental Sciences; Agriculture; Environmental Sciences; Agriculture and Food; Environment & Agriculture

Keywords: White lupin; alkaloids; soil fertility; orphan crops; Ethiopia

1. Introduction
White lupin is one of the most adopted and widely cultivated legume species in northwest part of Ethiopia (Ethiopian Central Statistical Agency, 2016/2017). It has been traditionally cultivated for several thousands of years in the Mediterranean region (from where it originated), and along the Nile valley including Ethiopia (Wolko et al., 2011). It is a promising leguminous crop for human consumption, green manuring, forage and has substantial importance in human nutrition and health (Hall, 2005; Johnson et al., 2006). White lupin is produced in Ethiopia exclusively by smallholder subsistence farmers, mainly for its food grain and soil fertility maintenance values (Yeheyis et al., 2010), and it has sustained quite long time in the farming system. It is traditionally used to cure some human disorders and diseases including high blood pressure. Moreover, the crop has social value, being generally consumed in bad crop harvest years and by poor communities. Furthermore, processing and marketing of processed lupin products is mainly carried out by women and youth, and hence generate cash income from the transaction (Atnaf et al., 2015c).

However, the local cultivars being used by farmers have several undesirable characteristics, such as low yielding potential, susceptibility to major diseases (Atnaf et al., 2015b) and high contents of alkaloids (Yeheyis et al., 2011). Despite lupin’s importance in improving the fertility of degraded farmland and providing cheap sources of protein for poor families, only very limited research and development efforts have been made to improve its productivity and quality in Ethiopia. The need to develop well adapted white lupin cultivars with farmers’ preferred traits including high grain yield, low alkaloid level and resistant to major lupin diseases and insect pests was pointed out by Atnaf et al. (2015b). Ascertaining lupin constraints along the value chain and documenting farmers’ experiences is important not only as a baseline information to set up national lupin improvement programs, but also to ensure farmers’ participation to develop demand-led lupin technologies.

Farmer’s long time indigenous practices in lupin production, product processing and utilization, knowledge and experience on the role of lupin in cropping systems, and its values for health and nutrition, are all worthy to be documented. Yeheyis et al. (2010) attempted to assess and document some of the practices and constraints mainly from feed and/or nutrition perspectives. Nevertheless, there is no comprehensive assessment that has been done to document white lupin production practices and constraints at least in the major producing areas of Ethiopia. This paper attempted to fill this knowledge gap and identify some research questions for breeders and provide important recommendations for policy makers regarding future lupin production and processing.

2. Methodology

2.1. Description of the study area
This study was undertaken from July to November 2013 in four different administrative zones of northwestern Ethiopia; namely, Awi, East Gojam, South Gondar and West Gojam. These zones contribute approximately 95% lupin production of the country (Ethiopian Central Statistical Agency, 2016/2017). For this study, one district was purposively selected from each zone based on lupin production potential and agro-ecological representativeness, and surveyed in detail. The selected districts were Fogata Lekoma, Machakel, Dera and South Achefer from Awi, East Gojam, South Gondar and West Gojam zones, respectively. These districts have well been known for high
lupin production in Ethiopia since long period of time. South Achefer and Dera districts are mainly characterized by nitosols, while Fageta Lekoma and Machakel are dominated by acrisols and luvisols, respectively (Adet Agricultural Research Center, unpublished data). Map of the study areas is provided in Figure 1. Even though mixed crop-livestock production is the typical farming system, crop production is a dominant practice and the main means of livelihoods in all the study districts. Livestock is an important component and plays key role in the farming system. Crop and livestock production are highly integrated where livestock provides draft power and manure for crop production while crop production provides crop residues as feed to the livestock sub-system (Yeheyis et al., 2010).

