World Journal of Agricultural Sciences 17 (5): 437-449, 2021
ISSN 1817-3047

DOI: 10.5829/idosi.wjas.2021.437.449

A Review - Assessment of Research Activities and Achievements in Enhancing Adaptability, Productivity and Nutritional Quality of Sweet Lupin (*Lupinus angustifolius*.) in Different Agro-Ecological Zones of Ethiopia

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Abstract: Lupine (*Lupinus albus* L.) is a multipurpose leguminous crop rich in protein and mineral sources. In Ethiopia different lupin cultivars has been cultivated for livestock feed and as grain for human consumption. However, its production is limited due to its relatively high alkaloid content and bitter. Currently the farmers are interested in production of sweat lupins cultivar due to relatively rich in quality protein, relatively tolerant to drought, acidity, increase the fertility of soils and can contribute to improve agricultural sustainability. Therefore, this paper outlines the efforts made by various local research institutions in developing more adaptable, productive and nutritious sweat lupin cultivars with low alkaloid content that fit to different agro-ecological conditions of the country. The study done on sweet lupins to distinguish the adaptability and productivity of these crops in different agro-ecological zones of northwestern Ethiopia showed that forage and seed yields of most of the sweet lupin cultivars evaluated were relatively good. At the high-altitude the narrow-leafed lupin cultivars, Vitabor, Probor, Sanabor and Bora gave the highest seed yield. On the other hand the study done at Lemo district, Hadiya zone, southern Ethiopia to perceive yield and nutritional quality of sweet lupin by using two sweet lupin (vitabor and sanabor) varieties, at two locations with six levels of planting space revealed that seed yield (t ha^{-1}) was highly affected by location. Number of pods per plant and forage CP content increases as spacing increased. The interaction of location and variety highly affected the dry matter (DM) content of sweet lupin forage. In the same manner, the interaction of location and stage of flowering also affected the organic matter (OM) and the total ash content of sweet lupin forage. A result obtained from a field experiment designed to characterize the growth and yield performance of narrow-leafed sweet blue lupin varieties (*Lupinus angustifolius* L.) at Gondar Agricultural Research Station showed that the highest DM yield was recorded by Bora and Boregine, whereas the lowest value was scored by vitabor. Forage of narrow-leafed lupin contains CP concentration of 15.8?30% at maturity, which makes it suitable for animal feeding. In the recent past, a highly productive and easily adaptive extra sweet soil acidity tolerant lupin variety /SWL-001/ locally named Walala was released by Holeta Agricultural Research Centre. Walala is an excellent food source with high nutritional and lower ant-nutritional composition as compared to local lupin varieties and showed better sensory quality. Lupins can be milled into flour and used in the preparation of multiple food products that can be consumed as a part of a mixed diet or in combination with cereals. Bread containing lupin flour up to 30% substitution level gave a similar sensory score in terms of all sensory properties compared to the bread made fully from wheat flour. The protein content of shiro recipe is higher and this is a worthy solution to combat the protein malnutrition problem of the society in Ethiopia. Sweet lupin is gaining more attention by small-holder farmers owing to its grain yield and due to its value as animal feed and human food. Thus, the cultivation and scaling up of this variety is highly recommended and should be given great emphasis in the soil acidity prone areas where other high land pulse crops (Faba bean and Field pea) can't be grown due to soil acidity stress.

Key words: Alkaloid · Nutritional Quality · Sweet Lupin · Sensory Score · Soil Acidity Tolerant

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INTRODUCTION

Lupin is characterized by wide range of varieties with about 300 different species[1]. Of these, only four of *L. albus* (white lupin), *L. angustifolius* (blue lupin), *L. luteus* (yellow lupin) and *L. mutabilis* (Pearl lupin) gained agricultural importance [2]. 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. However, its use as livestock feed and human food is limited due to its relatively high alkaloid content.

The crop is produced in different parts of the country where as the Amhara National Region is the major producer of the crop. Lupins are important legume crops that form a critical part of sustainable farming systems [3]. Globally, it is used for livestock, poultry feed and fertilizing the soil [4]. It's nature of adaptation to wide range of climates also making it an attractive crop [4]. The crop is adapted to 1500-3000 m.a.s.l. and is being produced mainly by subsistent farmers [5]. White lupin is adapted to well drained, light to medium textured, moderately acidic or neutral soils with a pH range of 4.5 - 7.5 [6]. In Ethiopia the soil types in most traditional lupin growing areas are Nitosol and Acrisol with soil pH ranging between 4 and 5 [7]. Lupin is relatively more tolerant to several abiotic stresses than other legumes and has a high potential for the recovery of poor and polluted soils [8].

Soil acidity is one of the causes for the loss of fertility; and it is a critical challenge facing land productivity in the highlands of Ethiopia [9, 10]. Most acidic soils have poor chemical and biological properties. The potentials of using lime for soils sustainable management is one of the approach to overcome soil acidity, but liming alone is expensive and in some situations subsoil acidity restricts the benefit of lime, therefore genotypes with better tolerance to acidity are alternative integral approach in-terms of cost efficiency, convenience and sustainability. Among crops tolerance to soil acidity lupin is the first choice. The ability of the crop to be grown in acidic soils is one of the major important features of the crop in the traditional lupine growing area of Ethiopia.

Different species of lupine were found in Ethiopia, but many have high levels of alkaloids (bitter tasting compounds) that make the seed unpalatable and sometimes toxic. Plant breeders in the 1920's in Germany produced the first selections of alkaloid-free or sweet lupin, which can be directly consumed by humans and livestock [11]. Sweet lupine is a new crop to the country and it has low alkaloid content. Lupines are very important for human consumption due to its high protein content. It's use has been carried out not only by consumption of whole grains, but also by its incorporation into products as flours, concentrates or isolates, in order to improve the stability, texture and nutritional aspect of preparations [12]. Lupines 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 [13]. This article attempts to review the status of sweet lupine production and research achievements in Ethiopia to obtain extra-sweet lupine variety and soil acidity tolerant once to give better insight to basic information on breeding and recent developments on the subject.

