New sweet blue lupin, *Lupinus angustifolius* L. varieties (Sanabor and Vitabor) for Ethiopia

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ABSTRACT

Though bitter white lupin is an ancient pulse crop to Ethiopia, sweet lupins are new to the country. Sanabor and Vitabor are recently introduced sweet blue lupin varieties to be used as multipurpose crop in the traditional lupin growing agro-ecologies of Ethiopia. These varieties were introduced from Germany and evaluated along with fourteen other varieties which have been tested in different locations of the country from 2009 to 2013. The varieties are registered at national level in 2014. The merits of the varieties are their low alkaloid content, high seed yield, resistance to anthracnose and fusarium, most importantly are palatable for livestock and can be used for human food. Thus, the varieties are recommended as multipurpose pulse crop for the traditional and new lupin growing areas.

Keywords:- Alkaloids; Blue Lupin; Sanabor; Sweet Lupin; Vitabor
DOI: https://dx.doi.org/10.4314/ejst.v15i1.5

INTRODUCTION

Wild lupines are believed to be originated and are concentrated in two large areas: The old world or the Mediterranean region and the new world or the Americas. Because of the diverse species, the genus Lupinus is found widely distributed in different parts of the world in several agro climatic conditions, from the sub-arctic climate, through the Mediterranean and semi-desert climates, to the highlands of East Africa, Mexico, and finally the sub-tropical lowlands of eastern South America and south-eastern USA. Among the four large seeded annual lupin species, three of the species, i.e., white lupin, blue lupin and yellow lupin, have originated in the Mediterranean basin (Kurlovich, 2002). White Lupin is one of the common pulse crops grown in Ethiopia (Likawent Yeheyis *et al.*, 2010). It is an

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ancient traditional multipurpose crop being cultivated particularly in North-western Ethiopia. In Ethiopia, white lupin is believed to have originated and introduced into Ethiopia from Egypt. It is also believed that the Amharic local name of lupin in Ethiopia, *Gibto*, has been derived from the Amharic name of Egypt, *Gibtsi*. It is produced by small holder farmers in two regional states of Ethiopia, Amhara and Benishangul Gumuz, the former being the largest producer. In this region of the country, the total crop land covered by lupin ranges between 7, 000 to 19,900 ha per year (ECSA, 2017). The crop is known as a very easy crop to grow with a relatively high yield and minimal agronomic practices. It grows from the warm mid-altitude areas of South Gondar up to the cool and humid high-altitude areas of West Gojam. The major soil types in these areas are Nitosols and Acrisols. The ability of the crop to be grown in acidic soils is one of the major important features of the crop in the traditional lupin growing areas of Ethiopia (Likawent Yeheyis *et al.*, 2010). However, this traditional pulse crop has low food value and is unpalatable to livestock due to its high alkaloid content (Likawent Yeheyis *et al.*, 2011a). Though there are sweet lupin species with very low alkaloid content (around 200 mg/kg dry matter) which are suitable for both human food and livestock feed, they were not introduced to Ethiopia.

Therefore, to answer this question, a series of experiments were conducted around West Gojam and Awi Administrative Zones. The experiments were adaptation trials using 14 sweet lupin varieties (Likawent Yeheyis *et al.*, 2012b), an extensive laboratory evaluation of these varieties (Likawent Yeheyis *et al.*, 2012a) and a feeding trial on sheep using lupin seed as protein source (Likawent Yeheyis *et al.*, 2012c). The results of the experiments showed that about four sweet blue lupin varieties (Sanabor, Vitabor, Bora and Probor) were found to be adaptive and promising to be used as livestock feed and other purposes in the study area and other similar agro-ecologies. But for wider dissemination and utilization of these varieties by farmers the varieties have to be officially registered by Ministry of Agriculture (MOA). Hence, a verification trial was conducted to verify the results obtained in the previous experiments and were officially registered as promising varieties by the MOA. After the verification trial, two multipurpose sweet blue lupin (*Lupinus angustifolius* L.) varieties namely Sanabor and Vitabor, were released for the traditional lupin growing areas of Ethiopia in 2014 (Table 1). These varieties currently are being introduced to the three districts of West Gojam area (South Achefer, Bure and Jabitehnan) as feed and food pulse crop. In south Achefer district, the varieties are being utilized by local farmers for the preparation of a traditional stew known as *Shiro* and *Kikwot*.