2.2. Sampling design

In the study area, survey was conducted to collect cross-sectional data from 303 farm households producing and using lupin. A combination of probability and non-probability random sampling methods were used at multistage sampling stages. At the first stage of sampling, from the targeted zones, districts were purposively selected based on their lupin production potential. At second stage, peasant associations (PAs) were selected based on lupin production area, i.e., PAs having lupin area coverage above the district average were selected. At the third stage, within each of the selected PAs, villages were picked randomly. At fourth and final stage, sample households were selected randomly from the already selected villages using simple random sampling tool (https://www.random.org/). The number of sampled household in each village was proportional to the total household population. Female-headed households were included proportionally in the sample. The survey covered a total of 303 households, whereby the four study districts, Dera, South Achefer, Fagta, and Machakel constitute 24%, 30%, 17%, and 29% of the total households, respectively.

Figure 1. Geographic location of the study districts.
2.3. Data
To capture relevant information for the study, primary and secondary data were collected. Primary data were collected through formal survey using structured questionnaire that was pre-tested and administrated to a randomly selected 303 farm households. Secondary data were collected from Central Statistics Authority of Ethiopia (CSA), regional, zonal and district agricultural offices reports, in consultation with appropriate representatives of these offices and through focused group discussions to get initial understanding of the farming system of selected areas. The structured questionnaire was used to capture data on household and farmland characteristics, farmers’ practices and constraints in lupin production, processing, utilization, and marketing as well as cropping system experiences. In addition, information on institutional support services including extension and marketing systems were collected using the questionnaire.

The data collected from primary sources were coded and entered into computer software, Statistical Package for Social Sciences (SPSS), version 20. The data were checked for consistence and completeness and analyzed using the same software. We employed descriptive statistics such as frequencies or percentages and ranges, cross-tabulations, means, and ratios to analyze, summarize, and present the data. Analysis was conducted by disaggregating the data by district to capture differences among the study districts. Comparisons were made using F-test (one-way ANOVA), and non-parametric tests including K-independent samples and Chi-square depending on the type of variables.

3. Results and discussion
3.1. Farm and household characteristics
Crop farming is by far the dominant activity and means of livelihood across the study areas. Maize, teff and finger millet are the major cereals produced in South Achefer, while wheat, teff, finger millet, barley, and maize are common in Dera. Oat (Avena species) is very common in addition to wheat, teff and barley in Machakel, whereas potato is the most common next to teff in Fageta district. Food legumes are key components of the cropping system in the study areas. Faba bean, field pea, and lupin are the major food legumes across the study areas, but with varying scale of production. For example, lupin is more common in Fageta than the other districts. Other food legumes, such as chickpea and grass pea are also important in the cropping systems.

Livestock on the other hand are an integral part of farming system, and mainly considered as an asset of the household. Common livestock species across the study areas are cattle, sheep, donkey and poultry. In addition, horses in Fageta and mule in South Achefer are important species. Nevertheless, the average livestock holding, quantified in Tropical Livestock Unit (TLU), varied among districts and ranged from 4.3 TLU in Dera to 6.5 TLU in Machakel, whereas households own 5.3 TLU at Fageta and 5.8 TLU in South Achefer.

3.2. Lupin cropping experience and practices
Lupin farming experience is not significantly different among farmers in the study districts. The sample farmers had an average lupin production experience of 16 years (Table 1). However, some farmers indicated that lupin had been grown by their fathers and grand-fathers. An average land area allocated to lupin production per household is larger at Machakel (0.32 ha) and Fageta (0.30 ha) districts, which are characterized by high-altitude agro-ecologies but relatively smaller in Dera (0.23 ha) and South Achefer (0.25 ha), which are dominated by mid-altitude agro-ecology. However, the districts had similar proportion of land allotted for lupin production as compared to the household owned total land area, which was about 20% in three of the study districts except in Fageta where it was as high as 29%. Similar study conducted on white lupin production in north-west Ethiopia indicated that relatively high proportion of land is allocated to the crop at higher altitude areas that have low soil fertility and degraded crop land (Yeheyis et al., 2010). These would indicate farmers in the high altitude agro-ecologies do have the knowledge that lupin performs well on infertile soils and degraded land than other crops and at the same time it has the potential
Atnaf, Environmental Science

