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Research Article

Adaptation Trial of Sweet Lupine (*Lupinus angustifolius* L.) Varieties in West Hararghe Zone, Oromia, Ethiopia

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Abstract

Little or no information is known about the adaptability and uses of sweet lupine in the Oromia region, especially in Hararghe zones where animal feed shortage is the bottleneck for smallholder farmers. This activity was initiated to evaluate and identifying the best performing sweet lupine varieties in herbage yield, best adaptive and high seed yielder from 2020/21 to 2021/22. The results of the analysis of variance indicated a significant ($p<0.05$) variation for most evaluated parameters. The longest date of 50% flowering and maturing date was recorded for Walala but the other varieties were similar. Statistical ($P>0.05$) variation was not recorded. Dry matter yield ranged from 0.66 to 3.10 t/ha at on station while at Quni Segeria and Arba Rakate FTC, it varied between 2.77 to 4.75t/ha and 2.58 to 3.78t/ha respectively. Lupines seed yield varied from 7.56 to 13.93 qt/ha at on station, from 3.92 to 57.5 qt/ha at Quni Segeria FTC, and from 6.22 to 18.6 qt/ha at Arba Rakate FTC. This study showed that there is a high potential to cultivate sweet lupines in the study area. Sweet lupine Walala followed by Propor varieties tolerant to diseases and pests. From this study, it is concluded that the sweet lupine variety Walala followed by Propor was found promising in terms of agronomic traits, DM yield, and seed yield than other varieties during the experimental years that need further evaluation of animal palatability and absorption potential. So, it is possible to recommend Walala and Propor varieties as alternative feed resources under smallholder conditions in the study areas and other places of the West Hararghe zone of the Oromia region with similar climatic and edaphic conditions.

Keywords

Dry Matter Yield, Sweet Lupine, Varieties, West Hararghe

1. Introduction

Ethiopia has the largest livestock population in Africa, with 66 million cattle, 38 million sheep, 46 goats, 2.14 million horses, 10 million donkeys, and 0.36 million mules, and about 7 million camels, 41.35 million poultry [4]. Livestock is a major source of animal protein, power for crop cultivation, means of transportation, export commodities, manure for farmland and household energy, security in times of crop failure, and means of wealth accumulation. The sector contributed up to 40% of agricultural Gross Domestic Product (GDP), nearly 20% of total GDP, and 20% of national foreign exchange earnings [6]. However, the role of the sector towards the country's economy has not been in line with its potential. This is associated with several complex and interrelated factors of which inadequate feed is the major one [19]. Major feed resources for ruminants in the country include natural pasture, crop stubble, road and riverside pas-

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ture, crop residues, and agro-industrial by-products [5]. These feed resources provide insufficient nutrients beyond maintenance requirements leading to low productivity. This situation is aggravated during the dry season when natural pastures are critically deficient in protein and energy content [13]. Thus, supplementation with high nutritive value feed resources is imperative to improve livestock growth performance and productivity in the country. Among the improved animal feed, sweet lupines crops are the most important one.

Sweet lupine (*Lupinus angustifolius L.*) is one of the major crops grown in different soil types. Its growth performance compares better than other lupine species [8]. Lupine is relatively more tolerant to several abiotic stresses than other legumes and has a high potential for the recovery of poor and polluted soils [15]. It is important legume crops that form a critical part of sustainable farming systems [11]. Its seeds are employed as a protein source for animal and human nutrition in various parts of the world [14]. It is nature of adaptation to wide range of climates also making it an attractive crop [21]. The crop is adapted to 1500-3000 m.a.s.l. and is being produced mainly by subsistent farmers [23]. 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 [9].

Lupine (locally in Amharic known as “Gibto” in Ethiopia) is widely used to describe the seeds of different domesticated lupines species. Lupines have twice as much protein as beans, chickpeas, lentils and other legumes [2]. It has crude protein ranging from 30% to 40% of whole seeds [11], digestible organic matter (DOM) content of 86.28% and relatively low alkaloid content [25]. Lupine is produced by smallholder subsistent farmers in Ethiopia [9]. Little or no information is known about the adaptability and uses of sweet lupines in most of Ethiopian regions like Oromia, especially in Hararghe zones. Currently sweet lupine is produced in many countries as a forage or grain legume. Although bitter white lupine is a traditional pulse crop in Ethiopia, sweet lupine is a new crop to the country [24]. Amhara and Benishangul-Gumuz region is the most potential area in Ethiopia, the former being the largest producer [26]. In Ethiopia, about 95.85% of land coverage and 99.29% of total productions were accounted in Amhara and Benishangulgumz region. [20]. But other regions in Ethiopia lack thus potential due to information gaps.

