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Improved Lupin (*Lupinus albus* L.) Cultivars Field Performance Under North-West Ethiopia

Zeru Yimer Kebede
Pawe Agricultural Research Center (PARC): P.O. Box:25, Pawe, Ethiopia
E-mail: *zeruyimer2000@gmail.com*

Abstract

Experiment on improved lupin (*Lupinus albus* L.) cultivars field performance under North-West Ethiopia conducted with the objective to evaluate the agronomic and phenology traits of lupin cultivars during 2018 and 2019 cropping seasons. The study implemented on three farmers field for two consecutive years. The randomized complete block design applied with plot size of 10m by 10m. The inter and intra row spacing was 0.4m by 0.15m. Three lupin varieties (Wollela, Sanabor and Local) tested properly. The parameters subjected for analysis task were days to flowering, days to maturity number of branches per plant, number of pods per plant, number of seeds per pod, height of sample plants, hundred seeds weight, and yield of treatments.The analysis of variance (ANOVA) over year result revealed that there was significant difference among the tested lupin varieties at $p<0.05$ level. Based on this, days to flowering was significant at ($p<.0001$) whereas days to maturity was significant at ($p<.0001$); similarly, number of branches per plant was significant at ($p<0.0095$), number of pods per plant was significant at ($p<.0001$), number of seeds per pod was significant at ($p<0.0156$), plant height was significant at ($p<.0001$), hundred seed weight was significant at ($p<0.0017$), and finally adjusted seed yield was significant at ($p<0.0080$) probability level. The yield advantage obtained from sweet lupin varieties (Wollela and Sanabor) against local check was 13.76 and 8.91 respectively. Thus, by considering the seed yield and other important traits of the tested lupin cultivars I recommend the two sweet lupin varieties (Wollela and Sanabor) for the study area and similar ecologies for food and/or feed purposes.

Keywords: ANOVA, Parameters, Traits, Lupin

Background and Justification

Legumes plants are important source of protein. Sweet lupine is one of the legumes plants which is protein and mineral source [1]. Furthermore, white lupin is an important grain legume in the Ethiopian farming system. However, farmers' cultivars contain undesirable characters, such as high alkaloid level, are susceptible to diseases and low yielders [2].

Lupinus is a very diverse genus with many species. However, only four of them—namely, L. albus, L. angustifolius, L. luteus and L. mutabilis—are cultivated [3].

Lupinus, commonly known as **lupin** or **lupine**, is a genus of flowering plants in the legumefamilyFabaceae. The genus includes over 199 species, with centers of diversity in North and South America [4]. Smaller centers occur in North Africa and the Mediterranean. [4], [5]. They are widely cultivated, both as a food source and as ornamental plants, although in New Zealand'sSouth Island, introduced lupines are viewed as a severe environmental threat.

White lupin (Lupinus albus L.) is the oldest crop species of the kind and may constitute a potential source of protein without gluten [6]. It is rich in quality protein, relatively tolerant to drought, soil salinity and acidity, increase the fertility of soils and can contribute to improved agricultural sustainability, food security and reduce malnutrition which has close associations with climate change [7].Similarly, sweet lupine has relatively high crude protein content and a high in vitro organic matter digestibility[8] . According to [3] Lupin species could be a realistic sustainable alternative source of protein for animal feeding.
Currently lupine, under Ethiopian condition, is cultivated mostly on marginal land. Farmers produce the crop with minimum or no cultural practices [9], [10]. According to [11] promising lupin varieties obtained with development of sustainable forage production strategies with limited external inputs.

Sweet lupin is multipurpose crop; such as intercropping white lupin with other crops (barley, potato field pea),snack as supplementary food, Income generation, nutritional as food and feed , medicinal values, soil fertility maintenance [10],[2]. In addition, it is source of protein for production of protein concentrates, nitrogen fixation and crop rotation, traditional alcohol production (“arekie”), hypertension treatment, live fence, etc[12]. Generating better food for home consumption, feed for their livestock, cash income from sale, fix nitrogen for better soil fertility, and rehabilitation of degraded lands [2]. According to [13] ,fattening of washera sheep using sweet lupin grain with hay as a basal diet has a daily gain of 0.09g/day weight change. Supplementation with different forms of processed lupingrain has generally a positive effect on feed intake, nutrient digestibility and carcass parameters on sheep[21].

