Hindawi
International Journal of Agronomy
Volume 2021, Article ID 6674452, 10 pages
https://doi.org/10.1155/2021/6674452

Research Article

Yield and Nutritional Quality of Sweet Lupine *(Lupinus angustifolius)* Grown in Midaltitudes of Lemo District, Hadiya Zone, Southern Ethiopia

Fikadu T. Riga,[1] Kassa S. Retta ,[2] and Melkamu B. Derseh[3]

[1]*Africa Rising Project, Hadiya, Ethiopia*
[2]*Department of Animal Sciences, Mekdela Amba University, South Wollo, Ethiopia*
[3]*International Livestock Research Institute (ILRI), Addis Ababa, Ethiopia*

Correspondence should be addressed to Kassa S. Retta; kassashawel@gmail.com

Received 12 November 2020; Revised 30 January 2021; Accepted 4 February 2021; Published 16 February 2021

Academic Editor: Mehdi Rahimi

The study was conducted to determine the yield and nutritional quality of sweet lupine (*Lupinus angustifolius.*) grown in midaltitude of Lemo District, Southern Ethiopia. The yield and nutritive value of sweet lupine in terms of quantity and quality was conducted using a factorial experiment arranged in a randomized complete block design (RCBD) with three replications. The treatments for the study were two sweet lupine varieties (Vitabore and Sanabore), two locations (Upper Gana and Jewe Kebeles, and six levels of planting spacing: 30 cm × 7 cm (S1), 40 cm × 7 cm (S2), 30 cm × 15 cm (S3), 40 cm × 15 cm (S4), 30 cm × 20 cm (S5), and 40 cm × 20 cm (S6)). The yield, chemical composition, and digestibility among parameters were studied. Sweet lupine varieties in Upper Gana Kebele gave the highest green forage yield (39.58 t/ha) and forage dry matter (4.84 t/ha) at 30 cm × 7 cm planting spacing, respectively. Seed yield (SYD) (t/ha) was highly affected ($P < 0.01$) by location. The maximum seed (2.98 t/ha) yield was observed in Upper Gana Kebele with the minimum (2.15 t/ha) at Jewe Kebele. The forage in Jewe Kebele gave the highest organic matter (OM) (87.01%) and acid detergent fiber (ADF) (37.50%) content at a stage of 100% flowering. Sweet lupine forage in Upper Gana Kebele gave the highest crude protein (CP) content (23.11%) while the highest forage CP content was recorded at a planting space of 40 cm × 20 cm (23.67%). Sweet lupine forage gave the maximum *in vitro* organic matter digestibility (IVOMD) (69.10%) at a spacing of 40 cm × 20 cm in Upper Gana. The highest CP (29.11%) content and IVOMD (80.49%) of seed were recorded in Upper Gana Kebele. The overall result of this study suggested that green forage yield and forage dry matter yield are affected by location, planting spacing, and stage of flowering, whereas the chemical composition of sweet lupine forage was affected by location and variety interaction (dry matter and acid detergent fiber), location and stage of flowering interaction (OM, ADF and total ash), location (CP, metabolizable energy (ME), and IVOMD), planting spacing (CP and IVOMD), and stage of flowering (CP and ME). On the other hand, sweet lupine seed yield, seed CP, and IVOMD were affected by location. The large differences in yield and nutritive values observed among sweet lupine varieties, growth environment, planting spacing, and their interactions entail consideration of these factors for appropriate utilization of sweet lupine as a feed resource for livestock.

1. Introduction

Feed is the most important input in livestock production and its adequate supply throughout the year is an essential prerequisite for substantial expansion in livestock production [1]. However, shortage of feed supply in terms of quantity and quality is the main factor limiting livestock productivity in Ethiopia [2]. Livestock feed resources in Ethiopia are mainly coming from natural grasslands, crop residues, crop aftermath, fodder trees, and shrubs followed by agroindustrial by-products, improved forage crops, and improved pastures [3]. Crop residues and natural pastures in the dry seasons are low in crude protein (CP), vitamin, and metabolizable energy (ME) content. As a result, livestock productivity and reproductive efficiency in Ethiopia is low [4]. Therefore, looking for other alternative home-grown protein supplements is crucial to improve livestock production and productivity. Growing and using legume crops like sweet lupine that have high nutritive value is one option to solve this problem [4].

Lupine (locally in Amharic known as *"Gibto"* in Ethiopia) is widely used to describe the seeds of different domesticated *Lupinus* species. Lupine seeds are employed as a protein source for animal and human nutrition in various parts of the world [5]. Lupine seed contains high amount of protein (32.2%), fiber (16.2%), oil (5.95%), and sugar (5.85%) [6]. Lupine is produced by smallholder subsistent farmers in Ethiopia: Amhara Regional State being the largest producer.

Little is known about the nutritional value and physicochemical and functional properties of the crop. Besides, little information is available for farmers, processors, and end-users on the utilization of the resource capacity of lupine seeds in the Ethiopian context [7]. This information gap does not allow intensive and extensive utilization of lupine as a value-added product in the country. It has a potential to grow in marginal lands where other food crops do not. Lupine seed storage and handling is easy as it is hardly attacked by pests. The only requirement for storage is a dry condition that enables its storage for about four to ten years without deterioration in quality. Another important feature is that lupine seed is the cheapest seed legume in the lupine producing areas of Ethiopia [8]. Although bitter white lupine is a traditional pulse crop in Ethiopia, sweet lupine is a new crop to the country.

Adaptability and productivity of forage legumes differ from place to place depending on several environmental and socioeconomic factors. To alleviate the feed quality and quantity problem, the demonstration and development of different legume crops are important for livestock production. The seed composition and high protein content make the sweet cultivars highly suitable for livestock diets in intensive farming systems. Generally, lupine which is a neglected legume crop has immense potential for feed, food, and soil fertility maintenance in Ethiopia. These being the cases, this study is aimed at evaluating the effect of location, planting spacing, and stage of harvesting on the yield and nutritional quality of two sweet lupine varieties.

2. Materials and Methods

2.1. Description of the Study Area. The experiment was conducted at Lemo district, Upper Gana (07° 34′ 24″ N, 037° 46′ 4″ E) and Jewe (07° 30′ 35″ N, 037° 47′ 1″E) Kebeles. The area is situated in Hadiya Zone, Southern Region, Ethiopia. The study site is located at 223 km South of Addis Ababa. The site has an altitude ranging between 2012 and 2202 meters above sea level. The average annual rainfall is between 1300 and 1400 mm with a bimodal distribution from February to April and from June to September and the average annual minimum and maximum temperatures are 18 and 23°C, respectively.