West Hararge is one of the parts of Oromia region that animal feed is the critical point hinders livestock production and productivity. Feed shortage and low quality problems are the first challenge in livestock production in West Hararghe zone [1, 7, 8, 18]. Introduction and promoting improved forage varieties through different mechanisms such as adaptation study, new varieties development and so on to solve animal feed shortage in West Hararghe zone is the most approaches. Among the improved legumes forage is sweet Lupine is the potential and newly introduced forages that have great role to reduce feed shortage. It is important to introduce improved forages (sweet Lupine) to the study area under smallholder farmers so as to alleviate the problems. So, this activity was initiated with the objective of to evaluate, identify and recommend the best adaptable, high yielder and disease resistance sweet Lupine varieties to the study area.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was conducted during the main cropping season of 2020/21 to 2021/22 in three selected districts of West Hararghe zone. Thus, three districts are Gemechis, Chiro Zuria and Daro Lebu. From Chiro Arba Rakate FTC (Farmer Training Center), from Gemechis Quni Segeria FTC (Farmer Training Center) and from Daro Lebu, Mechara Agricultural Research Center (on station) was used.

Table 1. *Study area description.*

Parameters	Daro Labu (On station)	Gemechis (Quni Segeria FTC)	Chiro (Arba Rakate FTC)
Altitude	1050-2710 masl	1213-2662 masl	1221-3021 masl
Latitude	08°27 - 08°69N	08°56 - 08°89N	08°97 - 09°21N
Longitude	040°31 - 040°65E	040°34 - 040°89E	040°64 - 041°09E
Mean Annual rain fall	700 - 1494	683 - 1305	444 - 1264
Mean annual max T	28	27	28
Mean annual Min T	15	13	13
Soil texture	Sandy clay loam	Sandy loam	Sandy clay loam-
Total OM	*0.1 -2.6*	0.0 -3.6	1.143 -2.913
Total N %	*0.01 - 0.16*	0.0 - 0.2	0.0 - 0.146

Parameters	Daro Labu (On station)	Gemechis (Quni Segeria FTC)	Chiro (Arba Rakate FTC)
Total P%	*0.0 – 5.0*	0.0 – 7.0	0.0 -6.65

2.2. Experimental Design and Layout

Five lupines varieties were collected from different research centers that include Vitabor, Bora, Propor, sanabor and Walala and evaluated at the above location for two years. This experiment was conducted with randomized complete block design (RCBD) with four replications of plot size 2 * 2.1 m= 4.2 m^2. These varieties were planted in seven rows with the space of 1m, 1m, 0.3m and 0.1m between block, plot, rows and plant respectively at the last week of June. Fertilizer application was uniformly applied to all plots in the form of nitrogen, phosphorous and sulfur blended fertilizer (NPS) and urea at the rate of NPSB 100 kg/ha and 50kg/ha respectively at the time of sowing and 30kg/ha seed rate was used. All other crop management practices like weeding were done uniformly to all plots as required.

2.3. Data Collection

The collected data for the trial were included 50% flowering date, plot cover, stand vigor, leaf to stem ratio, herbage yield, dry matter yield, disease occurrence, pest infestation and plant height, seed per pod, pod per branch and branch per plant. From each plot, 220 gram samples of lupine varieties were taken and dried in a forced draft oven dry at 105 ℃ for 24 hours to get constant weight of dry matter yield.

2.4. Model and Statistical Analysis

Agronomic data was analyzed using ANOVA by the general linear model procedure of SAS, 2002 version 9.0. Means were separated using Least Significant Difference (LSD) at 5% significant level.