Table 1. Farmers’ experience on lupin cropping explained as percentage or mean value depending on the type of measurement employed

| Values/measurement                           | Percentage (mean) |
|---------------------------------------------|-------------------|
| Experience in growing lupin (years)         | 15.9              |
| Purpose of growing lupin                    |                   |
| Food only                                   | 0.99              |
| Fertility restoring only                    | 1.65              |
| Cash                                        | 0.66              |
| Food and fertility restoring                | 8.25              |
| Food, fertility and cash                    | 54.5              |
| Food, fertility, cash, medicinal, and feed  | 34                |
| Growing different lupin cultivars           |                   |
| Yes                                         | 3.3               |
| No                                          | 96.7              |
| Seed saved to next planting                 |                   |
| Yes                                         | 98                |
| No                                          | 2                 |
| Ratio of land allocated for lupin to own land (%) | 22.33          |

to replenish the fertility of degraded lands. Furthermore, given the growing need to produce food crops on marginal lands with limited water availability and limited energy expenditure, lupin offers considerable promise (Schulze et al., 2006; Small, 2012).

Farmers across the study areas had similar purposes of growing lupin. Majority of the farmers (54.5%) mentioned that lupin has been grown for food, soil fertility restoration, and as source of cash from grain transaction and processed products (Table 1). Reasonable number of farmers (34%) also indicated that they grow lupin for livestock feed and medicinal values in addition to the abovementioned uses of the crop. These justify that farmers grow lupin for various purposes that range from farm/soil fertility management to household consumption; and also as source of cash and for medicinal values. Similar to the current findings, several studies reported that legumes, including lupin, offer multiple functions to the farming community (Atnaf et al., 2015b, 2015a; Kassie, 2011; Yeheyis et al., 2010).

Nearly 97% of the sample farmers responded that they were growing a local white lupin cultivar which they obtained mainly from their ancestors, local markets and fellow farmers (Table 1). Only few farmers in Machakel, South Achefer and Dera explained that they were using two different types of lupin cultivars, viz., the local white lupin and the narrow leaved sweet lupin cultivars. The present finding is contrary to the report of Jansen (2006) who indicated the presence of two types of cultivated white lupin cultivars (large seeded ones that are produced in Egypt and Sudan, and small seeded types with small leaves in Ethiopia). The sweet lupin cultivars in Dera and South Achefer were introduced during the CASCAPE (Capacity building for scaling up of evidence-based best practices in agricultural production in Ethiopia) project intervention in these districts (Abebe et al., 2015). Farmers usually save seeds of preferred varieties used for next season from the present harvest. In the present study, it was clearly indicated that about 98% of the respondent farmers save their own seed from the preceding year lupin grain production. However, the quantities of seed saved varied both within the district and among districts. The average amount of saved seed ranges from 10 kg at South Achefer to 24 kg at Machakel, while the amount is 16 kg at both Dera and Fagleta districts. This would be associated with the amount of land allocated for lupin production. The study showed that farmers in Machakel and Fageta allocated more land for
lupin cultivation, which is in-line with the high average amount of own saved lupin seed of farmers in these districts.

3.3. Lupin cropping constraints
The study identified the prevalence of different diseases, insect pests, and lack of improved varieties as the top production constraints repeatedly mentioned by individual farmers and by the focused group involved in the discussion. According to the interviewed farmers, “michi” or “wag” that dries-up parts of or whole plant was the common lupin disease in all study districts. This type of symptom might be associated with common lupin fungal diseases, such as pleiochaeta root rot, brown leaf spot and phomopsis. Occurrences of these fungal diseases in Ethiopia were reported by Atnaf et al. (2015b). However, further diagnosis and identification should be done to further characterize these diseases. Farmers in Machakel district mentioned the occurrence of frequent infestations of their lupin crop by insect pest called “green-black-gray” worm, which mainly occurs at podding stage. This insect pest might be associated with Australian native budworm which was reported in Ethiopia (Atnaf et al., 2015b).