2.2. Varity Description. There are two sweet lupine varieties (Sanabor and Vitabor) released by the Amhara Regional Research Institute (ARARI). The suitable altitude ranges from 1800 to 2600 meters above sea level and the mean annual rainfall ranges from 1100 to 2300 mm. The seed yield of sweet lupine ranges from 2.2 to 4.8 tons per hectare depending on the agroclimatic zone and other environmental factors [4].

2.3. Experimental Design and Treatments. A total of two sweet lupine varieties (Vitabor and Sanabor) were used. The experimental design was a $2 \times 2 \times 6$ factorial experiment arranged in a randomized complete block design (RCBD) with three replications. The treatments for the study were two sweet lupine varieties, Vitabor (V1) and Sanabor (V2); two locations, Upper Gna and Jewe Kebeles; and six levels of planting spacing, 30 cm between rows and 7 cm between plants (S1), 40 cm between rows and 7 cm between plants (S2), 30 cm between rows and 15 cm between plants (S3), 40 cm between rows and 15 cm between plants (S4), 30 cm between rows and 20 cm between plants (S5), and 40 cm between rows and 20 cm between plants (S6). The experiment covers a total area of $29.5 \times 10\ m^2$ and the net plot size of each plot was $3\ m \times 2\ m$. Each experimental plot and its replication had 10–15 cm borders on each side to avoid the border effect of treatment and block. There is also 0.5 m gap/path between plots and blocks for easy management. 100 kg diammonium phosphate (DAP)/ha fertilizer rate was used [4]. The seed was planted at a depth of 2.5 cm [9].

2.4. Land Preparation and Management Practice. Land was ploughed four times from March to June and harrowed. The seed rates used in the experiment sites were 88 seeds per plot at $40\ cm \times 20\ cm$ planting spacing (wide spacing) and 260 seeds per plot at $30\ cm \times 7\ cm$ planting spacing (narrow spacing), respectively. Weeding was conducted three times, once at seedling stage and the others just before flowering stage. Furrows were made to prevent water logging. Frequent disease monitoring was done.

2.5. Data Collection and Sampling Techniques. The growth and yield parameters collected during the experimental periods included were as follows: days to 50% and 100% flowering and days to physiological maturity were recorded [10].

2.5.1. Structure of Plant and Stand. Plant height was measured from ground to the tip of the longest leaflet, by taking five random plants at each growth stage from each plot [10]. Structure of plant and stand is as follows. Stands per a given area, number of pods per plant, and number of seeds per pod were recorded as individuals. The stands in a given area were estimated based on the total count at each growth stage from each plot, whereas the number of pods per plant and the number of seeds per pod were estimated by taking five random plants per plot [10]. The average pod length was measured by taking five random plants at maturity stage from each plot [4,10].

2.5.2. Green Forage and Dry Matter Yield. The vegetation from each plot was sampled using a quadrant of $0.5\,\text{m} \times 0.5\,\text{m}$ size during a predetermined sampling period. The quadrant was randomly thrown on plots and the average weight of the harvest per plot was used for determination of forage yield and quality. The green forage was harvested with a sickle at a clipping height (10 cm) above ground. The average weight of the forage in the quadrant was used and extrapolated into dry matter yield per hectare (t/ha). Subsamples representing 10% of the whole forage samples harvested from the treatments were taken for DM determination. According to [10], the green forage yield expressed (q/ha) and (t/ha) is therefore estimated by the following equation:

$$\text{Green forage yield} = \left(10000\text{m}^2/Y\,\text{m}^2\right)x\,(Z\text{kg}/100), \quad (1)$$

where Z is yield obtained from sampling area (kg/m^2) and Y is area of the sampling site/quadrant (m^2).

2.5.3. Seed Yield. Sample from 1 m^2 per plot was harvested, trushed and seed yield was recorded as the weight of the seed yield per plot after air drying about 12–14% moisture content following harvest and measuring using a sensitive balance, expressed in grams and then converted into tons per hectare.

Lupine seed samples (100 gram from each plot) were collected from the remaining area after forage sampling was done for chemical analysis [4,10]. A total of 72 seed samples were collected for chemical analysis from the two experimental sites (Jewe and Upper Gana Kebeles).

2.5.4. Hundred Seed Weight (g). The weight in a gram of a random sample of 100 seeds of each plot was collected and measured [4,10].

2.6. Chemical Analyses and In Vitro Organic Matter Digestibility. The collected sweet lupine green forage (50% and 100% flowering stage) and seed samples were analysed in International Livestock Research Institute Animal Nutrition Laboratory, Addis Ababa for chemical composition. The samples were dried to a constant dry weight in an oven at 100 ± 5°C for 24 hrs to determine the percent dry weight before any analytical procedure [11]. Then the dried sample was ground to 1 mm mesh size using Wiley mill and packed into paper bags and stored pending to further laboratory work. Near Infrared Reflectance Spectroscopy (NIRS) predictions were employed for the analysis of the intended nutritional values of both green forage and seed samples.

Accordingly, green forage samples were scanned for predication of DM (%), ash (%), nitrogen (N%), metabolizable energy (ME (MJ/kg DM)), *in vitro* organic matter digestibility (IVOMD%) and fiber fractions (neutral detergent fiber (NDF%), acid detergent fiber (ADF%), and acid detergent lignin (ADL%)) contents, while in seed samples, the scanning was done for the predication of CP%, ME (MJ/kg), and IVOMD%. Nitrogen (N) content was determined by taking subsamples from an oven-dried forage sample by Kjeldhal method [11]. For scanning purpose, an already-ground sample was dried overnight at 60°C in the oven to standardize the moisture conditions. Then, the partially dried sample was filled into NIRS cup and scanned using Foss NIRS 5000 with the software package WinISI II in the 1108–2492 nm spectrum range (Win Scan version 1.5, 2000, Intrasoft International). The chemical analysis of the samples was performed in duplicate and calculated on a dry matter basis. Finally, NIRS scanned information of the green forage and seed samples were used for the prediction of the above-mentioned nutritional values, using predictive equations developed based on previously conducted conventional analyses.

The modified Tiller and Terry method was used for the determination of IVOMD of forage samples [12]. It is calculated as follows:

$$\begin{aligned} \text{IVOMD}\,(\%) &= (\text{OM input} - \text{OM remaining undigested})/(\text{OM input}) * 100, \\ \text{digestible DM yield (DDMY) (kg/ha)} &= \text{DMY} * \text{IVOMD}, \end{aligned} \quad (2)$$

where IVOMD is *in vitro* organic matter digestibility and DMY is dry matter yield.

