



Challenges on Production and Utilization of White Lupin (*Lupinus albus* L.) in Ethiopia: A Strategic Orphan Crop

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Authors' contributions

This work was carried out in collaboration between all authors. Author FM proposed the study, enriched the proposal, the manuscript, supervised data analysis tools, techniques and all steps of the research until final submission. Author HA designed the study, wrote the proposal, collected the data, compiled, analyzed the data, interpreted the result and wrote the first draft and the revised versions of the manuscript. Author YD enriched the proposal, supervised the study design, data collection and reviewed enriched the manuscript and supervised the research activity. Author ZT enriched the proposal and reviewed the manuscript and supervised the research activity. Author NM enriched the proposal, reviewed the manuscript and supervised the research activity. All authors read and approved the final manuscript.

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ABSTRACT

Aim: To assess the potentials and constraints of production and utilization of white lupin in the major growing areas and analyze the production, area coverage and productivity trend in Ethiopia.

Study Design: Purposive sampling method was used to select districts and random sampling procedure followed to select respondents among white lupin producers.

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Methodology: Survey was conducted on Feb 2013 at Machakel and Banja districts of Eastern Gojjam and Awi Zones of Amhara Regional respectively. A sample size of 80 respondents for the two districts was used. The data was analyzed with SPSS 16.0 software, and descriptive statistics was used to interpret the results. In the trend analysis, three forecasting models such as linear trend model, quadratic trend model, and exponential growth model were used to find the best fitted model for area coverage, production, and productivity of white lupin. Forecasting errors namely mean absolute percentage error; mean absolute deviation and mean squared deviation were used as model selection criteria.

Results: The study areas showed significant difference ($p < 0.001$) for production and utilization practices.

About 82.5% and 66.7% of the respondents at Banja and Machekel districts respectively replied on consumption of snack as supplementary food. Farmers produce the crop with minimum or no cultural practices. About (40%) respondents intercrop white lupin with other crops. Farmers use their own seeds; lack of production packages, late maturity, disease and stepwise postharvest processing are the major constraints. The quadratic model, due to its lowest values of the forecasting errors, was best fitted to predict the future estimate of area, production, and productivity of white lupin.

Conclusion: If the current production practices remain unchanged, decreasing in total area coverage, production and productivity will continue. Therefore, for better utilization of this potential crop, the current indigenous farmers' practices need to be supported by research based technologies of production and utilization.

Keywords: *Gibto; technology; indigenous knowledge; postharvest; small-scale.*

1. INTRODUCTION

Lupin belongs to the genus *Lupinus*, Family *Leguminosae* also called *Genisteae* or *Fabaceae* and sub family *Papilionaceae* [1]. The genus *Lupinus* has rich diversity of species and has also been grouped into Mediterranean and North African 'Old world' species and American 'New world' species, covering a wide range of climate [2,3]. On *Lupinus* diversity it is noted that only four of the species which are *L. albus* (white lupin), *L. angustifolius* (blue or narrow-leafed lupin) and *L. luteus* (yellow lupin) of the "Old World" lupin species, and one "New World" species namely *L. mutabilis* (Pearl lupin or Tarwi) gained agricultural importance [4].

White lupin is traditionally grown in the Mediterranean region and along the Nile valley, where it has been grown for several thousand years ago. Although the time of introduction to Ethiopia is not clearly known, white lupin has been cultivated since so longer period of time. The crop is adapted to 1500-3000 m.a.s.l. and is being produced mainly by subsistent farmers [5]. The crop is produced in different parts of the country where as the Amhara National Region is the major producer of the crop (Fig. 6).

In Ethiopian, White lupin, is locally known as *Gibto* and it is the predominant species produced by small scale farmers. The farmers produce the

crop for its multipurpose benefits such as soil fertility maintenance, nutritional value as snack, local soup and local alcohol preparation, and for traditional therapy purposes [5,6]. White lupin seed is commonly used as supplementary food preparation in the form of snack and its flour is also used as traditional sauce as a component of meal with local bread, *Injera*. Equivalent to its food value, consumers have the perception of its hypertension treatment role on consumption of white lupin snack and drinking the alcohol prepared from its seed. White lupin seed has been used for hypertension control in traditional medicinal practices in North Western Ethiopia since longer period of time [7]. All these food values together with its role in soil fertility maintenance make white lupin as a dependable potential crop of the future.

In Ethiopian farming system, white lupin is produced as a sole crop or intercropped with other crops. When white lupin is produced as a sole crop, it is produced with minimum agronomic practices such as zero tillage, with no cultivation, and weeding practices, which are the main causes of low productivity and inconsistent production status of the crop. In this regard, Ethiopian Central statistics Agency 11 years' (2004-2014) assessment reports on crop production and area coverage indicated inconsistent condition for area coverage, total production and productivity (Tables 1 and 6).