MATERIALS AND METHODS

This paper is based on basic information, facts and figures supported by data sources (e.g. secondary data, bibliographic data base, etc.) in recently published journals, annual reports, technical reports and other relevant papers on issues of local lupine (bitter type) in general and sweet lupine in particular by different research centers, higher learning institutions and from other NGOs involving in a scientific research oriented activities. In this review, more than 53 scientific papers have been screened in which only 44 of them were included in the manuscript on the basis of their compatibility to the objective economic situation of the day: Food security and moderating malnutrition.

Adaptability, Productivity and Production Practice of Lupin Cultivars: The study was conducted to analyze the production and utilization trends of lupine in Ethiopia by [14] and using 16 years (2001/02 until 2017/18) secondary data of annual agricultural sample survey from CSA published data. The study result indicated that inconsistent trends of increasing and decreasing of total harvested coverage (ha), production (q) and yield (q/ha) of lupine had been shown in Ethiopia. The productions were ranged between 48, 326 and 443, 705.05 quintals. All the recorded yields were ranged between 3.22 and 16.65 q/ha, where a declining and increasing trend in yield was observed during 2009/10-2012/13 and 2014/15-2017/18 cropping seasons respectively (Figure 1).

The study result focused on local lupin (bitter type) had been used primarily as animal feed. In spite of the fact that, sweet lupin variety (*Lupinus angustifolius* L.)

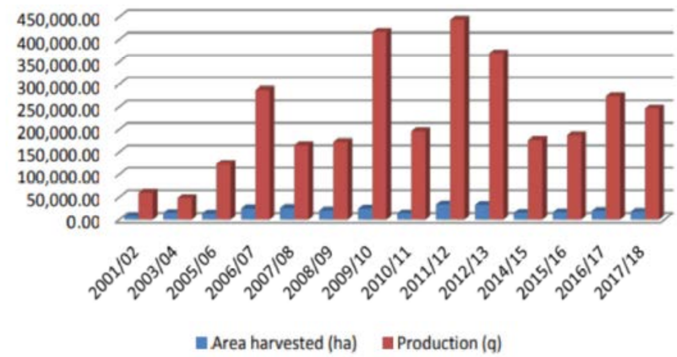

Fig. 1: Trends of land coverage and production (q) of Lupin in Ethiopia, 2001/02- 2017/18 cropping seasons
Source: [14]

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

	Mid Altitude						High Altitude					
	Merawi			Finoteselam			Kossober - 1			Kossober - 2		
Species, Cultivar	Mean	SE	Rank	Mean	SE	Rank	Mean	SE	Rank	Mean	SE	Rank
White, Local	3.6	0.38	1	5.8	0.78	1	0.2	0.34	14	0.9	0.31	12
NL, Bora	0.5	0.13	16	0.8	0.10	11	1.7	0.28	4	1.6	0.16	7
NL, Boregine	1.3	0.13	11	0.8	0.10	12	2.5	0.28	2	2.1	0.16	4
NL, Borlu	1.6	0.13	6	0.7	0.10	13	1.5	0.28	5	1.6	0.16	6
NL, Boruta	1.2	0.13	13	0.9	0.10	7	1.5	0.28	6	1.2	0.16	8
NL, Haags, Blaue	1.2	0.13	12	0.4	0.10	15	1.0	0.28	10	1.1	0.16	10
NL, Probor	0.9	0.13	14	0.4	0.10	16	1.2	0.28	9	1.1	0.16	11
NL, Sanabor	1.4	0.13	8	0.6	0.10	14	1.4	0.28	7	1.7	0.16	5
NL, Vitabor	1.4	0.13	9	0.8	0.10	10	1.7	0.28	3	1.2	0.16	9
Yellow, Bornal	1.9	0.42	4	1.4	0.35	5	2.9	0.28	1	2.3	0.53	3
White, Feodora	0.9	0.38	15	0.8	0.78	9	0.0	0.59	16	0.3	0.31	16
White, Fortuna	1.3	0.38	10	0.9	0.78	8	0.4	0.34	13	0.6	0.31	15
White, L-1082	2.3	0.38	2	4.5	0.78	2	0.2	0.34	15	0.8	0.31	13
White, L-1057	1.7	0.38	5	1.3	0.78	6	0.4	0.34	12	0.7	0.31	14
White, AU-Alpha	2.0	0.38	3	3.0	0.78	4	0.8	0.34	11	2.6	0.31	2
White, AU-Homer	1.5	0.38	7	3.4	0.78	3	1.3	0.34	8	4.4	0.31	1
Contrast	MDiff	SE	AdjP	MDiff	SE	AdjP	MDiff	SE	AdiP	MDiff	SE	AdjP
Local vs White	2.0	0.41	.0348	3.5	0.84	0.0513	-0.3	0.37	0.9657	-0.7	0.33	0.3751
Local vs NL	2.4	0.38	0.0189	5.1	0.78	0.0214	-1.3	0.35	0.0554	-0.5	0.31	0.5121
Local vs Yellow	1.7	0.57	0.1205	4.5	0.86	0.0322	-2.7	0.44	0.0136	-1.4	0.61	0.2615
White vs NL	0.4	0.16	0.1988	1.6	0.32	0.0328	-1.1	0.19	0.0160	0.1	0.14	0.8888
White vs Yellow	-0.3	0.45	0.9773	0.9	0.48	0.3635	-2.4	0.32	0.0079	-0.8	0.55	0.6808
NL vs Yellow	-0.7	0.43	0.5337	-0.7	0.36	0.3750	-1.3	0.29	0.0316	-0.9	0.53	0.5208
AU-det vs AU-indt	0.3	0.76	0.9494	-0.3	1.56	0.9972	-0.7	0.68	0.2979	-2.8	0.65	0.0132
AU-indt vs Other-indt	0.6	0.76	0.5412	2.3	1.56	0.1285	0.8	0.83	0.3755	3.0	0.62	0.0093

AU-det, AU-determinate; AU-indt, AU-indeterminate; Other -indet, Other –determinates; MDiff, LS mean difference; SE, Standard Error
Source: [15]

is much better than the local cultivars in terms of its adaptability, productivity, nutritional quality/served as source of food/ and its ability in maintaining soil fertility. The report lacks comprehensiveness that left out this variety, in which narration of its data could have given more inspiration for research efforts towards the improvement of its productivity and quality, which in effect creates more opportunity for adaptation/adoption and popularization of sweet lupine cultivation and utilization in the country.