Farmers in all study districts requested for urgent intervention to alleviate major lupin production constraints such as lack of improved varieties, diseases, and insect pests. Farmers in Machakel district gave more emphasis to diseases and insect pests, whereas farmers in Dera district focused more on the lack of improved varieties. They further indicated that most preferred improved variety should have high yield potential and low alkoidal level, be resistant to major lupin diseases and insect pests, and relatively earlier in maturity. Farmers in all study districts, except in Fageta, pointed out that the lack of recommended agronomic management practices such as optimum plant population, row planting and tillage practices have been affecting lupin productivity and need to be considered as researchable issues.

3.4. Lupin in the cropping system
Farmers have different criteria to decide which legume crop should get into the rotation scheme in their cropping systems. Among others, nitrogen fixing capacity, stubble (residue) yield and its utilization, extent of input requirement, drought tolerance, disease and insect pest resistance, tolerance to weed infestation, and grain yield potential of the legume crops are considered by the farmers to comparatively choose among the types of legumes. Faba bean, field pea, and lupin are the most common legumes in the study districts, while chickpea and grass pea are also produced.

Ordinal measures (poor, average/fair, good, and very good) of the mentioned criteria were used for the choice of legume species; and comparison was made among the common legumes. Based on experience and judgment, 48% and 46% of the farmers rated nitrogen fixing capacity of lupin as good and very good, respectively, whereas both faba bean and field pea were rated as good by 42% and 37% of the farmers (Figure 2). This result is in-line with earlier reports that lupin can potentially fix and accumulate a total of 150 to 400 kg/ha nitrogen per year, while faba bean fixes up to 200 kg/ha per year (Jansen, 2006; Sulas et al., 2016). More than 85% of the respondent farmers mentioned that lupin require minimal inputs, whereas about 50% of the respondents mentioned that field pea requires moderate level of input and 60% of the respondents mentioned that faba bean requires more inputs than lupin (Figure 2). Majority of the interviewed farmers (80.5%) mentioned that lupin had good level of drought tolerance as compared to faba bean that about 65% of the respondents mentioned its drought susceptibility. On the other hand, about 50% of the farmers indicated that filed pea is fairly tolerant to drought, while the other 50% evaluated as susceptible to drought. Small (2012) stated that lupin is an important food crop in marginal crop producing areas with limited water availability. The farmers indicated that lupin is more tolerant to weed infestation than faba bean and field pea. In view of the above mentioned relevance, most farmers consider lupin as key rotational legume crop in the cropping system across all study areas.
3.5. Experiences and constraints in lupin utilization

Almost all respondents mentioned that lupin production is targeted for multiple purposes that include food security, soil fertility replenishment and income generation. In addition, some households produce lupin for its medicinal value and as source of livestock feed. Most farmers indicated that lupin has usually been consumed as snack after processing, and also used to distil a local alcoholic drink called “Gebto arekie.” This beverage is believed to have medicinal value, especially to control hypertension. These products are very popular among lupin producing and consuming communities. The alcohol is getting high popularity and has got a brand name called “dembecha” from its nationwide users. The name came from the place where it is widely processed and marketed. It is produced by distilling a fermented brew prepared in the same way as other cereal-based alcoholic beverages, except that in this case flour of white lupin seeds are used as one of the major ingredients (Ambaye et al., 2002). In fact, seeds of lupin should go through debittering process before it is utilized for the alcohol preparation.

The snack from lupin is commonly consumed by less-privileged households, and usually used when the farmers face critical food grain shortage, mainly due to bad harvest. The farmers interviewed unanimously agreed that lupin snacks are among the types of foods usually consumed when the family faces food deficit. Before preparing lupin snack, lupin grain should be roasted and soaked in water for a couple of days. Hence, lupin snack preparation is highly associated with water availability. As a result, lupin based snack preparation and consumption in rural areas is usually common during the rainy season where most rivers in the study districts get enough volume of rainwater. However, despite water unavailability for the processing during the dry season, the snack consumption is increasingly high and year-round in local drinks “tella” houses and beer groceries found in most towns in the study area. Moreover, some women farmers mentioned their experience of using lupin for making local sauce called “shiro,” after debittering and grinding lupin grain.