Regardless of its diversified values, the post harvesting process is somewhat time taking and labor demanding as compared to other legumes, in addition the food and local alcohol preparation need longer processes of roasting, debittering, and washing-cleaning which are difficult and considered as the major limitations to exploit white lupin potential. Hence, generation of production packages and support of the experiences of the producers in relation to its cultural practices, post harvest processing and utilization of white lupin in Ethiopian condition is indispensable and timely. In addition, the major problems such as late physiological maturity, low yield performance, high alkaloid content are some the major limitations to maximize production.

Hence, the objective of this study was to assess the experiences of the producers in relation to its cultural practices, post harvest processing, utilization, and also to evaluate the previous trend in relation to area coverage, total production and productivity and forecast the prospects of white lupin in Ethiopian condition.

2. MATERIALS AND METHODS

2.1 Study Area

The survey was conducted on Feb 2013 at Banja and Machakel districts of Amhara National Regional State respectively. Banja district has an altitude of 2250-2700 m.a.s.l. average minimum and maximum temperature of 16°C and 26°C respectively and annual rainfall ranging from 2200 to-2400 mm (Banja District Agri. Office). Machakel district has an altitude range of 1500-3800 m.a.s.l. with average temperature 27°C and 1500-1800 mm annual rainfall (Machakel District Agri Office). The study districts were selected as the representatives of two different agro ecologies of white lupin production Zones of Amhara National Regional State.

2.2 Sampling and Data Collection

Purposive sampling methods were used to select Districts, where as the respondents were selected randomly among white lupin producers. A sample size of 80 respondents from the two districts was used in the study. Data were collected through group discussion with key informants and individual farmer interview using semi structured questionnaires. For trend

analysis, 11 years (2004-2014) cropping season of Central Statistical Agency (CSA) crop production report was used as a secondary data source.

2.3 Data Analysis

The data was analyzed using SPSS 16.0, and descriptive statistics was used to estimate the frequencies of the respondents. To assess a statistical significance of comparisons, Pearson's Chi-square and Cross tabulation were used for categorical variables whereas means comparisons were made using independent t-test for quantitative data.

3. RESULTS AND DISCUSSION

3.1 Land Preparation

For proper crop production, plowing is the basic practices of land preparation. The assessment on this practice showed that 75 respondents replayed about their experiences for white lupin production. The result indicated that 16.7%, 75%, and 8.3%, of the respondents at Machakel district used zero tillage, plough once, and three times tillage, for lupin production respectively. At Banja district, about 89.7%, 7.7%, and 2.6% of the respondents used one time, two times and three times tillage respectively. The experiences of respondents on land preparation indicated that most of them used minimum tillage. In this study, the farmers of Banja district have better land preparation experiences than Machakel district (Table 1). The result also indicated that low attention is given for land preparation for white lupin production in the two study districts where majority of the respondents practiced one plowing. Differences was observed among the two study districts in land preparation where some farmers at Machakel district used zero tillage whereas majority of the respondents at Banja district practiced one time tillage and very few used two and three times plowing which indicated better land preparation practices of the Banja district respondents. The Chi-square test result indicated significant difference ($P=0.003$) between the two study districts in land preparation practices. Lupin producers of the North western part of Ethiopia use zero-tillage or one plowing and they did not use weed management. Similarly, practices were reported at Sekela district with zero tillage and one time tillage [5].

3.2 Time of Sowing

Time of sowing for white lupin varied between and within the study districts where 35.9% and 48.7% of the respondent of Machakel districts sow the seed between June 1-15 and June 16-30 respectively, whereas only 12.5% of the respondents at Banja districts used to sow the crop between June 16-30. The other 55% and 22.5% of respondents of this district sow the crop between July 1-30 and August 1-30 respectively (Table 2). The rainy season which remains available for longer time at Banja district, helped to practice late sowing until the end of August.

3.3 Seed Rate

The seed rate practices of the respondents showed differences both within and between the study districts. The result indicated that 20.7%, and 10.3% of the respondents of Banja district used seed rate of 20-30, and 35 kg per hectare respectively with mean value 29.05 kg/ha. On the other hand, 25%, 10.7% and 17.9% respondents of Machakel district used 25, 60, and 100 kg seed per hectare respectively where majority of the respondents used more seed per hectare (60-100 kg/ha) with mean value 52.46 kg/ha. In the two study areas, significant difference ($P < 0.001$) for seed rate was observed where majority of the respondents at Machakel district used more seed per hectare. On the other hand, respondents of Banja district used relatively less

seed rate (Table 3). The seed difference could be to the difference in land preparation between the two sites. In Banja district farmers plow their land for three times which gives good germination and hence require low seed rate whereas at Machakel district, farmers use high seed rate since they use once or no plow. Seeding rate practices of the major white lupin growing areas are variable due to lack of recommended seed rate. Similarly in earlier study, variation on seed rate was reported between Sekela and Mecha districts [4].