A field experiment was conducted by Yeheyis *et al.* [15] in four lupine growing locations of Ethiopia to evaluate the adaptability and productivity of sweet lupines at different agro ecological areas. The test areas were Merawi and Finoteselam representing mid altitude, whereas Kossober-1 and Kossober-2 representing high altitude. The result indicated that the local landrace showed the highest forage yield at the mid-altitude locations. At the high altitude locations AU-Homer had the highest forage yield. As a group, the narrow-leafed lupine entries were consistent in their forage yield, which ranged from 0.7 t/ha at Finoteselam to 1.6 t/ha at Kossober-1 (Table 1).

Another study conducted by the same author for 69 days using sweet lupine grain as a supplement at 290 g/ head per day on Washera sheep shows that the animals can gain 74 g/ head per day and 5.1 kg/ head per 69 days indicating that sweet lupine (cultivar Sanabor) has a potential to substitute commercial concentrate feed supplement in Ethiopia.

Field experiment conducted to determine the biomass yield and nutritive value of sweet lupine varieties in mid altitudes of Lemo district, Hadiya zone, southern Ethiopia showed that green forage and forage dry matter yield were affected by location (Upper Gana produced relatively higher), planting spacing and stage of flowering, while sweet lupine forage crude protein (CP) content was affected by location and the highest CP content (23.11%) was recorded in Upper Gana Kebele (Table 2 and 3) [16]. This study showed that the dry matter (DM) content of sweet lupine forage was highly affected by the interaction of location and variety, whereas the interaction of location and stage of flowering also affected the organic matter (OM) and the total ash content of sweet lupine forage (Table 2). The result of this study also indicated that the forage total ash content decreased as the harvesting days of the plant advanced. This result is in agreement with other studies [17, 18] who reported that trend of total ash content decreased as age of plant advanced.

This study revealed that sweet lupine varieties at 50% flowering stage had the highest forage CP content (23.03%), while the lowest CP (21.22%) content at 100% flowering was recorded. The highest forage CP content was recorded at 40 cm × 20 cm (23.67%) and 30 cm × 20 cm (23.02%) compared to the narrower spacing (Table 3) [16]. This result indicated that similar to total ash the CP content of sweet lupine forage significantly decreased as the age of plants advanced and this was in line with other studies [18, 19] who reported a decline in CP content of the plant with increasing stages of harvesting.

Agro-ecological and Varietal Influences on Lupine Yield Performance: The study done to evaluate the adaptability and productivity of sweet lupines at different agro ecological areas by Yeheyis *et al.* [15] showed that the seed yield of the different sweet lupine entries was greater at the high-altitude locations than at the mid-altitude locations and this was in line with the reports of Fraser *et al.* [20] (2.86 t/ha) and Heidel [21] (2 t/ha). As a group, the narrow-leafed lupines had significantly higher seed yield than the white and yellow lupine entries across all locations. According to Spencer [22] compared to white and yellow lupines, narrow-leafed lupine can grow in different soil types.

The study conducted by Fikadu *et al.* [16] at southern Ethiopia representing mid-altitude showed that the sweet lupine seed yield (t ha^{-1}) and seed crude protein (CP) were highly affected by location. The maximum seed yield (2.98 t ha^{-1}) was observed in Upper Gana Kebele with the minimum (2.15t ha^{-1}) at Jewe Kebele (Table 4).

The study conducted to characterize the growth and yield performance of narrow-leafed sweet blue lupine varieties at Gondar Agricultural Research Station, north-western Ethiopia by Friehiwot *et al.* [19] showed that late-flowering varieties such as Boregine and Sanabor had the highest grain yields as they had the highest number of pods per plant, seeds per pod and thousand seed weight compared with the other genotypes. But late flowering and hence late seed set could have negative consequences in some circumstances [23].

The ranking of varieties in terms of grain yield was at variance with the previous report of Yeheyis *et al.* [15], who reported yield rankings in descending order: Vitabor, Sanabor, Probor and Bora, in north-western Ethiopia. These differences could be due to variation in agro-ecologies among the study areas. Tarekegn [24] also found that Sanabor gave higher grain yield than other tested narrow leafed lupine genotypes, while Yeheyis *et al.* [25] indicated that Boregine and Sanabor were the best-performing varieties among the present tested genotypes. This study also indicated that Sanabor, Boregine and Bora gave the highest thousand-seed weights (125, 121 and 118 g, respectively) (Table 5). This study also showed that forage DM yield was highest in Bora and Boregine and lowest in vitabor (Table 5), which is in agreement with findings of Yenesew Abebe *et al.* [26]. The present study showed that Sanabor has potential to be a suitable substitute for commercial concentrate feed supplement in Ethiopia and concludes that lupine seed is a highly nutritious product which can be used as a protein and energy supplement for livestock.

Generally, this study has shown that the narrow-leafed lupin varieties Boregine, Sanabor and Bora appear better suited to the study area than the other varieties tested because of better forage DM and seed yields. Hence these varieties seem promising for the development of sustainable forage production systems with a limited use of inputs.