All farmers repeatedly complained about bitterness of white lupin as the most persistent and outstanding constraint that limits lupin utilization. It makes processing and product development activities more laborious and time taking. Yeheyis et al. (2011) reported high level of alkaloid in Ethiopian white lupin landraces. Farmers mentioned that lupin debittering is a prerequisite to develop any product from lupin. For example, snack preparation involves roasting seeds on metal plate, soaking in water for about 5–8 days with repeated (one to three times) washing (Yeheyis et al., 2010).
Table 2. Farmers’ experience and evaluation of lupin as feed expressed as percentage

| Parameters                        | Unit | District                  | Sig. |
|----------------------------------|------|---------------------------|------|
|                                  |      | Dera | Fageta | Machakel | SA |
| Which animals prefer lupin       |      |      |        |          |    |
| Cattle                           | 4.05 | 4.00 | 5.81   | 9.89     |    |
| Sheep                            | 13.51| 10.00| 6.98   | 8.79     |    |
| Goats                            | 14.86| 4.00 | 27.91  | 19.78    |    |
| Equines                          | 2.70 | 42.00| 4.65   | 0.00     |    |
| Not preferred by animals         | 17.57| 4.00 | 16.28  | 26.37    |    |
| Sheep and goat                   | 47.30| 30.00| 37.21  | 35.16    |    |
| Cattle and equines               | 0.00 | 6.00 | 1.16   | 0.00     |    |
| Lupin feeding potential          |      |      |        |          |    |
| Very poor                        | 14.86| 18.00| 27.91  | 23.91    | 0.01 |
| Poor                             | 39.19| 32.00| 48.84  | 36.96    |    |
| Fair/average                     | 36.49| 38.00| 23.26  | 33.70    |    |
| Good                             | 9.46 | 12.00| 0.00   | 5.43     |    |
| Very good                        | 0.00 | 0.00 | 0.00   | 0.00     |    |
| Lupin palatability               |      |      |        |          | 0.001|
| Very poor                        | 8.11 | 0.00 | 18.39  | 14.13    |    |
| Poor                             | 31.08| 30.00| 54.02  | 53.26    |    |
| Fair/average                     | 50.00| 46.00| 24.14  | 25.00    |    |
| Good                             | 9.46 | 24.00| 3.45   | 7.61     |    |
| Very good                        | 1.35 | 0.00 | 0.00   | 0.00     |    |
| Lupin crop residue utilization   |      |      |        |          | 0.03 |
| Very poor                        | 1.35 | 0.00 | 0.00   | 1.09     |    |
| Poor                             | 14.86| 6.00 | 17.24  | 22.83    |    |
| Fair/average                     | 60.81| 54.00| 55.17  | 55.43    |    |
| Good                             | 18.92| 40.00| 26.44  | 19.57    |    |
| Very good                        | 4.05 | 0.00 | 1.15   | 1.09     |    |

Sig. = Significant test and was performed based on Independent Samples Kruskal Wallis one-way ANOVA test.

Utilization of lupin as feed source was assessed based on livestock preference, feeding potential of lupin, palatability and lupin residue as feed (Table 2). More than half of the respondent farmers (56%) mentioned that white lupin is poorly palatable to livestock, whereas only 34% indicated that the crop is fairly palatable to livestock. About two thirds of the respondents indicated that they do not believe in the potential of lupin as livestock feed. Similarly, Yeheyis et al. (2010) reported that white lupin is less palatable to livestock; and hence, offers limited potential as livestock feed. Nevertheless, the current study indicated that about 38% of the farmers in the study areas confirmed the potential of lupin as animal feed.