Table 1. Description of the released blue sweet lupin varieties, Sanabor and Vitabor.

Agronomic and morphological characteristics	**Varieties**	
	Sanabor	**Vitabor**
Adaptation area	Traditional lupin growing areas of West Gojam, Awi and South Gondar Zones	Traditional lupin growing areas of West Gojam, Awi and South Gondar Zones
Altitude (m.a.s.l.)	1935-2610	1935-2610
Rainfall (mm)	1189-2348	1189-2348
Seed rate when broadcasted (Kg/ha)	80 for broadcasting	80 for broadcasting
Spacing for row planting	30 cm between rows and 6-7 cm between plants	30 cm between rows and 6-7 cm between plants
Planting date	First week of July	First week of July
Fertilizer rate (Kg/ha)	100 DAP and 50 Urea at planting. It is also possible to plant it without fertilizer	100 DAP and 50 Urea at planting. It is also possible to plant it without fertilizer
Days to flowering	60 (days to 50% flowering)	66 (days to 50% flowering)
Days to maturity	140	141
Plant height (cm)	90	78
Growth habit	Indeterminate	Indeterminate
Flower color	A mix of white and blue, white is dominant	A mix of blue and white, blue is dominant
Thousand seed weight (g)	160	138
Seed color	Grey (Cream)	Grey (Cream)
Crop pest reaction	Tolerant to fusarium and anthracnose	Tolerant to fusarium and anthracnose
Crude protein content (%)	35	32
Seed Alkaloid content (%)	0.018-0.052	0.023-0.050
Forage Alkaloid content (%)	0.042-0.082	0.011-0.046
Grain yield (qt/ha) on researcher field	37	38
Grain yield (qt/ha) on farmer field	31	28
Year of release	2014	2014
Breeder seed maintainer	ARARI and Andassa	ARARI and Andassa

MATERIALS AND METHODS

Origin of seeds and evaluation method of the varieties

The varieties were developed using an adaptation trial in four locations (Merawi (11.27°N 37.56°E), Finote Selam (10.84°N 37.36°E), Kossober-1 and 2 (10.85°N 36.80°E) in north-western Ethiopia). A total of sixteen annual lupin varieties of three species were used, fifteen of them were introduced from Germany and USA in 2009. The varieties used were white lupin varieties (Local Landrace, Fortuna, Feodora, L-1082, L-1057, AU-Alpha, AU-Homer), blue lupin varieties (Bora, Boregine, Borlu, Boruta, Haags Blaue, Probor, Sanabor, Vitabor) and yellow lupin cultivar (Bornal). Except the white Local Landrace and AU-Homer, the remaining 14 varieties were sweet varieties. The white Local Landrace was included as a local check and the seed was purchased from local markets of the respective testing sites. Fortuna and Feodora seeds were obtained from Südwestdeutsche Saatzucht, Germany. The seed source for L-1082, L-1057, AU-Alpha, AU-Homer was Auburn University, Alabama, USA. For all blue lupin varieties and yellow Bornal the seed source was Saatzucht Steinach GmbH, Germany. For forage and seed sampling, each plot was divided in half crosswise to give an effective plot size of 1.2 × 2 m. One half of each plot was used for forage sampling and the other half for seed sampling. Forage samples were taken when plants were at around 50% flowering and seed samples at maturity. In both cases, sampling was conducted from the middle two rows excluding the border rows. Immediately after sampling, the fresh biomass was weighed to estimate green biomass yield. Forage samples were dried in a forced air oven at 65ºC to constant weight for DM determination. Seed samples were air dried to constant weight.