Table 2: Effects of location, variety, stage of flowering on dry matter, organic matter and total ash of sweet lupine forage

			Chemical composition on DM basis		
Location	Variety	Stage of flowering (%)	DM (%)	OM (%)	Ash (%)
U. Gana	vitabor		13.30^{b}	84.82	15.17
	sanabor		12.18^{c}	84.83	15.16
Jewe	vitabor		15.63^{a}	86.39	13.60
	sanabor		13.72^{b}	86.00	13.99
P value			0.0005	0.4158	0.4158
SE (±)			0.28	0.32	0.32
U. Gana		50	12.94	83.35^{b}	16.64^{a}
		100	12.54	86.30^{a}	13.69^{b}
Jewe		50	14.89	85.38^{ab}	14.61^{ab}
		100	14.45	87.01^{a}	12.98^{b}
P value			0.9542	0.0081	0.0081
SE (±)			0.28	0.24	0.24
LSD			0.56	0.84	0.84
CV(%)			12.33	1.72	10.16

a-c in a column with different superscripts differ (p<0.05); U.Gana = Upper Gana; DM = dry matter; OM=organic matter; SE = standard error; LSD = least significant difference; CV = coefficient of variation.

Source: [16]

Table 3: Effects of location, spacing and stage of flowering on CP content of sweet lupin forage

	Location				Variety				Spacing								Stage of flowering						
	U.Gana	Jewe	P value	SE (±)	Vitabor	Sanabor	P value	SE (±)	30 x 7	40 x 7	30x15	40x15	30x20	40x20	P value	SE (±)	50 %	100 %	P value	SE (±)	Interaction	LSD	CV (%)
CP (%) forage	23.11a	21.15b	<0.0001	0.20	22.40	21.85	0.0602	0.20	20.93b	21.61b	21.92b	21.60b	23.02a	23.67a	<0.0001	0.35	23.03a	21.22b	<0.0001	0.20	NS	1.00	7.92

a-b in a column with different superscripts differ (p<0.05); U.Gana - Upper Gana; CP - crude protein;
SE - standard error; LSD - least significant difference; CV - coefficient of variation; NS - non-significant.
Source: [16]

Table 4: Effects of location, spacing and variety on plant height, number of pods per plant, number of seeds perpod, seed yield, hundred seed weight and crude protein of seed

Factor	PHM(cm)	PP	SP	SYD (t/ha)	HSW(g)	CP(%)
Location						
U. Gana	105.32^{a}	52.31	4.88^{a}	2.98^{a}	14.58^{a}	29.11^{a}
Jewe	77.51^{b}	55.45	4.50^{b}	2.15^{b}	11.83^{b}	17.98^{b}
P value	< 0.0001	0.2828	< 0.0001	< 0.0001	< 0.0001	< 0.0001
SE (±)	1.74	2.04	0.03	1.38	0.21	1.45
Variety						
Vitabor	93.10	52.17	4.88	2.52	12.30^{b}	23.63
Sanabor	89.73	55.59	4.50	2.61	14.11^{a}	23.46
P value	0.1769	0.2430	0.2917	0.6507	< 0.0001	0.7713
SE (±)	1.73	2.04	0.03	1.38	0.21	0.42
Spacing						
30 x 7	94.87	35.97^{c}	4.75	2.56	13.08	22.30
40 x 7	96.31	43.41^{de}	4.68	2.63	12.75	23.26
30 x 15	86.75	48.62^{cd}	4.66	2.40	13.41	23.99
40 x 15	86.08	55.54^{b}	4.61	2.33	13.75	23.37
30 x 20	93.66	62.72^{b}	4.74	2.58	12.75	24.19
40 x 20	90.83	77.02^{a}	4.71	2.87	13.50	24.15
P value	0.0928	<0.0001	0.6670	0.6754	0.2884	0.4212
SE (±)	3.00	3.54	0.06	2.39	0.36	0.72
Interaction	NS	NS	NS	NS	NS	NS
LSD	4.94	5.83	0.11	0.39	0.60	1.19
CV (%)	11.39		4.90	32.37	9.59	10.65

a-e in a column with different superscripts differ (p<0.05); U.Gana = Upper Gana; PHM = plant height at
maturity; PP = number of pods per plant; SYD = seed yield; HSW=hundred seed weight; SE = standard error; LSD = least significant difference; CV = coefficient of variation; NS = non-significant.

Source: [16]

Table 5: Effects of variety on plant height (PH), forage dry matter yield (DMY), number of pods per plant (NP), number of seeds per pod (NS), seed yield (SY) and thousand seed weight (TSW) of seven narrow – leafed lupine varieties

Variety	PH	DMY(t/ha)	NP	NS	GY(kg/ha)	TSW (g)
Bora	64.3abc	2.69a	11.9	3.94ab[1]	1715ab	118a
Probor	60.1bcd	1.95b	12.2	3.18b	1129c	98b
Sanabor	67.6a	2.49ab	10.2	4.13ab	1794ab	125a
Vitabor	53.8d	1.23c	8.1	3.70ab	1257bc	96b
Haags blaue	59.4cd	2.10b	12.7	3.18b	786bc	102b
Borlu	64.2abc	2.07b	8.9	3.38ab	1233bc	91b
Boregine	66.3ab	2.67a	16.9	4.15a	1901a	121a
Mean	62.2	2.17	11.0	3.67	1402	107
CV(%)	6.96	17.13	28.97	10.21	27.95	8.93
S.E.	4.33	0.37	3.18	0.37	39.86	9.57
Significance	*	***	ns	***	**	***

[1]values within columns followed by different letters differ significantly ($p<0.05$).