3.4 Intercropping

In the two study districts, about 32 respondents replied their experiences of intercropping of white lupin with other crops where 37.5% and 56.2% used to sow first the main crop selected for the case followed by sowing of white lupin which is meant to minimize early stage shading effect. The assessment on practices of intercropping showed that about 81% and 19% of Banja and Machakel districts (Table 4) respectively used intercropping of lupin with small cereals (Fig. 1A). Similarly, 55% and 45% of Banja and Machakel districts of the respondent used intercropping of lupin with oil crops and other crops (Fig. 1C) there is also intercropping of white lupin with other pulse crops (Fig. 1B) where 27.5% and 5% of the respondent of Banja and Machakel respectively (Table 4) used this practice.

Table 1. Plowing frequency* study district

Plowing frequency	% study district		Total
	Banja	Machakel	
Zero tillage	0%	16.7%	8 %
One times tillage	89.7%	75%	72.7%
Two times tillage	7.7%	8.3%	8 %
Three times tillage	2.6%	0%	1.3 %
Fisher's exact test value = 7.998			
Fisher's exact p-value <.003			

Table 2. Time of sowing *study district

Time of sowing	% study district		Total
	Banja	Machakel	
June 1-15	0%	35.9%	17.7%
June 16-30	12.5%	48.7%	30.4%
July 1-15	10%	0%	5.1%
July 16-30	55%	10.3%	32.9%
August 1-30	22.5%	5.1%	13.9%
Fisher's exact test value 45.827			
Fisher's exact p-value < 0.001			

Table 3. Seed rate, length of maturity and yield *study districts

Variables	Mean values±-Wordas		Significant level p
	Banja -Mean ±SE	Machakel - Mean +SE	
Seed rate (kg) per hectar	29.05±2.99	52.46±6.3	<0.001
Seed rate (kg) per hectar (range)	20-35	25-100	
Length of maturity (months)	7.7±0.12	7.58±0.19	<0.001
Yield (q/ha)	11.06±0.50	15.79±1.56	<0.012



Fig. 1. White lupin intercropping with: Barley (A) Field pea (B) and Potato (C)

Table 4. Intercropping and study districts

Crop types for intercropping	% study district	
	Banja	Machakel
Intercropping with small cereals	81%	19%
Intercropping with oil crops	55%	45%
Intercropping with pulse crops	27.5%	5%

The farmers practices on intercropping of white lupin with tef, barley, and sometimes with Eucalyptus tree [5]; intercropping of white lupin with wheat, triticale, barley, maize and tef and finger millet were reported [7]. Provision of physical support to cereals and enhancing to increase total grain yield are the main reasons for practicing intercropping of white lupin with cereals [4]. Similar practices were also observed in the current study and majority of Banja district used mainly intercropping with cereals followed by oil crops where as the reverse is true for Machakel district for the same purpose (Table 4).

3.5 Crop Protection

With respect to weeding and pesticide application practices, about 95% of the respondents replied that they have no practices of weeding, and pesticide application as a result sever disease damage occurred in farmers' field (Fig. 2).The result indicated that lupin crop disease is one of the major problems in both districts where 43.3% and 56.7% of respondents at Banaja and Machakel districts respectively indicated their experiences on problem of

disease on white lupin. However, the importance of the damage is variable within the plant part and between the two districts where 25.8% and 74.2% at Banja and Machakel districts respectively replayed that leaf damage as the main problem. At Banja district, 66.7%, 10.5%, and 76.9% of the respondents replied on the common disease damage of stem, pod and root respectively. Similarly, 33.3%, 89.5%, and 23.1% of Machakel district responded that stem, pod, and root are attacked by disease respectively. Therefore, root and pod diseases are the primary diseases at Banja and Machakel districts, respectively.



Fig. 2. Disease infected plants at Farmers field

3.6 Physiological Maturity

The assessment result indicated that white lupin crop requires long period for physiological maturity where 61.8% and 38.2% respondents of Banja and Machakel respectively replied late

maturity is one of the major problems in white lupin production (Table 5).

At Banja district, 60.6% of respondents replied white lupin maturity requires 7-8 months where 53.5% of the respondents usually used harvesting on March. The result of Machakel district indicated that 44.8% respondents replied that maturity of white lupin needs 6-7 months (Table 5). In this study, late maturity was related to higher altitude and higher rainfall where most of the respondents at Banja district explained about late maturing nature of the crop where white lupin needs 6-8 months for physiological maturity. On other similar study, variation in maturity of Mecha and Sekla districts with 167 and 233 days respectively also reported [4]. In the present study, most of the respondents explained that as compared to other pulse crops, white lupin stays for 7-8 months on the field which created problem on double cropping practices for efficient utilization of a plot of land.