Livestock production in the European Union EU is highly dependent on imported soybean, exposing the livestock farming system to risks related to the global trade of soybean. Lupin species could be a realistic sustainable alternative source of protein for animal feeding [11].

Lupins are grown for their green mass as a manure and animal fodder and for their seeds as human food and animal fodder [14]. However, its use as livestock feed and human food is limited due to its relatively high alkaloid content [15].

Sweet blue lupin cultivars can better adapt in both mid and high altitude lupin growing areas of Ethiopia [15]. Sweet blue lupin has a relatively high CP content and a high digestibility. In addition, it has low alkaloid content. It has a CP content of 34.35% and a digestible organic matter (DOM) content of 86.28% [16].

Major production constraints of lupin in Ethiopia were the use of local varieties, shortage of access to production packages, late maturity, disease and stepwise postharvest processing [10]. Using lupin as a break crop and for soil fertility improvement is one of the practices to enhance productivity and improve soil fertility in Ethiopian conditions. However, the use of this practice by smallholder farmers is limited [17].

In Ethiopia, the productions were ranged between 48,326 and 443,705.05 quintals. All therecorded yields were ranged between 3.22 and 16.65 q/ha and declined in2009/10-2012/13 and increased trends in 2015/16-2017/18 cropping seasons[18].

Amhara national regional state alone comprised 137,386 number of holders, with area coverage of 19,135.99 hectares and earned production of

359,603.94 quintals with productivity potential of 18.79 quintal per hectare [22].

Most of the productions are limitedin Amhara region particularly in west Gojjam and Awizones; that is why West Gojjam and Awi zones were the major Lupin producer, which covered major productions in the country. The former was the leading and the later was the second producer in the region [18].

The study area is known by the production of midland and highland cereals including barley, wheat, potato, highland maize, faba bean, field pea, lupin, and others. The dominant lupin variety is local variety which is cultivated year after year. Due to this the yield is declined. Even the drawback of the cultivated local variety (farmers' variety) was not only yield penalty but also the bad taste (i.e. bitter); that made the cultivar not consumed well by humans and livestock unless the material is processed. Some varieties are referred to as "sweet lupines" because they contain much smaller amounts of toxic alkaloids than the "bitter lupin" varieties. Newly bred variants...

Therefor; improved lupin (*Lupinus albus* L.) cultivars field performance under North-West Ethiopia is designed and implemented:

- To evaluate the phenology and agronomy characters of lupin varieties
- To select and recommend better performing lupin variety for the study area (Guagusa Shikudad district)
- To generate and document preliminary information for future improvement of lupin cultivars for the area and similar agro-ecologies

Materials and Methods

Field experiment

The field experiment was conducted at Guagusashikudad district located at awi zone, Ethiopia from 2018-2019 cropping seasons. The cropping history indicated; the field was sown different cereals a year ago.

Description of study location (area):

Wasinchi water shade is located in Absela Kebele, Guagusa Shikudad district, ANRS, Ethiopia. Geographically it lies between $10^{o}45'$-$10^{o}48'$ N & $37^{o}03'$-$37^{o}04'$ E. Mean annual rainfall of the study area ranges from 1700 - 2560mm.Mean monthly minimum maximum temperature ranging from 7 ^{o}C -12 ^{o}C& 18 ^{o}C- 25 ^{o}C, respectively. The area has wet-cold locally known as wet degaagro-climatic zone. The study area has an altitude ranges b/n 2220 -2600 m.a.s.l. Farming system of the area is mixed farming, which includes major crops barley, potato, wheat, teff, pulse crops, maize and livestock (mainly sheep, cattle and horse).