Source: [19]

Table 6: Some agronomic characteristics of lupine genotypes grown on acid soils, 2014/2015

	Morpho - agronomic traits								
Genotype	PLHT (cm)	PPP	SPP	DTF	DTM	GFP	GY (kg/ha)	TSW	Stand C.
Probor (sweet)	79.4	36.6	4.23	70.8	157.25	86.45	1904.5	98.4	49.4
Acc.No 242249(bitter)	120.5	28.5	4.25	84.4	213.25	128.85	3167.3	268.9	61.6
Acc.No 239003(bitter)	132.3	35.6	4.2	85.4	214.17	128.77	3740.4	267.3	63.8
SWL-001(Sweet)	80.0	48.7	4.37	70.1	162.33	92.23	2555.7	111.5	47.73
Sanabor (sweet)	87.2	42.3	4.22	69.8	159	89.2	2380.8	124.5	50.93
Acc. No 239056 (bitter)	128.3	31.2	4.16	83.7	214.92	131.22	2952.1	239.4	57.6
Vitabor (sweet)	87.4	41.5	4.41	68.9	160.42	91.52	2420.2	103.4	49.73
Acc.No 239006 (bitter)	121.1	28.9	4.19	85.5	215.67	130.17	3435.3	275.3	59.4
Bora (sweet)	87.4	39.4	4.35	71.6	160.67	89.07	2339.5	103.6	47.73
Mean	102.67	36.95	4.26	76.69	184.18	107.49	2766.00	176.91	54.21
CV (%)	11.60	40.81	12.06	4.53	2.26	-	18.67	10.53	13.99
LSD	6.42	9.22	0.31	2.83	3.4	-	315.73	13.54	4.11

PHT = Plant height (cm), PPP = Pod per Plant, SPP= Seed per Pod, DTF= Days To flowering, DTM= Days to Maturity, GFP= Grain Filling Period, GY= Grain Yield, TSW = Thousand seed weight, SC=stand count.

Source: [29]

The major abiotic stresses production constraints for highland pulse crops in Ethiopia are soil acidity and deficiency of soil nutrients. Because of its hardy nature and demanding less input there is an expectation that sweet lupine can easily replace highland pulse crops in highlands of Ethiopia to revert the food legume shortage. But past research evidences on sweet lupine for human food is not promising. Though the potential is there, the productivity of sweet lupine haven't been fully exploited till now. Even though not satisfactory a good beginning was seen to generate a wealth of information on the nutritive value of sweet lupine for animal feed, but little work was done on screening to get an extra low alkaloid content sweet lupine variety which is also tolerant to soil acidity to fetch a solution for food legume shortage.

Demonstration and Familiarization of Lupin Cultivation and its Utilization: In deliberation of alleviating scarcity and improving quality of food, CASCAPE project has conducted introduction and demonstration of sweet lupine at its intervention districts in north-western Ethiopia, Dera (Shimie and Gelawodios Kebele) and Jabi Tehnan (Mana kebele). The experimental treatments include three narrow-leafed lupine cultivars (Sanabor, Probor and Bora). The grain yield of sweet lupines ranged from 3.15 to 3.60 t ha^{-1}; 3.07 to 3.33t ha^{-1} and 1.96 to 2.16 at Mana, Shimie and Gelawodios kebeles, respectively [27]. The grain yield of sweet narrow-leafed lupines in this study is comparable with the yield reported by Yeheyis *et al.* [15] who reported a mean grain yield of 3.2 t ha^{-1} , 2.0 t ha $^{-1}$and 2.8 t ha, $^{-1}$ for Sanabor, Probor and Bora respectively, at Merawi site in mid-altitude of Mecha district. Farmers were interested to adopt this multi-purpose legume crop as it has optimal yield potential and better palatability than the bitter type lupine as human food and livestock feed.

Development of Soil Acidity Tolerant Sweet Lupine Variety for Acid Soil Prone Areas of Ethiopia: White lupin (*Lupinus albus* L.) is an ancient traditional multipurpose crop in Ethiopia. However, its use as human food is limited due to its relatively high alkaloid content [26]. Adet agricultural research center, from Amhara regional state has released two dual purpose sweet lupine varieties namely, Vitabor and Sanabor in 2014 [28]. With the objective of finding highly productive and easily adaptive extra sweet lupin variety under acidic soils the crop breeders and acid soil research team of Holeta Agricultural Research Centre (HARC), of EIAR (Ethiopian Institute of Agricultural Research)- jointly carried out an adaptation trial.

The candidate variety (SWL-001) which was initially introduced from Australia, along with collected lupine accessions was planted on acid soils in multi-location. This candidate variety (SWL-001) gave the highest mean seed yield as compared to the other sweet lupine accessions (Table 6 and 7) and tolerant for seed shattering.

Researchers in Holeta nutrition laboratory have worked on nutritive values of SWL-001 (Walala) and confirmed that the variety has better nutritional and lower ant-nutritional composition as compared to local white lupine variety (Table 8) and showed better sensory quality (taste).

'Walala' is a variety name given for SWL-001 genotype which has equivalent meaning of 'nectar of honey comb' in English meant to reflect its sweetness. Farmers around Holeta showed interest to grow sweet lupine for human food, because in their area highland pulse crops are out of production due to soil acidity. On the other hand the expansion of this variety to other soil acidity prone areas of the country is limited because of less extension dissemination done on its use value and nutritional quality especially as one of the best protein supplement.

Utilization of a Sweet Lupine Walala as Human Food: In Ethiopia, grain legumes are used for the preparation of various traditional foods although the methods of utilization of these food legume crops show somehow a sort of variability. For instance, "*Shiro Wet*" (grain legume *stews*) is the most widely served traditional dish in Ethiopia prepared from entire or dehusked and split legume seeds and/or its flour with additional necessary spices. In the study done at HARC sweet lupine was prepared in different common Ethiopian traditional food preparation methods in the form of cooked bean (*Nifro*), Roasted bean (*Kolo*) and *Shiro* [31]. Walala potentially has a significant role to play in the nutrition of humans if consumed as a part of a mixed diet or in combination with cereals. It can improve protein contents of other food products as supplement.

Macro Nutrients (Protein and Fat) Content of Shiro, Nifro and Kolo

Protein: The results of the macronutrient compositions (protein and fat) of the seed and recipes are presented in Table 9. The recipe *shiro* has showed a bit better protein content as compared to other recipe and the seed itself. Dehulling increases the protein content(34.65%)when compared to the seed protein content (31.65%) and this was supported by the finding of Gladstones [32] which stated that industrial processing such as dehulling reduces the fiber while increases protein content. Sweet lupine has greater protein content than the field pea variety (22.32%). The protein content of *shiro* recipe is higher and this is worthy solution to combat the protein malnutrition problem of the society in Ethiopia.