3.7 Harvesting and Threshing

White lupin harvesting is practiced by manual cutting of plants which are naturally stiff stemmed; this method is practiced on both the study districts. The cut plants are collected and piled together at the farm land where they were grown (Fig. 3A) or transported to other places (Fig. 3B). In the study areas, beating of the pods with stick is the common practice for threshing of white lupin (Fig. 3C) where, 92.5% and 100% of the respondents at Banja and Machakel districts respectively have been practiced.

Similarly, two steps of threshing practices are used where the first step is manual separation of pods from the stem and the second step is animal threshing to separate the seed from the pod [5]. In this study it is also noted that seed cleaning is practiced by blowing and winnowing of the threshed seed on the air using large flat baskets where the wind blows away light matter

like dust and leaf fragments and the heavy and relatively healthy seeds fall down on the collecting material.

Table 5. Length of physiological maturity and study districts

Length of physiological maturity	% Study district	
	Banja	Machakel
Six months	2.6%	23.7%
Seven months	21.1%	21.1%
Eight months	39.5%	31.5%

3.8 Processing Practices for Nutritional and Medicinal Values

Lupins are now receiving national and international interest as a future source of food ingredients that could be used to enhance the nutritional profile of existing food products [8]. Lupin generally contains about twice the amount of proteins found in those legumes that are commonly consumed by humans [9]. Lupin seeds and flours are used as ingredient in different cereal products such as pasta and breads. White lupin snack preparation process required three steps such as roasting (to protect germination, and for better chewing), soaking and washing (to remove the bitter test and clean the snack) which are generally tedious and time taking. The bitter test of the seed is also supported by [10] where, seeds of traditionally cultivated populations contain from 1 to 3% of quinolizidine alkaloids, mainly lupanine and spartine, giving a bitter taste to the seeds of white lupin. High protein content (about 40%), and soluble fiber (about 30%) is very useful to use lupin as food or feed [11], with the basis of such nutritional values, white lupin seed has been used to prepare supplementary food and as ingredient. In the study areas, all respondents replied that they use white lupin snack as supplementary food.

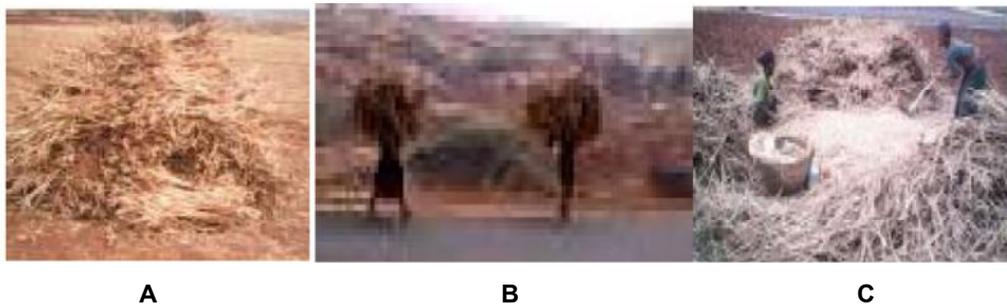


Fig. 3. Piling of White lupin (A). Transportation (B) and Manual threshing (C)

In the study areas, roasting and soaking are given different ranks based on their labor demand and length of time needed where 30.8% and 38.5% of the respondents at Banja and Machekel districts respectively responded roasting is the tedious process. The respondents also replied on the utilization of white lupin snack in their meal time where 82.5% and 66.7% of them at Banja and Machekel districts respectively replied on the consumption of snack as supplementary food the time interval laid between lunch and dinner. The experience of consumption of snack is either at home as part of meal for the family and /or in local beverage houses who used as income generation by selling (Fig. 4), and also the snack may be prepared at home or may be purchased from local market. Preparation and consumption of white lupin snack is mainly in the rainy season where 87.5% and 92.1% of Banja and Machakel districts respectively have such experience. Similarly [4] assessed the experience of high demand of white lupin snack consumption during the rainy season (June –September).



Fig. 4. The snack of white lupin seed as supplement food in beer house

In food preparation process, soaking of white lupin seed in the river is longer time demanding activity which takes 7-15 days and the length of days is variable within and between the study districts. In this regard, 35% and 67.5% of Banja and Machakel districts respectively responded their experience of debittering the seed by soaking in the river from 7-10 days whereas 27.5% and 22.5% of Banja and Machakel districts respectively have experience of soaking from 11-15 days for the same case. Similarly, [8] noted that the importance of white lupin seed to prepare food ingredients after roasting and soaking in the river for 3-7 days for debittering where as the average number of days lupin seed soaking in the river is 4.02 and 4.92 at two

different study districts [4]. In addition to snack preparation, white lupin seed is used to prepare local alcohol, *Areki* in the study areas and this is also supported by [8] and [4] in other study areas.