3.6. Information and marketing

About 43% of the farmers confirmed the availability of market for lupin whereas more than half (57%) of them mentioned lack of reliable market for the crop. One-way ANOVA showed that price of lupin grain varied significantly among the study districts. Mean grain price ranged from 2.51 ETB per kg at Dera to 3.42 ETB per kg at Machakel (Table 3) in year 2013. Considerable price variations were also noted within districts; the highest at Machakel (1.4–7.0 ETB) and the lowest at Dera (1.0–4.0). About 69% of the farmers indicated that the current overall price of lupin is low and unfair, especially as compared to the prices of other legumes commonly produced in the study areas.
Table 3. Sources and access of agricultural and market information for farmers, expressed as percentage or mean value depending on the type of measurement employed

| Parameter                                        | Unit                                      | Dera | Fageta | Mkl  | SA      | Combined | Sig.   |
|-------------------------------------------------|-------------------------------------------|------|--------|------|---------|----------|--------|
| Sources of output market (price of lupin grain) | Gov’t                                     | 9.46 | 12.00  | 1.16 | 6.53    | 6.60     | 0.476  |
|                                                 | Traders                                   | 31.08| 24.00  | 33.72| 29.35   | 30.13    |        |
|                                                 | Farmers                                   | 40.54| 32.00  | 32.56| 41.30   | 37.09    |        |
|                                                 | Radio/TV                                  | 1.35 | 8.00   | 12.79| 5.43    | 6.95     |        |
|                                                 | Others                                    | 17.57| 24.00  | 19.77| 17.39   | 19.21    |        |
| Sources of input market (price of pesticides)   | Gov’t                                     | 75.68| 95.83  | 90.80| 85.87   | 86.38    | 0.004  |
|                                                 | Traders                                   | 8.11 | 2.08   | 8.05 | 6.52    | 6.64     |        |
|                                                 | Farmers                                   | 2.70 | 0.00   | 0.00 | 1.09    | 1.00     |        |
|                                                 | Others                                    | 13.51| 2.08   | 1.15 | 6.52    | 5.98     |        |
| Buyer type                                      | Consumers                                 | 77.08| 71.43  | 81.36| 79.17   | 77.63    | 0.466  |
|                                                 | Assembler                                 | 8.33 | 0.00   | 6.78 | 5.56    | 5.26     |        |
|                                                 | Outside trader                            | 8.33 | 24.49  | 11.86| 15.28   | 14.91    |        |
|                                                 | Wholesaler                                | 6.25 | 0.00   | 0.00 | 0.00    | 1.32     |        |
|                                                 | Farmers’ coop.                            | 0.00 | 4.08   | 0.00 | 0.00    | 0.88     |        |
| Availability of reliable market                 | yes                                       | 53.42| 34.00  | 32.56| 50.00   | 43.19    | 0.015  |
|                                                 | no                                        | 46.58| 66.00  | 67.44| 50.00   | 56.81    |        |
| Lupin market value                              | Low                                       | 45.95| 20.00  | 28.74| 33.70   | 33.00    | 0.445  |
|                                                 | Not fair                                  | 16.22| 56.00  | 51.72| 26.09   | 35.97    |        |
|                                                 | Fair                                      | 35.14| 20.00  | 16.09| 33.70   | 26.73    |        |
|                                                 | Good                                      | 2.70 | 4.00   | 3.45 | 6.52    | 4.29     |        |
| Walking time*                                   | minutes                                   | 63.57| 65.83  | 66.25| 39.33   | 58.28    | 0.006  |
| Walking time**                                  | minutes                                   | 128.77| 78.67 | 86.09| 56.30   | 86.13    | 0.000  |
| Price of lupin                                  | ETB per kg                                | 2.5115| 2.5918| 3.4220| 2.8542  | 2.8726   | 0.000  |