Fat Content: The oil content of the sweet lupine recipes range from 7.75 -8.50%, but the oil content of the recipes never showed statistically significant difference (Table 9). The oil content of lupine is much lower than that of soya as stated by Gattás *et al.* [33].

Micronutrients (Zn, Fe, Ca, K and Na) Content of Shiro, Nifro and Kolo: Sweet lupine recipe Zn, Fe, Ca, K and Na content were ranged from 9-12 mg/100g, 3.5-21 mg/100g, 27-94 mg/100g, 18-29 mg/100g and 1.4-2.5 mg/100g respectively. Zn, Fe and Ca content of cooked bean (Nifro) showed greater values as compared to the other recipe; whereas Na content of *shiro* and *kolo* were higher than the other recipe (Table 10).

Iron content of sweet lupine grain and sweet lupine recipes ranges from 3.5-21mg/100g was in the range of world health organization in different age group. Recommended Daily Intake (RDI) for women (18mg/day), for men (8mg/day), for pregnant women (27mg/day). Zinc content of sweet lupine grain and sweet lupine recipes ranges from (8-12mg/100g) was in the range of world health organization in different age group. RDI for women (8mg/day) and for men (11mg/day).

Similar study result was reported by [34] that the mineral content of Australian sweet lupine showed calcium content ranged 15-29 mg/100g, sodium 3-11mg/100g. Potassium 66-90 mg/100g, Iron 31-150 mg/100g and Zinc 24-45 mg/100g.

Table 7: Seed yield (kg ha $^{-1}$) of different lupin genotypes at different acid soil testing sites, 2014/2015

	Seed yield (kg/ha) at different testing sites															
Genotype	Holeta	R	Jeldu	R	Bokoji	R	Jima	R	R/Gebya	R	Nedjo	R	Adet	R	Comb.analy	R
Probor (sweet)	2693.8	8	2235.4	9	1306.3	9	1822.9	9	1643.3	9	862.6	7	2767.1	9	1904.5	9
Acc.No 242249(bitter)	3787.5	3	3489.6	4	2549	5	3958.4	2	3998.8	1	753.2	8	3634.9	5	3167.3	3
Acc.No 239003(bitter)	4439.6	2	4659.4	1	4034.4	2	4791.7	1	3162.9	2	1209.4	3	3885.5	2	3740.4	1
SW-001(Sweet)	3179.2	5	3198.0	5	2882.3	4	2343.8	5	2140.5	6	470.3*	9	3675.6	4	2555.7	5
Sanabor (sweet)	2554.2	9	3621.9	2	1654.2	8	2239.6	6	2157.3	5	1632.4	1	2806.3	8	2380.8	7
Acc. No 239056 (bitter)	3745.8	4	2636.5	7	3111.5	3	3750	3	2778.2	4	1078.3	5	3564.2	6	2952.1	4
Vitabor (sweet)	3130.2	6	3130.2	6	1745.8	7	1927.1	7	1741.6	8	891.1	6	4375.5	1	2420.2	6
Acc.No 239006 (bitter)	4811.5	1	3606.3	3	4409.4	1	3645.8	4	3067.3	3	1119.3	4	3387.8	7	3435.3	2
Bora(sweet)	2852.1	7	2388.6	8	2017.7	6	1823	8	2023.9	7	1464.8	2	3806.5	3	2339.5	8
Mean	3465.90		3218.42		2634.5		2922.4		2523.7		1053.48		3544.81		2766.2	
CV(%)	17.76		19.08		15.68		13.98		23.21		35.45		15.19		18.67	
LSD	1065.30		1063.20		715.2		707.45		1013.6		646.37		932.31		278.45	

R= rank of the genotypes in respective testing locations.

Source: [29]

*The candidate was heavily damaged by termite at Nedjo may be because of lower alkaloid content.

Table 8: Comparison of sweet lupin/walala with local check/bitter lupin for some nutrition and anti-nutritional parameters as done at Holeta Agricultural Research Centre – Nutrition Laboratory

	Proximate composition						Mineral Analysis					
Bean	CP(%)	MC(%)	Fiber(%)	Fat(%)	Ash(%)	CHO(%)	K(%)	Zn(%)	Na(%)	Ca(%)	Fe(%)	Alkaloid
S.lupine	25.2	9.7	18.3	9.3	3.6	33.9	142.46	5.36	102.95	98.76	9.06	1.76
B.lupine	39.1	10.5	14.5	11.2	3.2	21.5	32.47	10.47	145.8	77.18	51.18	6.03

S.lupine =sweet lupine, B.lupine = bitter lupine, CP=Crude Protein, MC= Moisture Content, CHO=Carbohydrate

Source: [30]

Table 9: Macronutrient composition (Protein and Fat) content of sweet lupine (Walala) recipe the Ethiopian food compared to Field pea variety (Bursa)

Recipes and grain	Protein content	Fat content
1. Shiro	34.65 ± 0.00a	7.75 ± 0.07b
2. Nifiro (cooked bean)	30.22 ± 0.035c	8.35 ± 0.07a
3.Kolo (roasted bean)	30.12 ± 0.17c	8.50 ± 0.14a
4. Sweet lupine grain	31.65 ± 0.00b	8.30 ± 0.00a
5. Field pea (Bursa variety)	22.32 ± 0.00d	3.6 ± 0.00c

All results: mean ± Standard Deviation

Source: [31]

Table 10: Micronutrient composition (Zn, Fe, Ca, K and Na (mg/g) content of sweet lupine (Walala) recipe the Ethiopian traditional food compared to field pea variety (Bursa)