In addition to snack preparation, 30% and 5% of the respondents at Banja and Machakel districts respectively use white lupin seed to prepare local alcohol *Areki* and local sauce (locally known as *shiro* and *metata* made from lupin flour) respectively. White lupin consumed as snack or drunk in local alcohol, *Areki* form has been also got vast recognition for its medicinal value for hypertension treatment however, differences within and between the study areas are observed on the knowhow of its medicinal value. In this regard, 87.5% and 88.9% of the respondents at Banja and Machakel districts respectively responded about their perception of white lupin for hypertension treatment. This perception was also supported by [12] who reported the effect of white lupin on a significant reduction of total cholesterol. The practice of white lupin seed spiritual treatment for hypertension treatment is also reviewed [6]. On the other hand, 50% and 23.5% of Banja and Machakel districts have no information on its medicinal role.

3.9 Income Generation Value

Income generation is one of the diversified values of white lupin, and the local communities have been practiced on sale of the seed in the local market. In the study areas 67.5% and 50% of the respondents at Banja and Machakel districts respectively responded that they use major proportion of the product as income generation on selling in the local market (Fig. 5) similarly, in another study, it is indicated that white lupin producers have used to sell the major proportion of their production [4]. Selling and buying of seed is a common practice in the study areas where 94.7% and 94.5% of the respondents at Banja and Machakel districts respectively used selling of white lupin seed. On the other hand 69.4% and 40% at Banja and Machakel districts respectively have experiences purchasing of white lupin seed for seed source in the main cropping season. In the study areas, the price of seed is variable based on main cropping (high seed demand) and harvesting (more supply) season where 8.2% and 3.2% of Banja and Machakel districts respectively experienced selling of a kilo of white lupin snack with 6-10 Ethiopian birr.



Fig. 5. White lupin snack for retail sale at local market

3.10 Seed Conservation

The farmers in the study areas use their own saved seeds to sow for the next cropping season and 47.5% of the respondents in the two districts responded that the possibility of conserving white lupin seed without any problem for the next cropping season. In addition, white lupin seed which will be used for food preparation can be stored local storage structure for about 4-10 years without losing viability if the seed is well dried and kept on dry condition.

3.11 Use of White Lupin Stalk

In the study areas 87.5% and 97.4% at Banja and Machakel districts of the respondent respectively replied that white lupin stalk is used as energy source for cooking in the form of fire wood. This value has a great contribution for energy source problem solving since the availability of other wood materials are limited due to high demand of wood materials for construction and furniture and moreover, using lupin stubs for energy source may play reduction of deforestation practice.

3.12 Problems Related to Excess Consumption of White Lupin Snack

Consumption of excess white lupin snack causes health problem due to its alkaloid content and this condition is also expressed in the study areas where 64.8% and 62.5% of the respondent at Banja and Machakel districts respectively replied more consumption of the snack may cause headache, and 31.6% and 37.5% of the respondent at Banja and Machakel districts respectively replied more consumption cause stomachache. On the other hand, the respondents also expressed their experience on the practice of risk minimization via different

indigenous knowledge where 75% and 73.68% of the respondent at Banja and Machakel districts respectively replied that removal of the bitter test through proper soaking of the seed, through soaking in water avoidance of frequent consumption, reduction of the quantity of snack are alternative ways of risk minimization. Since the alkaloids are water soluble, the harmful effect on more intake of lupin can be easily managed through proper soaking of roasted seeds which help to remove the alkaloid at tolerable level and can be confirmed by testing the snack.

3.13 Feed Value of White Lupin Seed and Byproducts

There is a practice of using lupin seed for Animal feed in different part of the world, in the study areas also, there is experience of using white lupin seeds as animal feed where 14.3% and 29.6% of the respondents at Banja and Machakel districts respectively responded their experiences of feeding their animals with white lupin seed. In areas where white lupin is used as feed, the preference of animals is variable among and between the study areas where 58.3% of the respondent at Banja replied sheep preferred to feed white lupin seed as compared with other animals whereas 83.5% of respondents at Machakel district respond that goats prefer to feed lupin seed. However, the respondent explained that there is a harmful effect of white lupin seed when both groups of animals consume more quantity of white lupin seed. In this regard 92.9% and 31.2% at Banja and Machakel districts of the respondents respectively replied that animals which usually fed more quantity of the seed practiced health problem. The effect of decreasing of feed intake and growth rate when Pigs and Rats fed lupin seed was also noted [15]. Therefore, based on the experience obtained in the present survey, white lupin seed can be used as feed for different groups of animals and the quantity of feed need to be determined based on research findings.

3.14 Trend Analysis and Forecasting of White Lupin Production in Ethiopia

White lupin has been under production in different Administrative regions of Ethiopia [14]. However, the Central Statistics Agency (CSA) reports indicated that the Amhara national region is the major producer and contributor for the national total production (Fig. 6). The CSA crop production reports of 11 years [16-22,24] data indicated that there is inconsistent trend in area

coverage (ha), total production (q) and productivity (q/ha), (Fig. 7). Increased percent change for area coverage, total production, and productivity were observed for some cropping seasons [21]; on the other hand, decreased percent changes were observed for the other cropping seasons [22]. There is also a continuous decreasing trend for three consecutive cropping seasons in area coverage, total production and productivity (Table 6). Based on 11 years' data, it is possible to forecast the future trend hence a basic assumption of time series analysis/modeling is that some aspects of the past pattern will continue in the future.