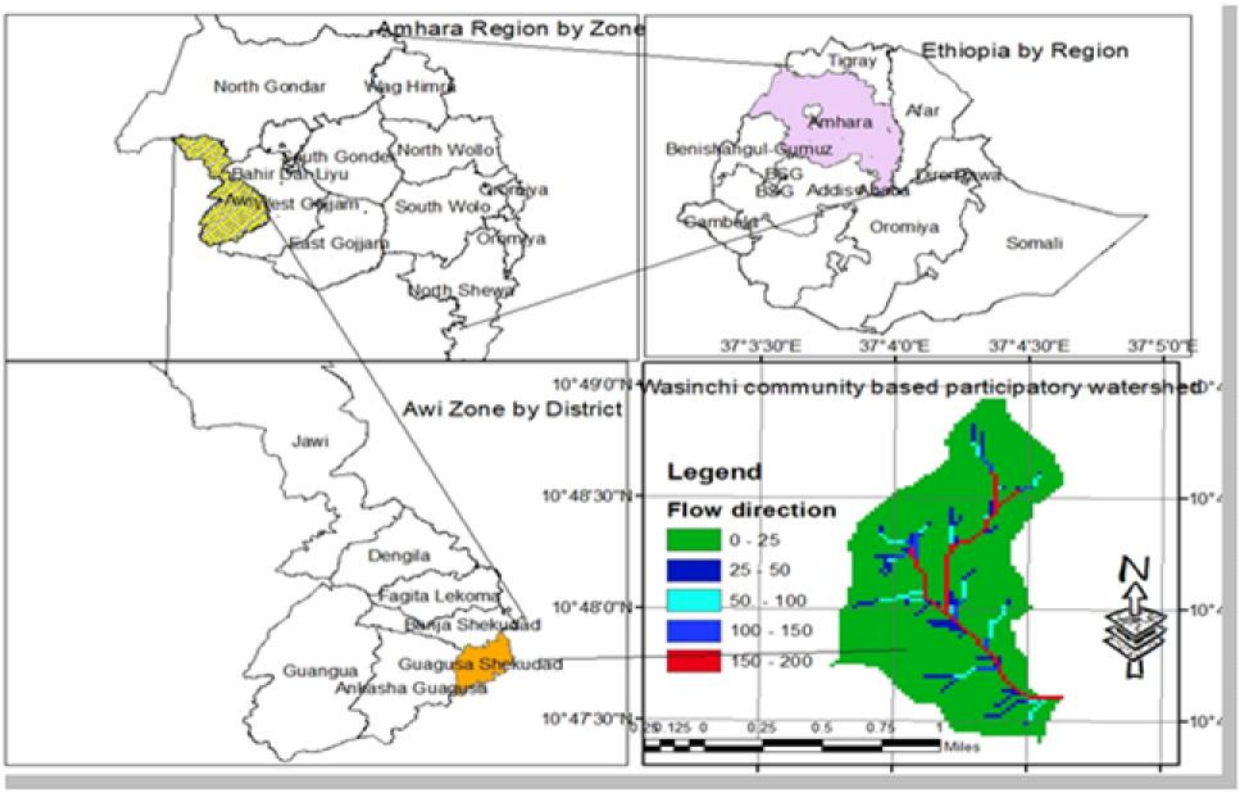

Figure 1: Map of study area

Measured parameters

The agronomic and phenology characters evaluated under this study were:

Days to emergence, days to flowering, plant height, number of pods per plant, number of seeds per pod, days to maturity, grain yield, seed moisture content, hundred seed weight, disease data recording.

Experimental design

The treatments laid out in Randomized Complete Block Design (RCBD) with two replications. The plot size was 10.0m × 10.0m which was equal to 100.00m^2 with 0.15m intra-row spacing with twenty-five rows of 0.40m inter-row spacing. The Net plot size was 10.0m × 9.2m which was equivalent to 92.00m^2 whereas distance between the independent plots was 1. 50m.Therefore; the total experimental area was 10.0m× 33.0m which was 330.0m^2. Planting materials was conducted on July 27/2018, July 25/2019 and July 30/2019 respectively. The sample plants were taken randomly from each plot per site and data recorded timely and properly. For easy of data analysis; the two cropping seasons (i.e., 2018/19 and 2019/20) were considered as the number of replications 1 and 2 respectively. Treatments setup for this particular study was presented by (Table 1) whereas the genetic materials applied for this study was presented by (Table 2).

Genetic materials

The genetic materials suggested for this particular study were two sweet lupin varieties (Wollela and Sanabor) the former variety was released byHoletta Agricultural Research Center under Ethiopian Institute of Agricultural Research (EIAR) and the second variety was released by Amhara Regional Agricultural Research Institute (ARARI) and lastly the local cultivar was obtained from small scale farmers of the district.