2.7. Statistical Analyses. Statistical analyses were made using the General Linear Model (GLM) Procedure of SAS version 9.1. Analysis of variance (ANOVA) was carried out for location, varieties, and spacing as a fixed effect in a factorial model. The treatment means showing significant differences at 5% level of significance was compared using Least Significant Difference (LSD) comparison procedure. The statistical model was

$$\begin{aligned} Y_{ijk} &= \mu + V_i + S_j + L_k + (V * S)_{ij} + (V * L)_{ik} + (S * L)_{jk} \\ &\quad + (V * S * L)_{ijk} + E_{ijk}, \end{aligned} \quad (3)$$

where Y_{ijk} is the measured response, μ is the overall mean, V_i is the variety effect, S_j is the spacing effect, L_k is the location effect, $(V * S)_{ij}$ is interaction effect of i^{th} variety and j^{th} spacing, $(V * L)_{ik}$ is interaction effect of i^{th} variety and k^{th} location, $(S * L)_{jk}$ is interaction effect of j^{th} spacing and k^{th} location, $(V * S * L)_{ijk}$ is interaction effect of i^{th} variety, j^{th} spacing, and k^{th} location, and E_{ijk} is the error term associated with each Y_{ijk}.

Table 1: Effects of location, variety, and spacing on days to flowering, first pod setting, pod filling, and full maturity.

Factor	DFF	DFPS	DHF	DPF	DFM	Stand (*H*)	Stand (*G*)
Location							
U. Gana	59.50	68.50[a]	72.50[a]	96.50[a]	118.50	13.90[a]	18.10[a]
Jewe	59.50	61.50[b]	65.50[b]	93.50[b]	118.50	12.26[b]	12.52[b]
P value	1.0000	<0.0001	<0.0001	<0.0001	1.0000	0.0057	<0.0001
SE (±)	0.11	0.11	0.11	0.11	0.11	0.24	3.89
Variety							
Vitabor	60.66[a]	66.16[a]	70.16[a]	96.16[a]	119.66[a]	13.02	16.13
Sanabor	58.33[b]	63.83[b]	67.83[b]	93.83[b]	117.33[b]	13.40	14.50
P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.5617	0.1101
SE (±)	0.11	0.11	0.11	0.11	0.11	0.24	3.89
Spacing							
30 × 7	59.50[ab]	65.00[ab]	69.00[ab]	95.00[ab]	118.50[ab]	19.26[a]	27.65[a]
40 × 7	60.00[a]	65.50[a]	69.50[a]	95.50[a]	119.00[a]	17.36[a]	19.09[b]
30 × 15	59.00[b]	64.50[b]	68.50[b]	94.50[b]	118.00[b]	11.72[b]	14.66[c]
40 × 15	59.00[b]	64.50[b]	68.50[b]	94.50[b]	118.00[b]	10.32[b]	10.77[d]
30 × 20	60.00[a]	65.50[a]	69.50[a]	95.50[a]	119.00[a]	10.24[b]	10.95[d]
40 × 20	59.50[ab]	65.00[ab]	69.00[ab]	95.00[ab]	118.50[ab]	10.08[b]	8.75[d]
P value	0.0006	0.0006	0.0006	0.0006	0.0006	<0.0001	<0.0001
SE (±)	0.20	0.20	0.20	0.20	0.20	0.59	9.53
Interaction	NS	NS	NS	NS	NS	NS	NS
LSD	0.33	0.33	0.33	0.33	0.33	0.65	11.08
CV%	1.68	1.53	1.44	1.05	0.84	30.02	27.73

a–d in a column with different superscripts differ ($P < 0.05$); U. Gana = upper Gana; DFF = days to 50% flowering; DHF = days to 100% flowering; DFPS = days to first pod setting; DPF = days to pod filling; DFM = days to full maturity; Stand (*H*) = number of stands per m^2 at herbage harvest; Stand (*G*) = number of stands per m^2 at seed harvest; NS = nonsignificant; SE = standard error; LSD = least significant difference; CV = coefficient of variation; Sanabor had earlier days to 100% flowering, first pod setting and pod filling in Jewe Kebele. The planting spacing of 30 cm × 15 cm and 40 cm × 15 cm had shorter days to 100% flowering (68.50 days), first pod setting (64.50 days), and pod filling (94.50 days). Generally, the days to maturity were having similar trend with days to flowering that the earlier to flower and the earliest to maturity and vice versa. The present result agrees with the result observed by [13]. The early maturing varieties such as Sanabor have an advantage over the late maturing ones in environments where rain begins late and ends early [14].

3. Results and Discussion

3.1. Days to 50% and 100% Flowering, First Pod Setting, Pod Filling, and Full Maturity. There was a highly significant difference ($P < 0.01$) in days to 50% flowering and days to full maturity between the two sweet lupine varieties and planting spacing (Table 1). Earlier days to 50% flowering (58.33 days) and days to full maturity (117.33 days) were noted for variety Sanabor. Late to reach days to 50% flowering (62 days vs. 65.30 days) and full maturity (130 days vs. 132.00 days) for the varieties Sanabor and Vitabor, respectively, were reported by [13]. The earlier days to 50% flowering (59.00 days) and days to full maturity (118.00 days) were observed at 30 cm × 15 cm and 40 cm × 15 cm planting spacing.

Location ($P < 0.01$) and planting spacing ($P < 0.01$) had a highly significant effect on the number of stands (Table 1). The higher stand number per m^2 at herbage harvested (13.90 stands/m^2) and seed harvest (18.10 stands/m^2) were observed in Upper Gana Kebele than Jewe Kebele (12.26 stands/m^2 at herbage harvested and 12.52 stands/m^2 at seed harvest), respectively. The result of this study disagreed with the result observed by [13], who reported that the number of stands per m^2 ranges from 15.41 to 15.66 at seed harvest. The number of plants per unit area influences plant size, yield components, and ultimately the seed yield [15]. The plants planted at narrower spacing between rows and plants 30 cm × 7 cm (19.26) resulted in higher ($P < 0.01$) stand numbers per m^2 compared to the wider spacing 40 cm × 20 cm (10.08) at herbage harvest stage. This study agreed with [16], that an optimum plant population is considered the foundation for having increased yield. The same authors also reported that the interrow spacing of 30 cm gave the maximum plant population per unit area (37.56), which was significantly different from the 40 cm interrow spacing (28.78) for pulse crops.