The model:

$$Yijk = \mu + Gi + Ej + Bk(j) + (GE)ij + eijk$$

Where Gi = Variety effect, Ej = Environmental effect, Bk(j) = Block effect, GEij = Variety and Environment interaction, μ = the overall mean and eijk = random error.

3. Results and Discussions

3.1. Analysis of Variance

The results of the analysis of variance indicated that a significant (p<0.05) variation between lupine varieties on 50% flowering date, maturity date, plant height, grain yield, seed per pod and pod per plant but did not showed significance (p>0.05) differences for leaf steam ration, plot cover, diseases, pest, dry matter and branch per plant (Table 2). The interaction effect of Varieties, locations and years showed a significant (p<0.001) variation for all tested parameters except leaf steam ratio. The effect of year also showed a significance (p<0.001) differences for all tested parameters expect diseases and branch per plant. This might be due to the variations of rainfall distribution during the experimental years. Locations also have significant (p<0.001) effect on all parameters except leaf steam ration.

Table 2. *Combined Analysis Mean Sum Square of ANOVA for agronomic parameters.*

Source of variation	Variety	Replication	Year	Location	Var*loc	Var*year	Var*Year*Loc
DF	4	3	1	2	8	4	10
50%FD	30.6***	7.05*	667.41***	205.51***	3.79NS	12.22**	56.73***
MD	47.6***	8.93NS	3499.20***	11801.6***	13.35*	38.5***	930.89***
LSR	13.28NS	3.89NS	506.35***	33.71NS	15.46NS	18.11NS	39.11NS
PC	40.35NS	53.73NS	6424.03***	6544.53***	54.63NS	107.4NS	504.33***
PH	454.7***	11.41NS	294.84***	5106.19***	107.7***	32.96NS	211.67***
DI	0.35NS	0.07NS	0.03NS	1.58**	0.38NS	0.22NS	2.58***
Pest	0.050NS	0.04NS	0.13*	0.13**	0.050*	0.050NS	0.07**
SYQtha	29.18*	55.50NS	7663.37***	3985.29***	37.16NS	16.26NS	1455.88***

Source of variation	Variety	Replication	Year	Location	Var*loc	Var*year	Var*Year*Loc
DMYtha	0.34NS	1.03NS	16.48***	31.84**	0.48NS	0.38NS	4.15***
BPP	20.47NS	85.64NS	86.36NS	235.81***	18.41NS	26.57NS	88.22**
PPP	285.97**	44.32NS	39737.88***	18757.79***	238.69***	200.76*	3684.46***
SPP	0.59*	1.31***	11.41***	1.94***	0.23NS	0.18NS	0.67**

DF = degree freedom, 50FD = 50% flowering date, MD = Maurity date, PC = Plot Cover, DMYtha = dry 50FD = 50% flowering date, MD = Maurity date, PC = Plot Cover, SV = stand vigor, DMYtha = dry matter yield tone per hectare, PH = plant height; SYQtha = Seed yield quintal per hectare, BPP = Branch per plant, PPP = Pod per plant, SPP = Seed per pod

3.2. Date of 50% Flowering and Maturity

Maturity and 50% flowering day were presented in (Table 3). Significance (P<0.05) variation between the varieties on 50% flowering date was observed at Arba Rakate FTC (Farmer Training Center) both years. For Quni Segeria FTC (Farmer Training Center) and on research station, variation was observed only second and first year respectively while no significance (P>0.05) variation was recorded at on station and Quni Segeria FTC for second and first year respectively. Walala variety produced the longest days to 50% flowering at all experimental sites which ranged from 55.5 to 65 days. Sanabor variety produced the shortest days to 50% flowering at on station while Propor, Sanabor, Vitabor and Bora varieties produced the same flowering days. At Quni Segeria FTC, walala variety produced the longest days to 50% flowering whereas the rest varieties produced the same 50% flowering days and at Mieso research site, Propor and Bora produced the shortest days to 50% flowering and Walala variety produced longest days to 50% flowering. The present result days to 50% flowering is shorter than the finding of [3] as reported from 74 to 85.75 days, [22] from 58 to 74 days but similar findings with the reports of [9] from 58.33 to 60.66 days to 50% flowering.