For subjective evaluation of the trend, three forecasting models such as linear trend model, quadratic trend model, and exponential growth model were used to find the best fitted model for area coverage, production, and productivity of white lupin in Ethiopia (Tables 7-9). Forecasting errors namely mean absolute percentage error (MAPE), mean absolute deviation (MAD), and mean squared deviation (MSD) (Tables 7-9) were used as model selection criteria [23]. Mean absolute percentage error measures the accuracy of fitted time series values and it expresses accuracy as a percentage. The mean absolute deviation measures the accuracy of fitted time series values and it expresses accuracy in the same units as the data, which helps conceptualize the amount of error. Mean

squared deviation is always computed using the same denominator, regardless of the model. It is a more sensitive measure of unusually large forecast error than mean absolute deviation. Smaller values of all these measures indicate it is a good fitted model with minimum forecasting error, a better model yields smaller forecasting error [15]. The quadratic model, due to its lowest values of the forecasting errors, was best fitted to predict the future estimate of area, production, and productivity of white lupin in Ethiopia. [24-26] also used quadratic model for trend analysis. The quadratic model is best fitted when the annual growth rate is significantly different from time to time.

Total area coverage (ha) showed inconsistent trends and the forecasting trend of the next five years indicated that decreasing condition in area coverage (Fig. 8). This trend indicated that priority have been given to other food crops and hence other crops may substitute white lupin.

The total production record of 11 years data indicated inconsistent trend of increasing and decreasing in total yield. Relatively increased production was observed in 2007, 2010, and 2012 cropping seasons respectively (Fig. 9). On the other hand, in 2008, 2011 and 2014 cropping seasons abrupt decrease in production was observed similar trend was also observed in productivity (q/ha) (Fig. 10).

Table 6. Percent change in white lupin 2004-2014

Year	Area	Production	Yield
2002/3-2004/5	107.06	-19.07	-60.87
2004/5-2005/6	-30.65	-10.6	28.88
2005/6-2006/7	33.86	185.42	113.25
2006/7-2007/8	83.17	133	27
2007/8-2008/9	3.42	-42	-44
2008/9-2009/10	-22.46	4.15	34.29
2009/10-2010/11	22.3	142	97.97
2010/11-2011/12	-42.94	-52.93	-4.61
2011/12-2012/13	139.63	126.2	-5.61
2012/13-2013/14	-3.1	-16.88	-14.2
2013/14-2014/15	-32.6	-37.51	-7.28

Table 7. Accuracy measures to select the best fitted model for area coverage of white lupin

Models	Criteria		
	MAPE	MAD	MSD
Linear trend model	26.2177	5.0929	34.4081
Quadratic trend model	26.1451	4.9806	32.5468
Exponential growth model	25.6414	5.2175	36.7053

MAPE =Mean absolute percentage error; MAD=mean absolute deviation, and MSD=mean squared deviation