Table 3: Experimental treatments setup

No.	Entry	Entry number	Site number	Year
1	Wollela	1	1	2018
2	Sanabor	2	1	2018
3	Local	3	1	2018
4	Wollela	1	2	2018
5	Sanabor	2	2	2018
6	Local	3	2	2018
7	Wollela	1	3	2018
8	Sanabor	2	3	2018
9	Local	3	3	2018
10	Wollela	1	1	2019
11	Sanabor	2	1	2019
12	Local	3	1	2019
13	Wollela	1	2	2019
14	Sanabor	2	2	2019
15	Local	3	2	2019
16	Wollela	1	3	2019
17	Sanabor	2	3	2019
18	Local	3	3	2019

Statistical analysis

Analysis of variance (ANOVA) was carried out using SAS version 3.4, RStudio 1.4.1106 versions and Microsoft Excel 2019. F-test was used to test the significance differences between the treatments, and least significance difference (LSD) for comparing the treatment means at $P \leq 0.05$. The analysis was fitted in the mathematical model as presented below:

$$yij \sim \mu + ti + rj + eij \quad (1)$$

yij: response corresponding to j^{th} rep/site of the i^{th} treatment
μ: general effect
ti: treatment effect
rj: replication effect
eij: errors associated with j^{th} rep/site of i^{th} treatment

Table 4: Experimental materials merit

No.	Variety	Seed color	Seed shape	Growth habit	Taste	Leaf surface
1.	Wollela (SW-001)	Blue	Round	Annual	Sweet	Narrow-leafed
2.	Sanabor	White	Round	Annual	Sweet	Narrow-leafed
3.	Local	White	Flat	Perennial	Bitter	Broad-leafed

Results

There was significant difference among the tested lupin varieties at $p<0.05$ level of significance (Table 5:). Similar result was reported by [7]. Parameters subjected for analysis purpose, for this specific study, were days to flowering, days to maturity number of branches per plant, number of pods per plant, number of seeds per pod, height of sample plants, the weight of hundred seeds, and adjusted yield of treatments.

Days to flowering

Days to flowering ranged from 73.50 to 94.33 days. The tested lupin varieties (Wollela, Sanabor and Local) had mean values of 73.50,75.83 and 94.33 days to flowering respectively (Table 6:). Similarly 87 days to flowering was reported by [11].

Days to maturity

Days to maturity ranged from 119.33 to 166.5. The tested lupin varieties revealed two maturity groups; thus, the two sweet lupin varieties (Wollela and Sanabor) matured early however the local variety matured lately (Table 7:). According to [16] report farmers were highly interested on higher grain yield and shorter maturity time of sweet lupin varieties.

Branches per plant

The two sweet lupin varieties (Wollela and Sanabor) had better number of branches per plant over the local with mean values of 12.54,11.50, and 9.17 respectively (Table 8:). However; according to [11] 20 branches per plant recorded.

Pods per plant

The average number of pods per plant ranged 12.08 to 1833; similarly, the two sweet lupin varieties (Wollela and Sanabor) had better number of pods per plant over the local with mean values of 18.33,15.67, and 12.08 respectively (Table 9:).

Seeds per pod

Seeds per pod ranged from 4 to 4.9. Just like to other agronomic parameters sweet lupin varieties lead the local check with mean value of 4.9,4.35 and 4 seeds per pod respectively (Table 10:).

Plant height

The plant height ranged from 57.70 to 84.91 (Table 11:). The local check surpasses the other sweet lupin varieties. This implied the local check was long in height and sweet lupin varieties were dwarf. This result was in agreement with [11].

Hundred seed weight

Hundred seed weight ranged from 12.80 to 13.35 (Table 12:). The two sweet lupin varieties had better hundred seed weight over the local check.

Seed yield

The seed yield ranged from 1588.17 to 1806.69 (Table 13:). The two sweet lupin varieties had better seed yield over the local check. This result was better than [15]who reported 900 kg/ha and 1500 kg/ha for mid and high altitude areas of Ethiopia. However, this finding is lower than [8] who reported 2980 kg/ha and (Fikadu T. Riga, 2021)who reported 2520kg/ha and 2610 kg/ha for the tested sweet lupin varieties of Vitabor and Sanabor respectively. Similarly;[7] reported the variation of genotypes for yield ranged from 122 to 3206 kg with a mean grain yield of 1938.13 kg ha-1.