Significance (P<0.05) variation between the sweat lupine varieties on maturing days were observed at on research station for both testing years, Quni Segeria FTC at second year while no significance (P>0.05) variation was recorded at Arba Rakate FTC for both study years. Days to maturity varied at on station from 97 to 114.75 days for Propor and Walal, from 121 to 160.75 days for Sanabor and Walala at Quni Segeria and from 109.5 to 121.75days for Propor and Walala at Arba Rakate FTC respectively. The longest maturing date was recorded for Walala varieties at on station both years which ranged from 99.75 to 114.75 days while the rest varieties were similar to each other. Walala variety also produced the longest days to maturity at Quni Segeria for second year with 160.75 days. Relatively mid altitude (On station) showed early maturing than highland altitude (Quni Segeria and Arba Rakate FTC). Different scholars reported various sweet lupines maturity date. The present result is early maturing than the report of [3] from 163 to 196 days to mature, [22] from 219.67 to 233 days but similar reports with the findings of [9] from 117.33 to 119. 66 days to maturity.

Table 3. Mean 50% flowering and Maturity date of Lupines varieties tested across locations.

	Date of 50% Flowering						Date of Maturity					
Varieties	On station		Q/Segeria		A/Rakate		On station		Q/Segeria		A/Rakate	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Vitabor	56^{a}	63.25	55.25	61.0^{b}	55.5^{a}	54.0b^{c}	97.25^{b}	110.75^{ab}	121	152.5^{b}	121	109.75
Bora	54.25^{a}	63	55.75	59.8^{b}	53.25^{b}	54.75^{b}	98.5^{ab}	108.25^{ab}	121.75	153.25^{b}	121.25	109.5
Propor	55^{a}	63.75	56.5	60.0^{b}	55.75^{a}	52.5^{c}	97^{b}	106.25^{b}	122.25	150.5^{b}	120.75	109.5
Walala	55.5^{a}	65	56.75	65.0^{a}	56.5^{a}	59.0^{a}	99.75^{a}	114.75^{a}	121.5	160.75^{a}	120.25	111
Sanabor	51.5^{b}	64.25	56.25	61.5^{b}	55.75^{a}	53.5^{bc}	98^{ab}	106.50^{b}	121	151.0^{b}	121.75	110.75
Mean	54.45	63.85	56.1	61.45	55.35	54.75	98.1	109.30	121.5	153.60	121	110.10
CV	3.21	2.99	1.99	2.72	2.29	2.66	1.2	4.68	1.25	1.54	0.87	1.3

Varieties	Date of 50% Flowering						Date of Maturity					
	On station		Q/Segeria		A/Rakate		On station		Q/Segeria		A/Rakate	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
LSD	2.69	2.94	1.72	2.58	1.95	2.24	1.82	7.88	2.38	3.64	1.63	2.20
P-Value	**	NS	NS	**	**	***	**	*	NS	***	NS	NS

Q/Segeria = Quni Segeria FTC, A/Rakate = Arba Rakate FTC

3.3. Dry Matter and Seed Yield

Dry matter yield and seed yield was presented in (Table 4). There was a statistical (P<0.05) variation between the varieties at Arba Rakate FTC in both testing years and only first year on station. On the other hand statistical (>0.05) variation was not recorded at Quni Segeria FTC for both years that similar findings were reported by [24] forage yield was not significantly different between the local landrace and lupines group at all locations except at one location. This result showed that the dry matter content of sweet lupine forage was not affected by the interaction of location, variety and year. Dry matter yield ranged from 0.66 3.10 t/ha at on station while at Quni Segeria, it was varied between 2.77 to 4.75t/ha. At Arba Rakate FTC, dry matter yield was ranged from 2.58 to 3.78t/ha. Walala produced the highest dry matter yield at on station while the rest four varieties were produced similar results. Propor and Walala varieties were produced the highest dry matter yield at Arba Rakate FTC and no dry matter yield difference at Quni Segeria FTC for both years. Relatively sweat lupines varieties gives higher dry matter yield for highland altitude location than midland altitude location. The forage yield of sweet lupines in this study is comparable with the yield reported by [9] who reported a mean forage yield of 3.46t/ha, 3.3 t/ha as reported by [25] but higher than the finding of [17] who reported dry matter yield from 0.52t/ha to 1.36 t/ha and [24] from 0.7 t/ha to 1.6 t/ha. Propor and Sanabor varietis performed better than other varieties in terms of dry matter yield.