Recipes and grain	Zinc (mg/100g)	Iron (mg/100g)	Calcium (mg/100g)	Potassium (mg/100g)	Sodium (mg/100g)
1. Shiro	9.5± 0.002ab	3.5± 0.05bc	27 ± 0.0014e	18.2 ± 0.75b	2.5±0.0021b
2. Nifiro	12.0± 0.014a	21 ± 0.012a	94 ± 0.0014a	18 ± 0.002b	1.4 ± 0.007b
3.Kolo	9.0± 0.014ab	20 ± 0.006a	78 ± 0.0035b	29 ±0.00b	2.5±0.00071b
4.Sweet lupine grain	8± 0.00 bc	21 ± 0.00a	69 ± 0.00c	29 ± 0.00b	1± 0.00b
5.Field pea (Bursa)	5 ± 0.00c	5.2 ± 0.00b	34 ± 0.00d	224 ±0.00a	20±0.00a

All results: mean ± Standard Deviation

Source: [31]

Sensory Evaluation of Walala Recipes: The recipe *shiro* (Ethiopian traditional food) has showed acceptable taste, colour and texture and all over acceptability compared to the other recipe. Next to *shiro* roasted bean (*Kolo*) has acceptable sensory result than cooked bean (*Nifro*) in which the sensory evaluation was evaluated by untrained twenty panellists and using five point hedonic scales (1= dislike very much, 2= dislike, 3= neither like nor dislike, 4= like, 5= like very much) (Figure 2).

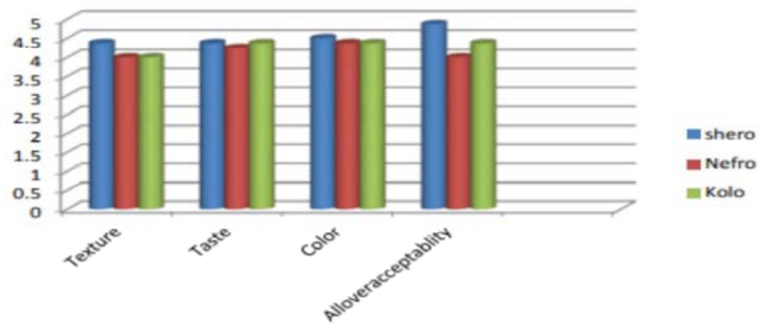

Fig. 2: Sweet lupine Recipe sensory result using five point hedonic scales
Source: [31]

Table 11: Functional property and nutrient content of Denda'a and Walala flour

Flour	Water absorption	Oil absorption	Moisture content	Ash	Protein content	Fat
Wheat (Denda'a)	2.7±0.30	2.30±0.10	9.50±0.00	1.50±0.50	10.66±0.40	2.1±0.10
Sweet lupine (Walala)	2.5±0.30	3.00±0.00	7.00±0.50	4.20±0.25	35.08±0.44	7.65±0.05

Source: [36]

Table 12: Formulations of samples from wheat (Denda'a) and sweet lupine (Walala)

Treatment	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9
Wheat flour (g)	100	95	90	85	80	75	70	65	60
Sweet lupine (g)	0 (control)	5	10	15	20	25	30	35	40

Source*:* [36]

Table 13: Macronutrient and moisture content of formulated bread

Treatment	Moisture content	Ash	Protein content	Fat
T_1	33.6±0.00	1.50±0.00	12.95±0.64cd	6.55±0.05h
T_2	28.50±2.90	1.50±0.00	11.68±1.32d	8.90±0.10b
T_3	35.40±2.20	1.75±0.25	14.00±2.12bcd	8.40±0.10cd
T_4	36.90±0.10	1.50±0.50	14.43±1.67bcd	8.10±0.10de
T_5	35.70±1.30	1.75±0.25	17.77±0.84abcd	7.30±0.10g
T_6	36.00±1.00	1.75±0.25	20.74±6.89ab	7.50±0.10fg
T_7	37.40±0.20	2.00±0.00	11.96±0.65d	8.50±0.10c
T_8	35.60±2.60	2.25±0.25	18.87±2.29abc	9.35±0.15a
T_9	38.40±4.00	2.25±0.25	21.93±2.25a	7.80±0.10ef

Source: [36]

Nutrient Content of Wheat and Walala Flour and Their Blend: Sweet lupine potentially has a significant role to play in the nutrition of humans if consumed as a part of a mixed diet or in combination with cereals. The ingredients of bread will impart characteristic colors, texture and nutritional value which may improve the bread quality. Therefore, a proper balance of ingredients needs to be obtained to produce high-quality bread. Concerns about the quality of breads go beyond the ingredients in the loaves themselves. One of the main quality criteria on bread is related with texture and the development of a desirable volume, related to alveoli formation. It has been proven that bread enriched by lupine flour has the potential to provide health benefits, such as increased satiety and reduce energy intake, decrease blood pressure and decrease blood glucose level [35].

Walala is high in protein and dietary fiber. In the study the bread product were made by blending the sweet lupine (walala variety) flour with wheat (Dandea variety) flour. The nutrient content of Danda'a (wheat variety) and walala (sweet lupine) was studied before blend formation. From the flour functional property the water absorption of the flour of wheat is greater than sweet lupine and oil absorption of sweet lupine is greater than the flour of wheat (Table 11).