3.2. Plant Height, Green Forage, and Forage Dry Matter Yield. The two-way interaction effect of location (*L*) and planting spacing (*S*) (LxS) and location (*L*) and stage of flowering (SF) (LxSF) were significantly ($P < 0.05$) affected by plant height, green forage yield (GFY), and forage dry matter yield (DMY) (Table 2). Sweet lupine varieties in Upper Gana Kebele gave the highest plant height (84.51 cm) at 30 cm × 7 cm planting spacing, whereas the lowest plant height (59.08 cm) was recorded at 30 cm × 20 cm planting spacing in Jewe Kebele. The reason could be plants under narrow spacing between plants, and the interplant competition will be too high that the individual plant increases in height [17]. Plant height was low at early stages of growth, but after 50% of days of flowering, enhanced growth was observed. The largest increment in mean plant height was recorded in the time from the intermediate to the last days of harvesting. This

Table 2: Effects of location, spacing, and stage of flowering on plant height (cm), green forage yield (t/ha), and forage dry matter yield (t/ha).

Location (*L*)	Spacing (*S*)	Variety (*V*)	PH (cm)	GFY (t/ha)	DMY (t/ha)
		Vitabor	69.79	23.23	3.41
		Sanabor	69.17	26.94	3.48
		P value	0.6121	0.0803	0.7616
		SE (±)	0.85	1.19	0.16
Upper Gana	30 × 7		84.51^{a}	39.58^{a}	4.84^{a}
	40 × 7		78.93^{ab}	32.16^{ab}	3.99^{abcd}
	30 × 15		71.31^{bcde}	17.86^{e}	3.10^{bcde}
	40 × 15		66.61^{defg}	21.55^{cde}	2.82^{de}
	30 × 20		74.68^{bcd}	31.11^{bc}	4.10^{abc}
	40 × 20		77.16^{abc}	33.04^{ab}	4.30^{ab}
Jewe	30 × 7		68.16^{def}	22.30^{cde}	3.28^{bcde}
	40 × 7		69.25^{cde}	26.79^{bcd}	4.01^{abcd}
	30 × 15		63.60^{efg}	20.88^{cde}	2.98^{cde}
	40 × 15		60.32^{fg}	19.98^{de}	2.92^{cde}
	30 × 20		59.08^{g}	17.33^{e}	2.53^{e}
	40 × 20		60.18^{fg}	18.45^{de}	2.54^{e}
P value			0.031	0.0038	0.0321
SE (±)			3.16	2.84	0.44
Location (*L*)	Stage of flowering (SF)				
Upper Gana	50%		65.34^{b}	21.07^{b}	2.86^{ab}
	100%		85.73^{a}	37.37^{a}	4.85^{a}
Jewe	50%		58.96^{c}	17.55^{c}	2.59^{c}
	100%		67.90^{b}	24.35^{b}	3.49^{b}
P value			<0.0001	0.0062	0.0190
SE (±)			1.19	1.64	0.22
LSD			2.39	3.33	0.45
CV%			10.35	30.69	30.47

a–g in a column with different superscripts differ ($P < 0.05$); PH = plant height at herbage harvest; GFY = green forage yield; DMY = dry matter yield; SE = standard error; LSD = least significant difference; CV = coefficient of variation.

Table 3: Effects of location, variety, and stage of flowering on dry matter, organic matter, total ash, and acid detergent fiber.

Location (*L*)	Variety (*V*)	Stage of flowering (SF) (%)	Chemical composition on DM basis			
			DM (%)	OM (%)	Ash (%)	ADF (%)
U. Gana	Vitabor		13.30^{b}	84.82	15.17	33.99^{b}
	Sanabor		12.18^{c}	84.83	15.16	35.86^{a}
Jewe	Vitabor		15.63^{a}	86.39	13.60	35.78^{a}
	Sanabor		13.72^{b}	86.00	13.99	35.34^{ab}
P value			0.0005	0.4158	0.4158	0.0013
SE (±)			0.28	0.32	0.32	0.53
U. Gana		50	12.94	83.35^{b}	16.64^{a}	34.92^{ab}
		100	12.54	86.30^{a}	13.69^{b}	34.93^{ab}
Jewe		50	14.89	85.38^{ab}	14.61^{ab}	33.61^{b}
		100	14.45	87.01^{a}	12.98^{b}	37.50^{a}
P value			0.9542	0.0081	0.0081	<.0001
SE (±)			0.28	0.24	0.24	0.45
LSD			0.56	0.84	0.84	1.57
CV%			12.33	1.72	10.16	7.79

a–c in a column with different superscripts differ ($P < 0.05$); U. Gana = Upper Gana; DM = dry matter; OM = organic matter; ADF = acid detergent fiber; SE = standard error; LSD = least significant difference; CV = coefficient of variation.

physiological change could be due to massive root development and efficient nutrient uptake allowing the plant to continue the increase in height. Similar results have also been reported by other workers [13,18].

Sweet lupine varieties in Upper Gana Kebele gave the highest green forage yield (39.58 t/ha) at 30 cm × 7 cm planting spacing, whereas the lowest GFY was recorded at Jewe Kebele (17.33 t/ha) at 30 cm × 20 cm and Upper Gana Kebele (17.86 t/ha) at 30 cm × 15 cm planting spacing. The result of this study agreed with [19], which indicated that higher yield was attributed to high plant populations that allowed the fodder crop to thrive well in terms of nutrient uptake from soil and solar interception in the early period of plant growth and development by an increase in green forage yield.

Table 4: Effects of location, spacing, and stage of flowering on CP, NDF, ADL, and ME content of sweet lupine forage.

Factor	Chemical composition on DM basis			
	CP (%)	NDF (%)	ADL (%)	ME (MJ/kg)
Variety (*V*)				
Vitabor	22.40	47.79	5.45	9.26
Sanabor	21.85	47.99	5.44	9.23
P value	0.0602	0.6652	0.9533	0.4703
SE (±)	0.20	0.31	0.05	0.03
Location (*L*)				
U. Gana	23.11[a]	47.04[b]	5.42	9.17[b]
Jewe	21.15[b]	48.74[a]	5.46	9.31[a]
P value	<0.0001	0.0003	0.6336	0.0003
SE (±)	0.20	1.56	0.05	0.02
Spacing (*S*)				
30 × 7	20.93[b]	48.72	5.61[a]	9.21
40 × 7	21.61[b]	48.26	5.60[a]	9.22
30 × 15	21.92[b]	48.28	5.43[ab]	9.25
40 × 15	21.60[b]	48.35	5.46[a]	9.29
30 × 20	23.02[a]	47.05	5.37[ab]	9.24
40 × 20	23.67[a]	46.69	5.17[b]	9.25
P value	<0.0001	0.0610	0.0327	0.8632
SE (±)	0.35	0.55	0.10	0.04
Stage of flowering (SF)				
50%	23.03[a]	47.86	5.21[b]	9.04[b]
100%	21.22[b]	47.92	5.67[a]	9.44[a]
P value	<0.0001	0.8935	<0.0001	<.0001
SE (±)	0.20	0.31	0.05	0.02
Interaction	NS	NS	NS	NS
LSD	1.00	1.54	0.28	0.07
CV%	7.92	5.62	9.12	2.43

a-b in a column with different superscripts differ ($P < 0.05$); U. Gana = Upper Gana; DM = dry matter; CP = crude protein; NDF = neutral detergent fiber; ADL = acid detergent lignin; ME = metabolizable energy; SE = standard error; LSD = least significant difference; CV = coefficient of variation; NS = nonsignificant.