Alkaloid and amino acid analysis

The alkaloid content of the samples was determined by capillary GLC and GLC-MS according to the procedures described by Wink *et al.* (1995) (Table 2). First the ground samples were homogenized in 0.5 N HCl solution. This homogenate solution was adjusted to pH 12 with 6 N aqueous NaOH solution.

Then from this solution, the alkaloids were extracted by a solid phase extraction method and analyzed by Gas Chromatography-Mass Spectrometry (GLC-MS). The alkaloid analysis was done at the University of Heidelberg, Germany. Analysis of the amino acid profiles (Table 2) was done according to the procedures described by Naumann and Bassler (1997).

Table 2. Forage and seed alkaloid contents (mg/kg DM) from laboratory evaluation of selected white, blue, and yellow annual lupin accessions at four locations in Ethiopia (2009/10).

Species, Cultivar	**Mid-altitude**		**High-altitude**	
	Merawi	**Finote Selam**	**Kosober 1**	**Kosober 2**
Seeds				
White, Local	16752			11426
Blue, Bora	2261			983
Blue, Boregine	1365	375		622
Blue, Borlu	2292	750		703
Blue, Boruta		653	272	357
Blue, Haags Blaue	651		303	158
Blue, Probor		946	365	430
Blue, Sanabor	524			178
Blue, Vitabor	452	495	231	
Blue, Bornal			1642	
White, L-1082	769	656		481
Forages				
White, Local		10231		6153
Blue, Borlu	267			607
Blue, Sanabor	421			816
Blue, Vitabor	112		459	
Blue, Bornal	1306		542	
White, L-1082		328		542

The analyzer used was Biochrom 20 amino acid analyzer. During the analysis, hydrolysis was done by diluted HCl solution and the quantity of the amino acids in the hydrolysate was determined by ion exchange chromatography using amino acid analyzer (high pressure liquid chromatography). Analysis of the amino acid profiles was done at Technical University of Munich, Germany. The values of all chemical composition parameters are expressed in DM basis. During the field evaluation the alkaloid and amino acid profiles were not analysed for all varieties because of cost implications (Tables 2 and 3).

Table 3. Amino acid profile (g/kg DM) of the original (imported) Blue Sanabor seed, and the Ethiopian grown white local and Blue Sanabor (2009/10).

Amino Acid	Mid altitude		High altitude		Original Seed Blue Sanabor
	White local	Blue Sanabor	White local	Blue Sanabor	
Cysteine	5.32	4.84	4.61	4.88	5.14
Asparagine	34.72	32.69	35.33	31.76	33.25
Methionine	2.03	1.95	1.94	1.84	1.91
Threonine	12.41	11.35	12.46	10.76	11.43
Serine	17.78	16.40	18.21	15.90	16.63
Glutamine	66.05	63.08	67.31	63.25	65.74
Glycine	13.71	13.61	13.77	13.33	14.11
Alanine	11.00	11.25	11.51	10.71	11.87
Valine	13.61	12.62	13.82	12.34	13.02
Isoleucine	15.27	14.09	15.86	13.54	14.38
Leucine	24.55	22.71	24.70	22.15	23.30
Tyrosine	15.69	12.67	17.69	11.81	12.63
Phenylalanine	13.24	12.83	13.82	12.49	13.24
Histidine	8.18	9.20	8.22	9.24	9.63
Lysine	16.16	15.82	16.43	15.59	16.68
Arginine	33.37	34.37	35.33	35.64	29.87
Proline	14.65	13.25	14.97	13.12	13.78