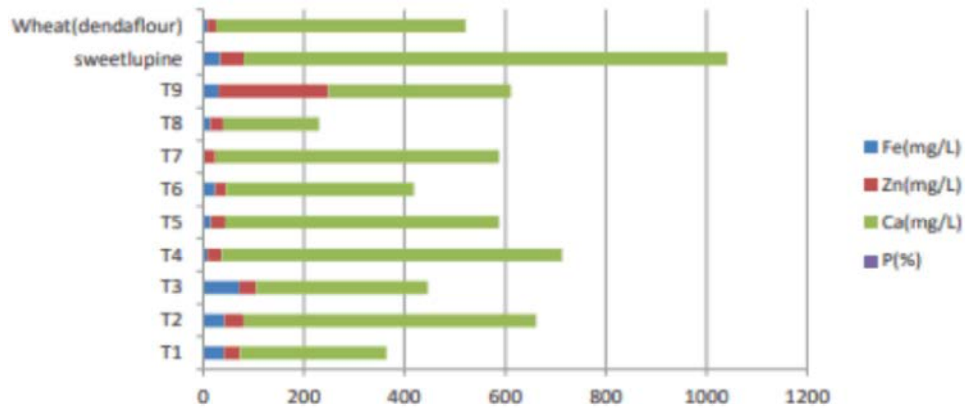

Fig. 3: Mineral content of formulated bread
Source: [36]

Table 14: Sensory data of the formulated bread using five point hedonic scales

Treatment	Taste	Color	Texture	Crumb color	Aroma	Over all
T_1	4.78±0.71a	4.57±0.14a	4.50±0.07a	4.14±0.14a	4.42±0.14a	4.60±0.21a
T_2	4.35±0.71b	4.07±0.07b	4.21±0.30ab	4.21±0.21a	4.14±0.00b	4.07±0.07bc
T_3	4.35±0.71b	4.53±0.036a	4.28±0.20ab	4.35±0.07a	3.71±0.00c	4.42±0.00ab
T_4	4.21±0.71b	4.39±0.11a	4.21±0.30ab	4.35±0.07a	3.78±0.07c	4.42±0.14ab
T_5	3.85±0.00c	4.00±0.00b	3.92±0.10b	4.00±0.14ab	3.78±0.07c	3.92±0.07c
T_6	3.71±0.20c	3.92±0.07bc	3.92±0.30b	3.57±0.14bc	3.35±0.07d	3.78±0.07c
T_7	3.21±0.71d	3.67±0.10cd	3.07±0.10c	3.50±0.21cd	3.07±0.07e	3.00±0.14d
T_8	2.92±0.71e	3.50±0.00d	2.92±0.10c	3.07±0.07d	2.71±0.00	3.00±0.00d
T_9	2.71±0.00e	3.39±0.035e	2.78±0.10c	3.14±0.14cd	2.64±0.07f	2.85±0.14d

Source: [36]

The blend of cereal and legume helps to balance out the amino acid profile and make it a more complete food. Great interest has been generated in supplementing wheat flour with high protein, high lysine material to increase the protein content and improve the essential amino acid balance of baked products, especially bread. Bread wheat flour and sweet lupine flour was blended in the ratios of 95:5, 90:10, 85:15, 80:20, 75:25, 70:30, 65:35, 60:40 and 100% wheat flour as a control (Table 12).

Protein and Fat Content of the Formulated Bread: Even though inconsistent, ash and protein content showed a trend of increment as sweet lupine amount in the blend increased (Table 13). The chemical properties of wheat flour have been studied previously by several researchers and they found that moisture content ranged between 12.5 to 14.6%, crude protein 8.23 to 12.71% and ash 0.42 to 0.66 [37]. As reported by William [38] lupine seeds are rich in protein source (33 - 47%) and oil (6 - 13%). Whereas protein content of sweet lupine-walala used for formulated bread and sweet lupine recipes ranges from 31-35% which was higher than other legumes (Table 13). Favier *et al.* [39] reported that haricot bean, lentil and soy bean contain 28.8%, 26.7% and 40.5% protein, respectively.

Mineral Content of Wheat and Walala Flour and Blends: The calcium content of sweet lupine is higher when compared to wheat flour. Calcium content of the blend has showed a trend of increase as sweet lupine flours ratio increases. Treatment 9 (wheat 60: Sweet lupine 40) has showed higher zinc concentration when compared to the other treatments. Sweet lupine flour zinc concentration (47.96) was higher than the wheat flour (17.04). Similarly, Lupine flour has higher amounts of k and P when compared to wheat flour (Figure 3). Similar results for mineral content of lupine flour have been reported by different researchers [40-44].

Sensory Evaluation of the Formulated Bread: Sensory evaluation was carried out using 20 untrained panellists to assess the organoleptic attributes of the bread samples. The organoleptic attributes assessed were; taste, aroma, texture, crumb color and the overall acceptability. The sensory acceptability of the bread up to treatment T6 (75 Wheat: 25 sweet lupine) were acceptable by using five point hedonic scale. Bread containing lupine flour up to 30% substitution level gave higher or similar sensory score in terms of all sensory property compared to control bread (Table 14). Gorecka *et al.* [45] reported that 10%

addition level of lupine flour to shortcakes, ginger breads, pancakes enables preparation good quality food stuffs in terms of sensory properties.

CONCLUSION AND RECOMMENDATION

In Ethiopia different lupine cultivars has been cultivated for livestock feed and as grain for human consumption. Various researches have been conducted on production and nutritional quality lupine cultivars. Different authors suggested that sweat lupine is relatively more productive, nutritious with low alkaloid content, easily adaptable and tolerant of soil acidity, increase the fertility of soils and can contribute to improve agricultural sustainability. Experiments done on screening different lupine genotype confirmed that easily adaptive extra sweet, soil acidity tolerant, lupine variety /SWL-001/ locally named "Walala" is an excellent food source with high nutritional and lower ant-nutritional composition as compared to other local lupine varieties and showed better sensory quality. Sweat lupines can be milled into flour and used in the preparation of multiple food products that can be consumed as a part of a mixed diet or in combination with cereals. Despite the valuable importance and wide use, the production and productivity of sweat lupine in Ethiopia is not to the standard level of expected. Therefore the following recommendation were made:(1) breeding extra low alkaloid content, high yield varieties in diverse locations, (2) sensitizing the agrarian communities about its use value and creating awareness about its nutritional quality.(3) government and agricultural extension should give priority to strength and promote sweet lupine production technologies that enhance production and productivity.(4) maximizing the market value chains of the crop to sustain production and food self-sufficiency.

ACKNOWLEDGMENT

I would like to acknowledge all researchers contributed for soil acid management to fetch a solution to minimize its adverse impact and foster its contribution to the country's food security. My sincere thanks also go to Mr. Derib Kifile for reviewing the paper entirely.

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