Table 5: Effects of location and spacing on *in vitro* organic matter digestibility of sweet lupine forage.

Factor	IVOMD (%)
Variety (*V*)	
Vitabor	67.62
Sanabor	67.41
P value	0.5503
SE (±)	0.25
Location (*L*)	
U. Gana	68.15[a]
Jewe	66.88[b]
P value	0.0006
SE (±)	0.25
Spacing (*S*)	
30 × 7	66.50[c]
40 × 7	67.06[bc]
30 × 15	67.32[bc]
40 × 15	66.96[bc]
30 × 20	68.18[ab]
40 × 20	69.10[a]
P value	0.0007
SE (±)	0.43
Interaction	NS
LSD	1.23
CV%	3.17

a–c in a column with different superscripts differ ($P < 0.05$); U. Gana = Upper Gana; IVOMD = *in vitro* organic matter digestibility percent; SE = standard error; LSD = least significant difference; CV = coefficient of variation; NS = nonsignificant.

Sweet lupine varieties in Upper Gana Kebele gave the highest forage dry matter yield (DMY) (4.84 t/ha) at 30 cm × 7 cm planting spacing. The highest forage DMY (4.85 t/ha) was observed at Upper Gana Kebele at 100% flowering stage. The forage DMY reported by [20] of white lupines in the United States ranged between 0.8 and 2 t/ha, which was not in line with this study. However, the forage DMY were lower than those reported by [21] (8.7 t/ha) for white lupines in Serbia and by [22] (8.45 t/ha) from narrow-leafed lupine in the United Kingdom. On the contrary, the forage DMY were higher than those reported by [23] (1.4 t/ha) in narrow-leafed sweet lupine in Ethiopia.

3.3. Chemical Composition of Sweet Lupine Forage

3.3.1. Dry Matter, Organic Matter, Total Ash, and Acid Detergent Fiber Content of Sweet Lupine Forage. The interaction of location (*L*) and variety (*V*) (LxV) highly affected ($P < 0.01$) the dry matter (DM) and acid detergent fiber (ADF) content of sweet lupine forage. The interaction of location (*L*) and stage of flowering (SF) (LxSF) also affected ($P < 0.01$) the organic matter (OM), ADF, and the total ash content of sweet lupine forage (Table 3).

Vitabor in Jewe Kebele gave higher forage DM content (15.63%) than Sanabor in Upper Gana Kebele (12.18%). Sweet lupine forage in Jewe and Upper Gana Kebele gave similar OM content (87.01% and 86.3%, respectively) at a stage of 100% flowering. Sweet lupine forage in Jewe Kebele gave the highest ADF content (37.50%) at a stage of 100% flowering. This study agreed with [4], which reported increasing trends in ADF content with advance in harvesting days.

The highest forage total ash content (16.64%) was obtained in Upper Gana Kebele at the stage of 50% flowering and the lowest at Jewe Kebele (12.98%) at the stage of 100% flowering. The present study indicated that the forage total ash content decreased as the harvesting days of the plant advanced. This result is in agreement with other studies [24,25] who reported decreased trend of total ash content as age of plant advanced.

3.3.2. Crude Protein, Neutral Detergent Fiber, Acid Detergent Lignin, and Metabolizable Energy Content of Sweet Lupine Forage. Sweet lupine forage in Upper Gana Kebele gave the highest crude protein (CP) content (23.11%) followed by Jewe Kebele (21.15%) (Table 4). Sweet lupine varieties at 50% flowering 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%)

Table 6: Effects of location, spacing, and variety on plant height, pod length, number of pods per plant, number of seeds per pod, seed yield, and hundred seed weight.

Factor	PHM (cm)	PL (cm)	PP	SP	SYD (t/ha)	HSW (gm)
Location						
U. Gana	105.32[a]	4.90[a]	52.31	4.88[a]	2.98[a]	14.58[a]
Jewe	77.51[b]	3.72[b]	55.45	4.50[b]	2.15[b]	11.83[b]
P value	<0.0001	<0.0001	0.2828	<0.0001	<0.0001	<0.0001
SE (±)	1.74	0.03	2.04	0.03	1.38	0.21
Variety						
Vitabor	93.10	4.31	52.17	4.88	2.52	12.30[b]
Sanabor	89.73	4.31	55.59	4.50	2.61	14.11[a]
P value	0.1769	0.8641	0.2430	0.2917	0.6507	<0.0001
SE (±)	1.73	0.03	2.04	0.03	1.38	0.21
Spacing						
30 × 7	94.87	4.27	35.97[e]	4.75	2.56	13.08
40 × 7	96.31	4.35	43.41[de]	4.68	2.63	12.75
30 × 15	86.75	4.27	48.62[cd]	4.66	2.40	13.41
40 × 15	86.08	4.29	55.54[bc]	4.61	2.33	13.75
30 × 20	93.66	4.32	62.72[b]	4.74	2.58	12.75
40 × 20	90.83	4.35	77.02[a]	4.71	2.87	13.50
P value	0.0928	0.8304	<0.0001	0.6670	0.6754	0.2884
SE (±)	3.00	0.05	3.54	0.06	2.39	0.36
Interaction	NS	NS	NS	NS	NS	NS
LSD	4.94	0.09	5.83	0.11	0.39	0.60
CV%	11.39	4.46	22.79	4.90	32.37	9.59

a–e in a column with different superscripts differ ($P < 0.05$); U. Gana = Upper Gna; PHM = plant height at maturity; PL = pod length; SP = number of seeds per pod; 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 = nonsignificant.

compared to the rest of the narrower spacings. This result indicated that the CP content in the samples harvested during the experiment period significantly decreased as the age of plants advanced. The CP content obtained in this study agreed with other studies [25,26] who reported a decline in CP content of the plant with increasing stages of harvesting. This might be due to the dilution of the CP content by an increase in structural carbohydrate content of forage materials harvested at late maturity [27]. The higher CP content in plants harvested at wider spacing between rows and plants in this study might be attributed to the higher absorption of nitrogen available in the soil with low competition compared to higher plant density under narrow spacing.