RESULTS AND DISCUSSION

Forage yield

Most white lupin varieties (including the Local Landrace) and yellow cultivar tested had relatively better foliage than the blue varieties. As a result of this the forage yield (Table 4) from most white lupin varieties at the mid-altitude locations and yellow lupin at all locations was relatively good. The lower forage yield from most white lupins at the high-altitude locations could be due to Fusarium wilt and the extended lower temperature during germination and seedling stage as opposed to the lower vernalization requirement of most sweet white lupins. The forage yield of white sweet lupins in this study was comparable with the yield reported by Muyekho (1999) who reported a mean forage yield of 2.5 t/ha from sweet white lupin cultivar (Ultra) when harvested at three months of age. In addition, the forage yield reported by Bhardwaj *et al.* (2010) on white lupins in USA ranged between 0.8 and 2 t/ha which was inline with the observed forage yield performance of most lupin varieties in this study. However, the forage yield observed in this study was lower than the yield reports by Mihailovic *et al.* (2008) (8.7 t/ha) from white lupin accessions in Serbia and by Fraser *et al.* (2005) (8.45

t/ha) from blue lupin in the UK. This variation in forage yield performance could be due to differences in growing environment and lupin varieties evaluated. Since it is not palatable, the highest biomass yield performance of the Local Landrace at the mid-altitude area shows the potential of the crop as green manure in the mixed crop livestock farming system of the study area. In an experiment conducted to evaluate yellow lupin as a green manure crop preceding winter rye grass in Russia, Takunov and Yagovenko (1999) found that green manuring of yellow lupin increased rye grain yield by 77 and 25% over the fallow plot and NPK applied plot, respectively.

Table 4. Least square means and contrast estimates for forage yield (t/ha) from an adaptation trial of seven white, eight blue, and one yellow annual lupin accessions at four locations (Merawi, Finoteselam, Kossober-1 and Kossober-2) in Ethiopia (2009/10).

	High Altitude					
	Kossober-1			**Kossober-2**		
	Mean	**SE**	**Rank**	**Mean**	**SE**	**Rank**
White, Local	0.2	0.34	14	0.9	0.31	12
Blue, Bora	1.7	0.28	4	1.6	0.16	7
Blue, Boregine	2.5	0.28	2	2.1	0.16	4
Blue, Borlu	1.5	0.28	5	1.6	0.16	6
Blue, Boruta	1.5	0.28	6	1.2	0.16	8
Blue, Haags Blaue	1	0.28	10	1.1	0.16	10
Blue, Probor	1.2	0.28	9	1.1	0.16	11
Blue, Sanabor	1.4	0.28	7	1.7	0.16	5
Blue, Vitabor	1.7	0.28	3	1.2	0.16	9
Yellow, Bornal	2.9	0.28	1	2.3	0.53	3
White, Feodora	0	0.59	16	0.3	0.31	16
White, Fortuna	0.4	0.34	13	0.6	0.31	15
White, L-1082	0.2	0.34	15	0.8	0.31	13
White, L-1057	0.4	0.34	12	0.7	0.38	14
White, AU-Alpha	0.8	0.34	11	2.6	0.31	2
White, AU-Homer	1.3	0.34	8	4.4	0.31	1
Contrast	**MDiff**	**SE**	**AdjP**	**MDiff**	**SE**	**AdjP**
Local vs White	-0.3	0.37	0.9657	-0.7	0.33	0.3751
Local vs Blue	-1.3	0.35	0.0554	-0.5	0.31	0.5121
Local vs Yellow	-2.7	0.44	0.0136	-1.4	0.61	0.2615
White vs Blue	-1.1	0.19	0.016	0.1	0.14	0.8888
White vs Yellow	-2.4	0.32	0.0079	-0.8	0.55	0.6808
Blue vs Yellow	-1.3	0.29	0.0316	-0.9	0.53	0.5208
AU-det vs AU-indt	-0.7	0.68	0.2979	-2.8	0.65	0.0132
AU-indt vs Other-indt	0.8	0.83	0.3755	3.0	0.62	0.0093