Table 14: Performance of Improved Lupin Varieties over year (2018-2019)

Treatment	DF	DM	Branch^{-1}plant	Pod^{-1}plant	Seeds^{-1}pod	Height	Hsw	Yield (kg/ha)
Wollela	73.50 b	119.33 b	12.5417 a	18.3333 a	4.9167 a	57.708 b	13.35 a	1806.69 a
Sanabor	75.833 b	122.83b	11.5083 a	15.6667 b	4.35 a	58.433 b	13.13 a	1729.75 a
Local	94.333 a	166.5 a	9.175 b	12.0833 c	4 b	84.917 a	12.80 b	1588.17 b
Mean	81.22	136.22	11.08	15.36	4.42	67.02	13.09	1708.20
LSD (0.05)	3.82	3.51	2.03	2.02	0.59	4.66	0.26	127.41
CV	3.80	2.08	14.83	10.61	10.75	5.61	1.61	6.02

Note: DF=Days to flowering, DM=Days to maturity, Branch^{-1}plant=number of branches per plant, Pod^{-1}plant= number of pods per plant, Seeds^{-1}pod=number of seeds per pod, Height= height of sample plants in (cm), Hsw= the weight of hundred seeds in (gram), Yield (kg/ha) = yield of treatments in (kg/ha)

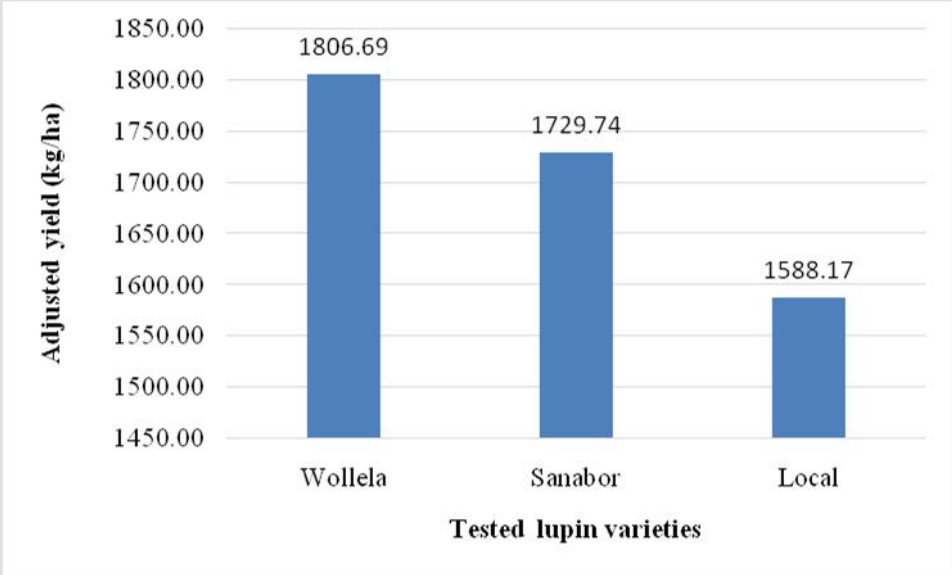

Figure 1: Improved lupin varieties grain yield (Over year)

Table 15: Correlation matrix of improved lupin varieties traits

	Flower	Maturity	Branch	Pods	Seeds	Height	Hsw	Yieldkgha
Flower	1							
Maturity	0.953633309	1						
Branch	-0.580168665	-0.643239928	1					
Pods	-0.697796394	-0.771178832	0.382301231	1				
Seeds	-0.683423813	-0.604149061	0.096377759	0.77699907	1			
Height	0.843047078	0.930679303	-0.611360876	-0.713226368	-0.442633386	1		
Hsw	-0.364565464	-0.557699707	0.415760787	0.628651558	0.273563536	-0.648531128	1	
Yieldkgha	-0.525727286	-0.627960959	0.597370287	0.477291384	0.226280353	-0.67769851	0.626770415	1