The highest (48.74%) NDF content was recorded at Jewe and Upper Gana Kebeles, respectively. The highest (5.67%) mean forage ADL content was observed at 100% and 50% stage of flowering, respectively (Table 4). Lignification of the forages appeared to occur almost constantly with an increase in harvesting days. The authors in [28] reported that as maturity advanced, forage yield increased, but CP content dropped by about 40 to 50%, and ADF and NDF levels increased by 15 to 25%. The lowest forage ADL content was recorded in sweet lupine which was planted at 40 cm × 20 cm (5.17%) and 30 cm × 20 cm (5.37%) compared to the rest narrower intra- and interspacing. The predominant features of increasing plant density resulted in a tremendous reduction in leaf to stem ratio, which in turn resulted in an increase in cell wall and lignin contents [29].

The highest metabolizable energy content (9.31 MJ/kg) was obtained in Jewe Kebele. Significantly higher (9.44 MJ/kg) and lower metabolizable energy (9.04 MJ/kg) were recorded at 100% and 50% flowering stage, respectively (Table 4). This might be due to the fact that as the plants grow longer, there is a greater need for structural tissue with increased proportion of stem that has higher structural carbohydrates (cellulose and hemicelluloses) by affecting the metabolizable energy content of the plant [30].

3.4. In Vitro Organic Matter Digestibility of Sweet Lupine Forage. *In vitro* organic matter digestibility (IVOMD) of sweet lupine forage was significantly affected ($P < 0.01$) by both location (L) and planting spacing (S) (Table 5).

Sweet lupine forage gave the maximum IVOMD (68.15%) in Upper Gana Kebele against the minimum (66.88%) in Jewe. Planting at a spacing of 40 × 20 cm gave the highest IVOMD (69.10%) against the lowest IVOMD (66.50%) at 30 cm × 7 cm planting spacing. The maximum IVOMD was recorded at wider and the minimum at the narrow planting spacing. These results were in agreement with those of [31]. These differences in digestibility may be related to the morphological and anatomical characteristics of the plant tissues [32]. The higher leaf to stem ratio under wider planting pattern causes differences in digestibility of forage compared to narrow spacing because of the lower rate of lignification in the leaf and accelerated rate of lignification in the stem component [33].

3.5. Yield and Yield Components of Sweet Lupine. The effect of location on plant height, pod length, and the number of seeds per pod, seed yield, and hundred seed weight, the effect

Table 7: Effects of location, variety, and spacing on crude protein, IVOMD and metabolizable energy content of sweet lupine seed.

Factor	Chemical composition on DM basis		
	CP (%)	IVOMD (%)	ME (MJ/kg)
Variety			
Vitabor	23.63	79.23	11.91
Sanabor	23.46	79.38	11.93
P value	0.7713	0.7364	0.6499
SE (±)	0.42	0.23	0.02
Location			
U. Gana	29.11[a]	80.49[a]	11.94
Jewe	17.98[b]	78.16[b]	11.90
P value	<0.0001	<0.0001	0.3045
SE (±)	1.45	0.23	0.02
Spacing			
30 × 7	22.30	78.82	11.86
40 × 7	23.26	79.29	11.90
30 × 15	23.99	79.64	11.94
40 × 15	23.37	79.56	11.96
30 × 20	24.19	79.17	11.89
40 × 20	24.15	79.46	11.94
P value	0.4212	0.7376	0.3870
SE (±)	0.72	0.40	0.04
Interaction	NS	NS	NS
LSD	1.19	0.66	0.06
CV%	10.65	1.76	1.18

a-b in a column with different superscripts differ ($P < 0.05$); U. Gana = Upper Gana; CP = crude protein; IVOMD = *in vitro* organic matter digestibility; ME (MJ/kg) = metabolizable energy in mega joules per kilogram; DM = dry matter; SE = standard error; LSD = least significant difference; CV = coefficient of variation; NS = nonsignificant.

of variety on hundred seed weight, and the effect of planting spacing on number of pods per plant were highly significant ($P < 0.01$).

Both sweet lupine varieties in Upper Gana Kebele were found to be the highest with an average height of 105.32 cm and relatively short in Jewe Kebele (77.51 cm) (Table 6). Similarly, sweet lupine varieties planted in Upper Gana Kebele gave the maximum pod length (4.90 cm) and the highest number of seeds per pod (4.88) compared to planted at Jewe Kebele (pod length 3.72 cm and seeds per pod 4.50, respectively). Similar result has been also reported by [18]. The plant height of sweet lupine in Ethiopia at maturity reported by [13] ranged between 56.30 cm and 56.70 cm which were not in line with the plant height of this study. The same author also reported that the number of seeds per pod range between 4.33 and 4.67 almost agreed with this study.

Plants planted at wider spacing 40 cm × 20 cm resulted in higher pod number (77.02) compared to the narrower spacing 30 cm × 7 cm (35.97). The results indicated that the number of pods per plant increased as the planting space increased, since sweet lupines were affected by the number of branches. The result of the present study was similar with [23], which indicated that narrow-leafed lupines (Vitabor and Sanabor) had inflorescence on all branches (main stem, primary, secondary, and basal lateral branches).

Sweet lupine gave the maximum seed (2.98 t/ha) yield in Upper Gana Kebele against the minimum seed (2.15 t/ha) yield at Jewe Kebele. The seed yield of narrow-leafed sweet

Table 8: Pearson correlation between agronomic attributes of two sweet lupine varieties.

Variables	Stand	PH (cm)	PP	PL (cm)	SP	SYD (t/ha)	HSW (gm)
Stand	1.00						
PH	0.48**	1.00					
PP	−0.57**	0.00	1.00				
PL	0.28*	0.76**	−0.04	1.00			
SP	0.28*	0.58**	−0.01	0.51**	1.00		
SYD	0.31**	0.69**	0.15	0.42**	0.42**	1.00	
HSW	0.20	0.47**	0.02	0.65**	0.42**	0.43**	1.00

Level of significance: ** = $P < 0.01$; * $P < 0.05$; PP = number of pods per plant; PL = pod length (cm); PH = plant height; SP = number of seed per pod; SYD = seed yield; HSW = hundred-seed weight.

lupines at the midaltitude in this study was in line with the reports of [22] (2.86 t/ha), but higher than the findings of [13] (0.32 to 0.36 t/ha). In addition, [23] reported that the relatively good performance of narrow-leafed sweet lupines at all locations, compared to the other species, showed the wider adaptability of narrow-leafed sweet lupines in different growing environments.