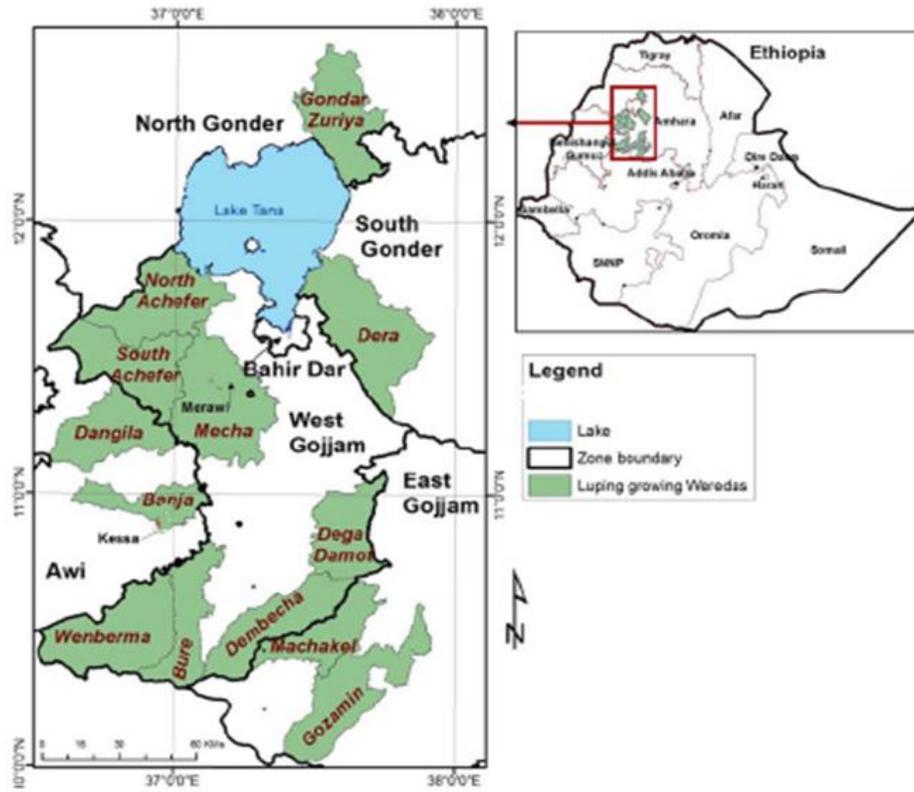


Fig. 6. Major growing areas (brown colored) of white lupin in Ethiopia

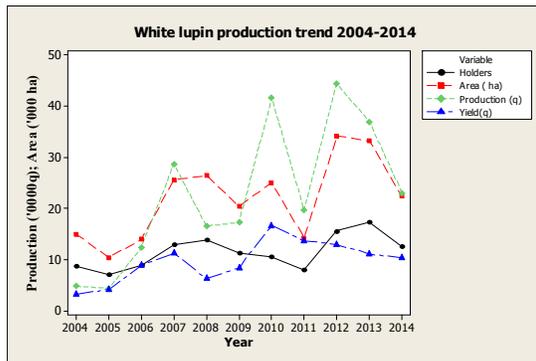


Fig. 7. Production trend of White lupin in Ethiopia in 2004-2014 cropping season

This fluctuating nature of production may be the consequences of traditional way of production practices adopted by the farmers which is due to unavailability of improved production packages. The actual data and the forecasted trend are the key evidences of the need of intervention of technologies in white lupin production system. The trend analysis indicates that if the current production practices remain unchanged, decreasing in total area coverage, production

and productivity will continue (Table 10) unless the correction measure is taken. Therefore, to maintain this potential crop in the farming system and exploit its contribution for sustainable crop production in the future, to increase its production and productivity to enable the farmers use more efficiently their plot of land and avail nutritious food source options, attention should be given to the generation of production packages for this potential crop.

Table 8. Accuracy measures to select the best fitted model for total production (q) of white lupin

Models	Criteria		
	MAPE	MAD	MSD
Liear trend model	45.7573	7.8536	86.5826
Quadratic trend model	43.2082	7.6876	71.4980
Exponential growth model	48.328	8.1870	128.279

MAPE = Mean absolute percentage error; MAD = mean absolute deviation, and MSD = mean squared deviation

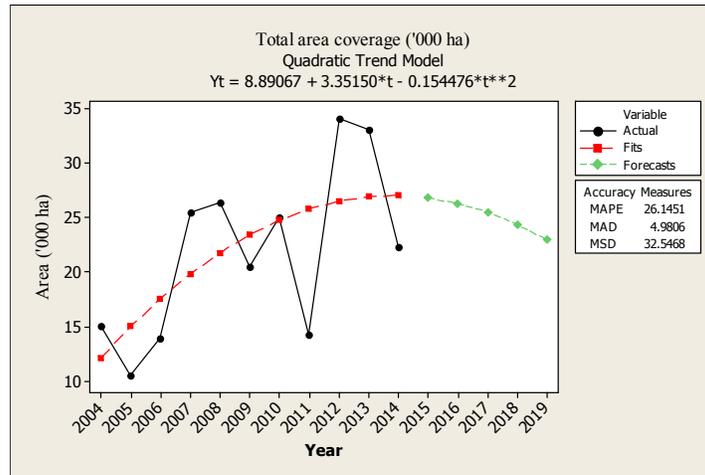


Fig. 8. Quadratic trend model for area coverage (000 ha) of White lupin in Ethiopia in 2004-2014

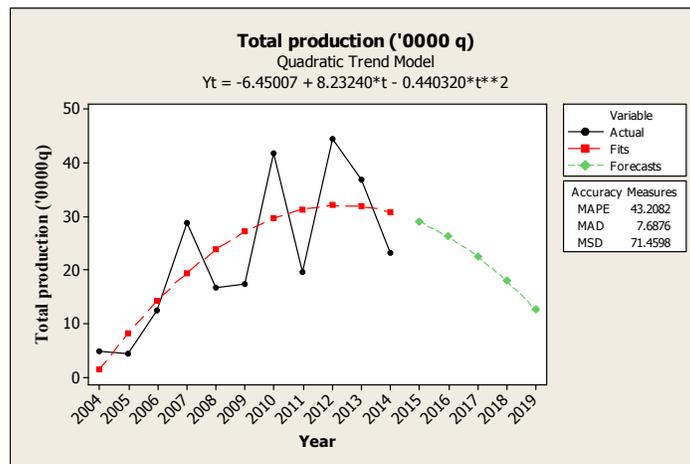


Fig. 9. Quadratic trend model for total production (0000 q) of white lupin in Ethiopia in 2004-2014