	Mid Altitude					
	Merawi			Finote Selam		
Species, Cultivar	**Mean**	**SE**	**Rank**	**Mean**	**SE**	**Rank**
White, Local	3.6	0.38	1	5.8	0.78	1
Blue, Bora	0.5	0.13	16	0.8	0.1	11
Blue, Boregine	1.3	0.13	11	0.8	0.1	12
Blue, Borlu	1.6	0.13	6	0.7	0.1	13
Blue, Boruta	1.2	0.13	13	0.9	0.1	7
Blue, Haags Blaue	1.2	0.13	12	0.4	0.1	15
Blue, Probor	0.9	0.13	14	0.4	0.1	16
Blue, Sanabor	1.4	0.13	8	0.6	0.1	14
Blue, Vitabor	1.4	0.13	9	0.8	0.1	10
Yellow, Bornal	1.9	0.42	4	1.4	0.35	5
White, Feodora	0.9	0.38	15	0.8	0.78	9
White, Fortuna	1.3	0.38	10	0.9	0.78	8
White, L-1082	2.3	0.38	2	4.5	0.78	2
White, L-1057	1.7	0.38	5	1.3	0.78	6
White, AU-Alpha	2	0.38	3	3	0.78	4
White, AU-Homer	1.5	0.38	7	3.4	0.78	3
Contrast	**MDiff**	**SE**	**AdjP**	**MDiff**	**SE**	**AdjP**
Local vs White	2	0.41	0.0348	3.5	0.84	0.0513
Local vs Blue	2.4	0.38	0.0189	5.1	0.78	0.0214
Local vs Yellow	1.7	0.57	0.1205	4.5	0.86	0.0322
White vs Blue	0.4	0.16	0.1988	1.6	0.32	0.0328
White vs Yellow	-0.3	0.45	0.9773	0.9	0.48	0.3635
Blue vs Yellow	-0.7	0.43	0.5337	-0.7	0.36	0.375
AU-det vs AU-indt	0.3	0.76	0.9494	-0.3	1.56	0.9972
AU-indt vs Other-indt	0.6	0.76	0.5412	2.3	1.56	0.1285

AU-det,AU-determinate; AU-indt, AU-indeterminate; Other-indt,Other-indeterminates; MDiff, LSmean difference; SE, Standard error.

Seed yield

The seed yield result from sweet white lupins at all locations in this study was lower than the other varieties evaluated together and the yield report from other studies. According to Natera *et al.* (1999) in their adaptation trial on white lupin as an alternative plant protein source in Mexico found a seed yield of 2.8 t/ha. In addition, Heidel (2005) reported that the seed yield productivity of white lupin in Germany was 3.5 t/ha. According to Mey (1999), sweet white lupin is adapted to cooler areas and cooler periods of the year. The high-altitude areas in Ethiopia are cooler than the mid-altitude areas. However, sweet white lupins didn't perform well (hit by anthracnose and root rot) at the high-altitude locations which could be associated with other factors like relatively higher rainfall during the whole growing season favored the disease incidence. According to Hill (2011), lupins are negatively affected by higher rainfall during the growing season if the amount of moisture is greater than the moisture deficit of the soil. In this study the average total annual rainfall from a ten-year data (2000-2009) at the high-altitude locations was 2348 mm. In addition to this, Fusarium wilt could be the other factor for lower seed yield performance of sweet white lupins. Except at Finote Selam, the seed yield performance of yellow lupins was similar to the results by Heidel (2005) who reported a seed yield of 1.2 t/ha from yellow lupin. The relatively good seed yield performance of blue lupins at all locations compared to the other species with in location shows the wider adaptability of blue lupins in different growing environments. According to Spencer (2002), compared to white and yellow lupins, blue lupin could grow in different types of soils. In this study the seed yield obtained from most of the varieties evaluated at the mid altitude area was relatively lower than the high-altitude area. This shows that the productivity of lupin was relatively higher in the cool highland areas than in the mid-altitude areas of Ethiopia. According to a survey work done by the proponents of this study (Likawent Yeheyis *et al.*, 2010) under traditional management system the average grain yield of local white lupin was 0.9 and 1.5 t/ha in the mid and high-altitude areas of Ethiopia, respectively.