Mkl = Machakel; SA = South Achefer; Gov’t = Government; Ext. material = Extension material; Interaction* = Interaction with an extension agent in the past 12 months; walking time* = Minutes of walking time to the nearest village market; Walking time** = Minutes of walking time to district/main market; and Sig. = Significant test and was performed based on Independent Samples Kruskal Wallis one-way ANOVA test.
On the other hand, 31% of the farmers considered the current lupin grain price as fair and good. Pack animals (61.8%) followed by cart pulled by mule (25.7%) are commonly used by the farmers to transport lupin grain to the market across the study districts except at South Achefer, where large number of the farmers (69%) use mule pulled cart. Some farmers (10.6%) in all districts head-carry lupin grains as means of transportation to the market place. Most farmers (77.6%) sell lupin grain in local markets, whereas 15% of them sell to outside traders. Some farmers consider other market places including assembler (5.3%).

4. Conclusion
Given the long-standing lupin farming experiences and practices in Ethiopia, there was very limited attention given to the research and development of lupin as food security or cash crop. This study attempted to document wealth of farmers’ experience and practices on lupin production, processing, and its role in the farming and cropping systems. The study identified that farmers are conscious about the multifaceted uses of lupin, from farm to kitchen and its cash and medicinal values, when deciding lupin production. Thus, majority of the farmers across the study districts had lupin farming activity either each year or every other year. The study results indicated that compared to other common food legumes, lupin is preferred to be involved in the rotation system across the study districts. This was evidenced with farmers’ evaluations of three common food legumes (faba bean, field pea and lupin) against the major criteria they often considered while choosing a particular legume to put into the rotation scheme. Lupin was favored for better nitrogen fixation, drought adaptation and generally could offer considerable human food in marginal lands with limited water availability. The study further grasped farmers’ experience and practices on product development out of lupin and its utilization. It also identified major lupin production, processing and utilization challenges and constraints in the value chain. These include, lack of improved varieties profiled with low alkaloids level, resistance/tolerance to major lupin diseases and insect pests, and early maturing. These research findings would be used as platform to set up breeding programs aiming at lupin improvement. It further informs development practitioners and other stakeholders in the lupin value chain.

Acknowledgments
The authors would like to acknowledge the financial support from Ethiopian Institute of Agricultural Research (EIAR) and Pawe Agricultural Research Center (PARC) through Sustainable Intensification of Maize-Legume Systems for Food Security in Eastern and Southern Africa (SIMLESA) project funded by the Australian Center for International Agricultural Research (ACIAR).

Funding
This work was supported by the Australian Government [SIMLESA].

Competing Interests
The authors declares no competing interests.

Author details
Mulugeta Atnaf1
E-mail: atnafmulugeta@gmail.com
ORCID ID: http://orcid.org/0000-0002-3395-6303

Dagne Wegary2
E-mail: d.wegary@cgiar.org
ORCID ID: http://orcid.org/0000-0003-2301-4440

Kassahun Tesfaye3
E-mail: kassahuntesfaye@yahoo.com

Kifle Dagne3
E-mail: dagnekifle51@gmail.com

Yalew Mazengia1
E-mail: meetyalew@gmail.com

Birhanu Ayalew3
E-mail: birhanu08@gmail.com

Adane Melak3
E-mail: addrm_2006@yahoo.com

Moti Jaleta2
E-mail: M.Jaleta@cgiar.org

1 Ethiopian Institute of Agricultural Research, Pawe Agricultural Research Center, Pawe, Ethiopia.

2 CIMMYT-Ethiopia, ILRI Campus, CMC Road, P.O. Box 5689, Addis Ababa, Ethiopia.

3 Department of Microbial, Cellular and Molecular Biology, Addis Ababa University, College of Natural Sciences, Addis Ababa, Ethiopia.

Cover image
Source: Author.

References
Abebe, Y., Ahmed, A., Tafere, M., Dagnaw, S., Gebre Selassie, Y., Yeheyis, L., Amane, A., & Molla, D. (2015). Best fit practice manual for sweet lupin (Lupinus angustifolius L.) production. BDU-CASCAPE working paper 11.