Days to flower is positively correlated with days to maturity, and plant height; however, it is negatively correlated with other traits like branches per plant, pods per plant, seeds per pod, hundred seed weight, and seed yield (Table 16:). Whereas days to maturity is positively correlated with plant height and negatively correlated with branches per plant, pods per plant, seeds per pod, hundred seed weight, and seed yield(Table 17:). Branches per plant is positively correlated with pods per plant, seeds per pod, hundred seed weight, and seed yield and negatively correlated withplant height (Table 18:). Pods per plant is positively correlated with seeds per pod, hundred seed weight, and seed yield and negatively correlated with plant height (Table 19:). Seeds per pod is positively correlated with hundred seed weight, and seed yield and negatively correlated with plant height (Table 20:). Plant height is negatively correlated with hundred seed weight, and seed yield whereas hundred seed weight is positively correlated with seed yield (Table 21:). However; according to [11] plant height, days to maturity and number of seeds per pod had the greatest influence on grain yield.

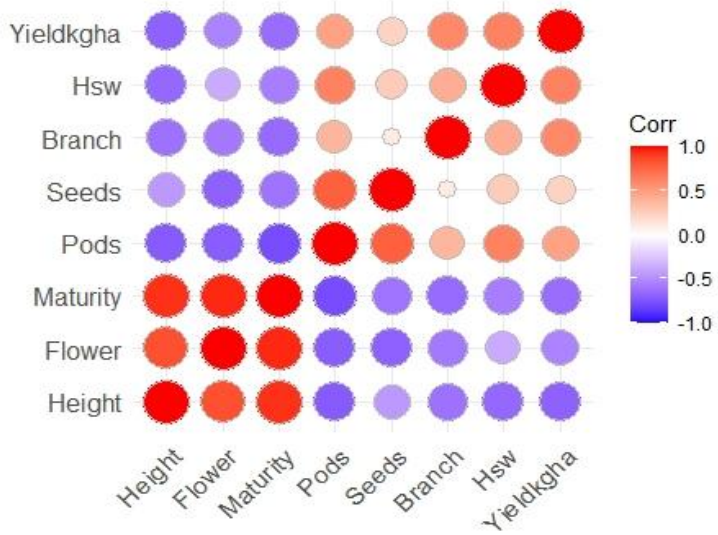

Figure 2: Correlation index of improved lupin varieties traits

The correlation index of lupin varieties' traits described those positively highly correlated lupin varieties are highlighted by red color whereas those positively moderately correlated lupin varieties are highlighted by light red color (Figure 3:). Similarly; those negatively highly correlated lupin varieties are highlighted by blue color whereas those negatively moderately correlated lupin varieties are highlighted by light blue color (Figure 4:).

Conclusion

Improved lupin varieties have the potential to secure both food and feed deficit in the context of current legume productivity nationally. Sweet lupin varieties seed yield potential and short duration maturity characteristics become main selection parameters against the control (local variety). Tested lupin cultivars showed significance level on proposed traits for analysis. In line with this yield and yield contributed traits revealed variability; however, no significance difference for tested site and tested year or duration. Overall, I recommend the two sweet lupin varieties (Wollela and Sanabor) for the study area and similar areas. But future improvement of lupin cultivars needs great attention. Similarly; according to [11] it has to be understood that modern cultivars, mostly of *L. albus* and *L. angustifolius*, contain low levels of alkaloids.

However, for future breeding efforts, the implementation of marker-assisted selection and the available genomic tools is of great importance. Enhancing further research and development initiatives on lupin could help smallholder farmers living on marginal lands to generate better food for home consumption, feed for their livestock, cash income from sale, fix nitrogen for better soil fertility, and rehabilitation of degraded lands [2].

Abbreviations

AGP2 --- Agricultural Growth Program (phase 2)
ANRS --- Amhara National Regional State
ARARI --- Amhara Regional Agricultural Research Institute
CBSM … Community Based Seed Multiplication
CP … Crude Protein
E.C … Ethiopian Calendar
EIAR … Ethiopian Institute of Agricultural Research
EU … European Union
GDP … Gross Domestic Product
i.e. … that is
kg … kilo gram
m.a.s.l … metere above sea level
mm … mili meter
PARC … Pawe Agricultural Research Center
Qt/ha … Quintal per hectare
Wt … Wilt disease

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