Table 5. Least square means and contrast estimates for seed yield (t/ha) from an adaptation trial of seven white, eight blue, and one yellow annual lupin accessions at four locations (Merawi, Finoteselam, Kossober-1 and Kossober-2) in Ethiopia (2009/10).

	Mid Altitude					
	Merawi			**Finote Selam**		
Species, Cultivar	**Mean**	**SE**	**Rank**	**Mean**	**SE**	**Rank**
White, Local	2.5	0.09	6	3.9	0.2	1
Blue, Bora	2.8	0.2	4	2	0.38	7
Blue, Boregine	3.3	0.2	2	2	0.38	6
Blue, Borlu	3.3	0.2	1	2.6	0.38	2
Blue, Boruta	1.8	0.2	10	2.4	0.38	3
Blue, Haags Blaue	2.1	0.2	7	1.1	0.38	9
Blue, Probor	2	0.2	8	1.3	0.38	8
Blue, Sanabor	3.2	0.2	3	2.2	0.38	4
Blue, Vitabor	2.7	0.2	5	2.1	0.38	5
Yellow, Bornal	2	0.12	9	0.4	0.11	10
White, Feodora	0	0.09	12	0.3	0.2	12

White, Fortuna	0	0.09	13	0.1	0.2	13
White, L-1082	0.7	0.09	11	0.4	0.2	11
White, L-1057	0	0.09	15	0	0.2	15
White, AU-Alpha	0	0.09	14	0	0.2	16
White, AU-Homer	0	0.09	16	0.1	0.2	14

Contrast	**MDiff**	**SE**	**AdjP**	**MDiff**	**SE**	**AdjP**
Local vs White	2.4	0.09	0.0008	3.8	0.22	0
Local vs Blue	-0.2	0.11	0.4811	2	0.24	0.0008
Local vs Yellow	0.5	0.14	0.0711	3.5	0.22	0
White vs Blue	-2.5	0.08	0.0005	-1.8	0.16	0.0004
White vs Yellow	-1.8	0.12	0.0028	-0.3	0.13	0.2528
Blue vs Yellow	0.7	0.13	0.0291	1.5	0.17	0.0006
AU-det vs AU-indt	0.4	0.16	0.0492	0.2	0.4	0.9335
AU-indt vs Other-indt	0	0.16	1	-0.2	0.4	0.9084

	High Altitude					
Species, Cultivar	**Kossober-1**			**Kossober-2**		
	Mean	**SE**	**Rank**	**Mean**	**SE**	**Rank**
White, Local	0.9	0.25	10	3.1	0.33	8
Blue, Bora	4.2	0.37	4	4.4	0.61	4
Blue, Boregine	3.8	0.37	6	4.1	0.61	5
Blue, Borlu	1.6	0.37	9	4	0.61	6
Blue, Boruta	3.9	0.37	5	3.2	0.61	7
Blue, Haags Blaue	2.2	0.37	7	2.1	0.61	9
Blue, Probor	4.7	0.37	3	4.9	0.61	2
Blue, Sanabor	4.8	0.37	2	4.7	0.61	3
Blue, Vitabor	5.4	0.37	1	5	0.61	1
Yellow, Bornal	1.8	0.39	8	1.9	0.39	10
White, Feodora	0	0.44	13	0.2	0.33	16
White, Fortuna	0	0.25	15	0.7	0.33	14
White, L-1082	0	0.25	14	0.8	0.33	13
White, L-1057	0	0.25	16	0.6	0.41	15
White, AU-Alpha	0.3	0.25	12	1.1	0.33	12
White, AU-Homer	0.4	0.25	11	1.5	0.33	11