The effect of location and variety on hundred seed weight had highly significant ($P < 0.001$). Upper Gana Kebele gave the highest hundred seed weight (14.58 gm) followed by Jewe Kebele (11.83 gm). Sanabor had higher hundred seed weight (14.11 gm) than Vitabor (12.30 gm). This study was numerically higher than Vitabor (9.07 gm) and Sanabar (10.50 gm) conducted in Tigray region, Ethiopia [13].

3.6. In Vitro Organic Matter Digestibility of Sweet Lupine Seed. The effect of location on sweet lupine seed CP content and IVOMD was highly significant ($P < 0.01$) (Table 7). The metabolizable energy (ME) content of sweet lupine seed due to location was not significant ($P > 0.05$).

The highest (29.11%) and the lowest (17.98%) sweet lupine seed CP content were recorded at Upper Gana and Jewe Kebeles, respectively. Data on IVOMD of sweet lupine seed in Upper Gana Kebele gave higher IVOMD (80.49%) than Jewe Kebele (78.16%). The CP content of sweet lupine seed at the midaltitude locations in this study was lower than the reports of [34] (38.8%) and [35] (30–40%). Reference [36] also showed that lupine seeds contain 86% digestible energy and 15.7 MJ ME/kg on DM basis, which were higher than the current observation.

3.7. Pearson Correlations between Agronomic Attributes and Seed Yield of Sweet Lupine. Seed yield (SYD) was found to be positively correlated with number of stands, plant height, pod length, and the number of seeds per pod, while hundred-seed weight was positively correlated with plant height, pod length, number of seeds per pod, and seed yield. The number of seeds per pod was positively correlated with pod length, plant height, number of stands, seed yield, and hundred-seed weight (Table 8). The results revealed that selection for higher number of stands, plant height, pod length, number of seeds per pod, and hundred-seed weight would be helpful in increasing the seed yield in plants [37].

4. Conclusions and Recommendations

The overall result of this study suggested 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 seed yield, seed crude protein, and *in vitro* organic matter digestibility were affected by location. Sweet lupine has relatively high crude protein content and a high *in vitro* organic matter digestibility. The differences in yield and nutritive values observed among sweet lupine varieties, growth environment, planting spacing, stage of flowering, and their interactions entail consideration of these factors for appropriate utilization of sweet lupine as a feed resource for livestock and seed yield. Continual research work on adaptability in different agroecology and animal performance evaluation is recommended [38].

Data Availability

The Data used to support the findings of this study are available from the corresponding author upon request.

Disclosure

This research article is part of Fikadu T. Riga MSc. thesis, a self-sponsored person who covered the majority of the COST by himself, and the rest of the authors are his technical advisors from which the authors extracted the present manuscript (https://cgspace.cgiar.org/bitstream/handle/10568/103250/thesis_fikadu.pdf?isAllowed=y&sequence=1).

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

The authors are indebted to Africa Research in Sustainable Intensification for Next Generation Project (Africa RISING Project) for covering the laboratory analysis expense and facilities needed for this research work. The authors are grateful to Lemo Wereda Office of Agriculture for all their cooperation and generous response to requests for experimental sites and data collection.

References

[1] S. Sofia, "Lupine products—concepts and reality," in *'Lupines for Health and Wealth'*, J. A. Palta and J. B. Berger, Eds., International Lupine Association, Canterbury, New Zealand, Proceedings of the 12th International Lupine Conference, 14–18 Sept. 2008, Fremantle, Western Australia, 2008.

[2] A. Tolera, "Livestock feed supply situation in Ethiopia: commercialization of livestock agriculture in Ethiopia," in *Proceedings of the 16th Annual Conference of Ethiopian Society of Animal Production (ESAP)*, pp. 21–25, Addis Ababa, Ethiopia, August 2008.

[3] A. Mengistu, "Country pasture/forage resource profiles, Ethiopia," 2003, http://www.fao.org/ag/AGP/AGPC/doc/Counprof/Ethiopia/Ethiopia.htm.

[4] Y. Denkew, "Effect of stage of harvesting on Botanical composition of selected natural pastures for optimum hay production at Andassa," MSc. thesis, Presented to the School of Graduate of Haremaya University, Dire Dawa, Ethiopia, 2004.

[5] Z. Kohajdova, J. Karovičova, and Š. Schmidt, "Lupine composition and possible use in bakery. A review Institute of biochemical and food technology," *Czech Journal of Food Science*, vol. 29, no. 3, pp. 203–211, 2011.

[6] M. Erbas, M. Certel, and M. K. Uslu, "Some chemical properties of white lupine seeds (*Lupineus albus*) Turkey," *Food Chemistry*, vol. 89, pp. 341–345, 2004.

[7] P. J. Van Soest, J. B. Robertson, and B. A. Lewis, "Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition," *Journal of Dairy Science*, vol. 74, no. 10, pp. 3583–3597, 1991.

[8] P. McDonald, R. A. Edwards, J. F. D. Greenhalgh, and C. A. Morgan, *Animal Nutrition*, Longman Group UK Ltd., England, UK, 6th edition, 2002.

[9] S. Brebaum and G. J. Boland, "Sweet white lupine: a potential crop for Ontario," *Canadian Journal of Plant Science*, vol. 5, pp. 71–74, 1995.

[10] M. Aklilu and M. Alemayehu, "Measurements in pasture and forage cropping systems," Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia, Technical Manual 18, 2007.

[11] AOAC (Association of Official Analytical Chemists), *Association of Analytical Chemists Official Methods for Analysis*pp. 12–98, AOAC, Washington, DC, USA, 15th edition, 1990.

[12] P. C. Whiteman, *Tropical Pastures Science*, Oxford University Press, New York, NY, USA, 1980.

[13] H. Tizazu and S. Emire, "Chemical composition, physicochemical and functional properties of lupine (*Lupineus albus*) seeds grown in Ethiopia," *African Journal of Food Agriculture, Nutrition and Development*, vol. 10, no. 8, pp. 3029–3046, 2010.

[14] E. M. Njoka, M. M. Muraya, and M. Okumu, "Plant density and thinning regime effect on maize (Zea mays) grain and fodder yield," *Australian Journal of Experimental Agriculture*, vol. 44, no. 12, pp. 1215–1219, 2004.

[15] N. I. Ashour, K. S. H. Abou, and M. E. Mosalem, "Introduction of mungbean in Egypt. Effect of genotype, planting density and location on mungbean yield," *Egypt Journal of Agronomy*, vol. 20, no. 1-2, pp. 99–108, 1995.