Ambaye, C., Tolessa, T., Abera, A., Sheriet, H. T., Abebe, D., & Urg, K. (2002). Antihypertensive activity of residue from Gebto Arekie, locally distilled medicinal spirit from a brew containing Lupinus albus seeds in renovascular hypertensive guinea-pigs. Ethiopian Journal of Health Sciences, 12, 25–35.
Atnaf, M., Tesfaye, K., Dagne, K., & Wegary, D. (2015b). Extent and pattern of genetic diversity in Ethiopian White Lupin landraces for agronomical and phenological traits. African Crop Science Journal, 23(4), 327–341. https://doi.org/10.4314/acsj.v23i4.3

Atnaf, M., Tesfaye, K., & Kifle, D. (2015c). The importance of legumes in the ethiopian farming system and overall economy: An overview. American Journal of Experimental Agriculture, 7(6), 347–358. https://doi.org/10.9734/AJEA/2015/11253

Ethiopian Central Statistical Agency (ECSA). (2016/2017). Report on area and production of crops (Private peasant holdings, Meher season).

Hall, R. S. (2005). Australian sweet lupin flour addition reduced the glycaemic index of a white bread breakfast without affecting palatability in healthy human volunteers. Asia Pacific Journal of Clinical Nutrition, 14(1), 91–97.

Jansen, P. C. M. (2006). Lupinus albus L. [Internet] Record from Protobase. In: Brink, M., Belay G. (eds.). Plant Resources of Tropical Africa, Prota, Wageningen, Netherlands. http://database.prota.org/search.htm

Johnson, S. K., Chua, V., Hall, R. S., & Baxter, A. L. (2006). Lupin kernel fiber foods improve bowel function and beneficially modify some putative faecal risk factors for colon cancer in men. British Journal of Nutrition, 95(2), 372–378. https://doi.org/10.1079/BJN20051648

Kassie, M. (2013). Economic and environmental benefits of forage legume-cereal intercropping in the mixed farming system: A case study in West Gojam, Ethiopia. EDRI.

Schulze, J., Temple, G., & Temple, S. J. (2006). Nitrogen fixation by White Lupin under phosphorus deficiency. Annals of Botany, 98(4), 731–740. https://doi.org/10.1093/aob/mcl154

Small, E. (2012). Lupins—benefit and harm potential. Biodiversity, 13(1), 54–64. https://doi.org/10.1080/14888386.2012.658327

Sulas, L., Canu, S., Ledda, L., Carroni, M. A., & Salis, M. (2016). Yield and nitrogen fixation potential from white lupine grown in rain-fed Mediterranean environments. Scientia Agricola, 73(4), 338–346. https://doi.org/10.1590/0103-9016-2015-0299.

Wolko, B., Clements, J. C., Naganowska, B., Nelson, M. N., & Yang, H. (2011). Lupinus. In C. Kole (Ed.), Wild crop relatives: Genomic and breeding resources (pp. 153–206). Springer Berlin Heidelberg.

Yeheyis, L., Kijora, C., Solomon, M., Anteneh, G., & Peters, K. J. (2010). White lupin (Lupinus albus L.), the neglected multipurpose crop: Its production and utilization in the mixed crop-livestock farming system of Ethiopia. Livestock Research for Rural Development, 22(4). http://www.lrrd.org/lrrd22/4/yeye22074

Yeheyis, L., Kijora, C., van Santen, E., & Peters, K. (2012). Sweet annual Lupins (Lupinus spp.): Their adaptability and productivity in different agro-ecological zones of Ethiopia. Journal of Animal Science Advances, 2(2), 201–215.

Yeheyis, L., Kijora, C., Wink, M., & Peters, K. J. (2011). Effect of a traditional processing method on chemical composition of local white lupin (Lupinus albus L.) seed in north-western Ethiopia. Zeitschrift für Naturforschung, 66(7–8), 403–408. https://www.doi.org/10.1515/znc-2011-7-812

Yildiz, S. (2011). Rotational and nematicidal effect of lupin (Lupinus albus L.). African Journal of Biotechnology, 10(61), 13252–13255.