Contrast	MDiff	SE	AdjP	MDiff	SE	AdjP
Local vs White	0.8	0.28	0.1254	2.3	0.36	0.015
Local vs Blue	-2.9	0.28	0.0044	-0.9	0.39	0.2424
Local vs Yellow	-0.9	0.47	0.4222	1.2	0.51	0.2755
White vs Blue	-3.7	0.18	0.0009	-3.2	0.26	0.0031
White vs Yellow	-1.7	0.41	0.0476	-1.1	0.42	0.1681
Blue vs Yellow	2.0	0.41	0.03	2.1	0.45	0.035
AU-det vs AU-indt	-0.3	0.5	0.6724	-0.6	0.7	0.5454
AU-indt vs Other-indt	0.3	0.61	0.8226	0.8	0.66	0.1966

AU-det, AU-determinate; AU-indt, AU-indeterminate; Other-indt, Other-indeterminates; MDiff, LSmean difference; SE, Standard Error.

Alkaloid and amino acid profiles of lupin forage and seed

Just as important as crude protein content in lupin seed is the alkaloid content because it limits the use of the crop as livestock feed and/or human food. The alkaloid content presented in this study might not be conclusive due to lack of replications. Nevertheless, the results show the difference in alkaloid content between bitter and sweet varieties and the variations within sweet varieties. The seed alkaloid content for the Local Landrace in this study was in agreement with the report by the proponents of this study (Likawent Yeheyis *et al*., 2011a) who reported an alkaloid content of 11,700 and 14,300 mg/kg DM from the Local Landrace seeds sampled from mid and high-altitude lupin growing areas, respectively. The seed alkaloid contents of most sweet entries in this study were in agreement with other studies outside Ethiopia (Bruno-Soares *et al*., 1999; Gdala *et al*., 1999). However, the maximum alkaloid content from sweet lupins in this study (2292 mg/kg DM) was much higher than the maximum alkaloid content (720 mg/kg DM) reported by the same authors. The overall mean seed alkaloid content (2067 mg/kg DM) was higher at the mid-altitude than the high-altitude (1297 mg/kg DM). A similar result was obtained with bitter lupins from the Rocky Mountain lupin (*L. argenteus* Pursh) in which alkaloid contents were negatively correlated with altitude (Carey and Wink, 1994). In addition, it could be associated with differences in the amount of rainfall in the two altitude areas. According to Christiansen *et al*. (1997), moisture stress during the vegetative phase increases seed alkaloid content in lupin. In general, the two sweet blue entries (Sanabor and Vitabor) had the lowest seed alkaloid content.

The amount of the individual amino acids in both species in this study was in line with other similar studies (Campos-Andrada *et al*., 1999; Gilbert and Acamovic, 1999). In addition, the amount of the essential amino acids profile in this study fulfils the requirements of the ideal protein. According to Cole and Van Lunen (1994), the appropriate balance of essential amino acids in the ideal protein would be: lysine, 100; methionine + cysteine, 50; threonine, 65-67; tryptophan, 18; isoleucine, 50; leucine, 100; histidine, 33; phenylalanine + tyrosine, 100; and valine, 70. The relatively good balance of the essential amino acids is very important for the use of sweet lupin seeds as home-grown protein supplement feed in poultry production in Ethiopia.

CONCLUSION

Bitter white lupin is a traditional pulse crop in Ethiopia. However, the local landrace is unpalatable for livestock because of its high alkaloid content. In recent years, sweet blue lupines have been introduced and are being promoted as multipurpose crops. After a series of experiments, i.e., adaptation trials, laboratory evaluation, feeding and verification trials, the two sweet blue lupin varieties, Sanabor and Vitabor, were released and registered by the Ethiopian Ministry of Agriculture. The merits of the varieties are their low alkaloid content, high seed yield, resistance to anthracnose and fusarium, palatable for livestock and can be food for people. Thus, the varieties are recommended as multipurpose pulse crops for the traditional and new lupin growing areas in Ethiopia.

Conflict of interest

The authors declare no conflict of interest.

Contribution of authors

The first author (LY) conducted the field work, collected and analyzed the data, interpreted and prepared the manuscript. The second author (WM) also participated in the field work and data collection.

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