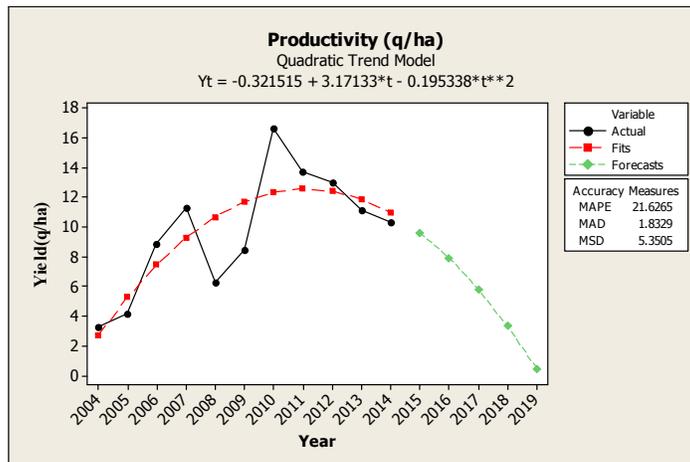


Fig. 10. Quadratic trend model for total productivity (q/ha) of White lupin in Ethiopia in 2004-2014

Table 9. Accuracy measures to select the best fitted model for productivity (q/ha) of white lupin

Models	Criteria		
	MAPE	MAD	MSD
Liear trend model	31.1775	2.5469	8.3267
Quadratic trend model	21.6265	1.8329	5.3505
Exponential growth model	29.6416	2.7198	10.8512

MAPE =Mean absolute percentage error;
MAD=mean absolute deviation, and MSD=mean squared deviation

Table 10. Five years forecast of area, total production and productivity of white lupin in Ethiopia

Year	Area (000 ha)	Production (0000 q)	Yield (q)
20015	26.8641	28.9327	9.60576
2016	26.3537	26.1571	7.89364
2017	25.5344	22.5009	5.89364
2018	24.4061	17.9640	3.28737
2019	22.9688	12.5465	0.41322

4. CONCLUSION

White lupin (*Lupinus albus* L.) is member of the genus *Lupinus* in legume crops. In Ethiopia, it is locally known as *Gibto* and is adapted to 1500-3000 m.a.s.l. It is being produced mainly by subsistent farmers. The crop has multipurpose benefits such as, nutritional value as food and feed, therapeutic values and soil fertility maintenance which make the crop as strategic potential crop. However, unavailability of improved production packages caused low productivity of the crop which deterred the efficient utilization of this potential crop. In addition, food and alcohol preparation of white lupin requires series processes such as roasting, debittering, and washing which are cumbersome. The survey data analysis result indicated that the farmers have been producing the crop with minimum or no cultural practices such as zero to two times tillage, time of planting, spacing, seed rate related packages have not been available; no weeding, pesticide application and disease control. The farmers have been producing using their own traditional production system.

Hence, lack of production packages, late maturity, disease stepwise postharvest processing are the major constraints in

production and utilization. Nevertheless, farmers have been producing white lupin since longer period of time using their own seed and indigenous knowledge. Regardless of its potential use and longer history of the crop in Ethiopian farming system, the area coverage allotted to the crop and the number of producers engaged in white lupin production, little attention has been given from the scientific community and white lupin has been neglected far behind other legume crop which contributed for its low area coverage, production productivity as compared with other pulse crops. Therefore, the research system should work on white lupin to generate improved production and utilization technologies.

Previous research works to improve white lupin production is deficient and caused the declining trend in terms of production productivity and area. Hence, to assess the current production status of white lupin in Ethiopia, trend analysis on areas coverage, production and productivity was determined using 11 years data of Central Statistics Agency. For subjective evaluation of the trend analysis, three forecasting models such as linear trend model, quadratic trend model, and exponential growth model were used to find the best fitted model for area coverage, production, and productivity of white lupin. Forecasting errors namely mean absolute percentage error (MAPE), mean absolute deviation (MAD), and mean squared deviation (MSD) were used as model selection criteria. The quadratic model, due to its lowest values of the forecasting errors, was best fitted to predict the future estimate of area, production, and productivity of white lupin in Ethiopia.

The trend analysis indicated that if the current production practices remain unchanged, decreasing in total area coverage, production and productivity will continue. Therefore, the indigenous knowledge based farmers' practices need to be supported by technologies and the agricultural research system should give due attention to provide improved production and utilization packages so as to maintain this potential strategic crop in the farming system and help to boost its contribution for sustainable crop production system.

Generally, the current study identified the major production problems such as lack of production practices packages, late maturity, disease occurrence, stepwise postharvest processing as the challenges in production and utilization of

white lupin. Different indigenous knowledge for lupin production and utilization including therapeutic values were noted which can be exchanged among the producers. The major production problems mentioned in this research can be used as research ideas for researchers for further problem solving on production and utilization of white lupin.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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