[16] S. Membere, A. Tegegne, and B. P. Hedge, "Feed resource availability, utilization and management in smallholder livestock production systems in Yerer water shed of Ada Libon district," in *Proceeding of the 16th Annual Conference of the Ethiopian Society of Animal Production (ESAP)*, Addis Ababa, Ethiopia, 2008.

[17] F. Rasul, M. A. Cheema, A. Sattar, M. F. Saleem, and M. A. Wahid, "Evaluating the performance of three mungbean varieties grown under varying inter-row spacing," *The Journal of Animal & Plant Sciences*, vol. 22, no. 4, pp. 1030–1035, 2012.

[18] A. Yenesew, A. Abel, and T. Molla, "Best fit practice manual for sweet lupin (*lupinus angustifolius* L.) production," capacity building scaling up of evidence-based best practices in agricultural production in Ethiopia, working paper No. 11, 2015.

[19] S. Pholsen and N. Sornsungnoen, "Effects of Nitrogen and Potassium rates and planting distances on growth yield and fodder quality of a forage Sorghum (*Sorghum bicolor* L. Moench)," *Pakistan Journal of Biological Science*, vol. 7, no. 10, pp. 1793–1800, 2004.

[20] H. L. Bhardwaj, D. E. Starner, and Van Santen, "Preliminary evaluation of white lupine (*Lupinus albus* L.) as a forage crop in the mid-ATLANTIC regions of the United States of America," *Journal of Agricultural Science*, vol. 2, no. 4, pp. 13–17, 2010.

[21] A. Mikić1, V. Perić, V. Dornević, M. Srebrićand, and V. Mihailović, "Anti-nutritional factors in some grain legumes," *Belgrade-zemun UDC*, vol. 633, no. 3, 2009.

[22] M. D. Fraser, R. Fychan, and R. Jones, "Comparative yield and chemical composition of two varieties of narrow-leafed lupin (*Lupinus angustifolius*) when harvested as whole-crop, moist grain and dry grain," *Animal Feed Science and Technology*, vol. 120, no. 1-2, pp. 43–50, 2005.

[23] L. Yeheyis, C. Kijora, M. Solomon, G. Anteneh, and K. J. Peters, "White lupine (*Lupineus albus L.*), the neglected multipurpose crop: its production and utilization in the mixed crop-livestock farming system of Ethiopia," *Livestock Research for Rural Development*, vol. 22, no. 74, 2010.

[24] A. Kitaba, "Effect of stage of growth and fertilizer application on dry matter yield and quality of natural grassland in the highlands of North Shoa, Oromia Region," Msc. thesis, Presented to the School of Graduate of Haremaya University, Dire Dawa, Ethiopia, 2003.

[25] Teklay Abebe Teferi, M. Legesse, and T. Birhane, "Searching and testing of white lupine (*Lupineus albus L.*) for adaptation and resistant to crenate broomrape in Tigray, Ethiopia," *World Journal of Agricultural Sciences*, vol. 11, no. 6, pp. 341–345, 2015.

[26] V. Mihailovic, G. D. Hill, A. Mikic, B. Cupina, and S. Vasiljevic, "White lupin as a forage crop on alkaline soils," in *Lupines for Health and Wealth*, J. A. Palta and J. B. Berger, Eds., International Lupine Association, Canterbury, New Zealand, Proceedings of the 12th International Lupine Conference, 14–18 Sept. 2008, Fremantle, Western Australia, 2008.

[27] W. E. W. Hassan, R. H. Phipps, and E. Owen, "Dry matter and nutritive value of improved pasture in Malaysia," *Tropical Agriculture*, vol. 67, no. 4, pp. 303–308, 1990.

[28] J. Johnston, B. Wheeler, and J. Mckinlay, *Forage Production from Spring Cereals and Cereal-Pea Mixture*, Ministry of Agriculture and Food, Ontario, Canada, 1998.

[29] H.-J. G. Jung and K. P. Vogel, "Lignification of switchgrass (*Panicum virgatum*) and big bluestem (*Andropogon gerardii*) plant parts during maturation and its effect on fibre degradability," *Journal of the Science of Food and Agriculture*, vol. 59, no. 2, pp. 169–176, 1992.

[30] J. R. Wilson, "Variation in leaf characteristics with level of insertion on grass tiller. I. Development rate, chemical composition and dry matter digestibility," *Australia Journal of Agricultural Research*, vol. 27, p. 343, 1989.

[31] J. S. Graybill, W. J. Cox, and D. J. Otis, "Yield and quality of forage maize as influenced by hybrid, planting date, and plant density," *Agronomy Journal*, vol. 83, no. 3, pp. 559–564, 1991.

[32] M. V. D. Wouw, J. Hanson, and L. Samuel, "Morphological and agronomic characterization of a collection of Napier grass (*Pennisetum purpureum*) and *Pennisetum glaucum*," *Tropical Grassland*, vol. 33, pp. 150–158, 1999.

[33] J. D. Kabuga and C. A. Darko, "In sacco degradation of dry matter and Nitrogen in oven dried and fresh tropical grasses and some relationships to in vitro dry matter digestibility," *Animal Feed Science and Technology*, vol. 40, no. 2-3, pp. 191–205, 1993.

[34] T. T. Negash, A. Azanaw, T. Getachew, M. Kibersew, and S. W. Samuel, "Evaluation of Faba bean (*Vicia faba* L.) varieties against chocolate spot (*Botrytis fabae)* in North Gondar, Ethiopia," *African Journal of Agricultural Research*, vol. 10, no. 30, pp. 2984–2988, 2015.

[35] A. Syed, S. Sajid, and M. Rashid, "Evaluation of different oat *(Avena sativa L.)* varieties for forage yield and related characteristics," *Open Access Journal*, vol. 3, no. 1, pp. 13–16, 2015.

[36] W. Hawthorne and G. Fromm, "Effect of hay plus crushed or whole lupin grain on the growth and carcase fat cover of heifers and lambs," *Australian Journal of Experimental Agriculture*, vol. 17, no. 85, pp. 230–233, 1977.

[37] T. Bayable, "Effects of days of harvesting on yield, chemical composition and in vitro organic matter digestibility of Pennisetum purpureum sole or intercropped with Desmodium introtum or Lablab purpureus," MSc. thesis, Presented to the School of Graduate School of Haremaya University, Dire Dawa, Ethiopia, 2004.

[38] L. Yeheyis, C. Kijora, E. Van Santen, and K. J. Peters, "Sweet annual lupines (*Lupineus* spp.); their adaptability and productivity in different agro-ecological zones of Ethiopia," *Journal of Animal Science Advances*, vol. 2, no. 2, pp. 201–215, 2012.