Seed yield of sweet lupine varieties used for the present study has not showed significance (p>0.05) variation among varieties at Quni Segeria both study years and first year at on station and similar results reported by [24] there was no significant difference in seed yield among all determinate and indeterminate groups of lupines across locations except at one location. On the other hand, there were statistical (p<0.05) variation between the varieties at Arba Rakate FTC both experimental years and second year at on station. Lupines seed yield varied from 7.56 to 13.93 qt/ha at on station while from 3.92 to 57.5qt/ha. On the other hand, at Arba Rakate FTC, it was varied from 6.22 to 18.6 qt/ha. The maximum and minimum seed yield was recorded at Quni segeria and on station during the second experimental year. The seed yield of the present finding is higher than the reports of [22] from 2.68 to 4.7qt/ha of same varieties but lower than the findings of [24] who reported the maximum seed yield to 33qt/ha, from 16.8 to 43.75qt/ha as reported by [3]. Walala and Propor varieties are high seed yielder than the rest varieties so as recommended for the study area.

Table 4. Mean Dry matter Yield and Grain yield of Lupines varieties tested across locations.

Treatments	Dry matter Yield (t/ha)						Seed yield (qt/ha)					
	On station		Q/Segeria		A/Rakate		On station		Q/Segeria		A/Rakate	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Vitabor	2.88	0.78^{ab}	2.77	3.22	3.12^{ab}	3.02^{bc}	11.89^{ab}	7.56	3.92	46.4	6.22	12.3^{bc}
Bora	2.91	0.62^{ab}	3.84	2.87	3.19^{ab}	3.56^{ab}	11.91^{ab}	9.62	4.63	52.3	9.33	8.5^{c}
Propor	2.61	0.66^{ab}	4.75	3.14	2.76^{b}	3.78^{a}	10.81^{b}	7.95	6.31	57.5	7.01	12.4^{bc}
Walala	2.8	0.92^{a}	3.54	3.16	2.58^{b}	3.72^{a}	12.33^{ab}	8.69	4.12	52	9.93	18.6^{a}
Sanabor	3.10	0.71^{ab}	3.52	3.86	3.44^{a}	2.66^{c}	13.93^{a}	9.82	4.08	48	9.74	14.2^{ab}
Mean	2.86	0.74	3.68	3.25	3.02	3.35	12.17	8.73	4.61	51.2	8.45	13.2

Treatments	Dry matter Yield (t/ha)						Seed yield (qt/ha)					
	On station		Q/Segeria		A/Rakate		On station		Q/Segeria		A/Rakate	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
CV	17.06	24.6	38.47	45.7	14.41	11.54	12.75	17.57	59.5	16.2	39.84	25.9
LSD	0.75	0.28	2.18	2.29	0.67	0.59	2.39	2.36	4.23	12.8	5.18	5.3
P-Value	NS	*	NS	NS	*	**	**	NS	NS	NS	NS	*

Q/Segeria = Quni Segeria FTC, A/Rakate = Arba Rakate FTC, (qt/ha) = quintal per hectare, (t/ha) = tone per hectare

3.4. Diseases and Pest Occurrences

Diseases caused by *Fusarium spp* are the most important ones in sweet lupine production [25]. The results of insects and diseases occurrence were presented in (Table 5). From the present result, there is no significance (p>0.05) variation in terms of diseases occurrence among the varieties except first year at Quni Segeria FTC. Relatively, Sanabor followed by Propor varieties infected by fusarium wilt while Bora and Walala varieties were tolerant. In contrast to the present result, [22] that Vitabor, Sanabor, Probor and Bora was not infected by the diseases.

Figure 1. Fusarium oxysporum f.sp. lupini (wilt of lupin).

Table 5. Mean Insect Incidences and Diseases occurrence of Lupines varieties tested across locations.

Varieties	Insect Incidences						Diseases occurrence					
	On station		Q/Segeria		A/Rakate		On station		Q/Segeria		A/Rakate	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Vitabor	1	1	1	1^{b}	1	1	2.5	1	1.25^{b}	1	1.5	1
Bora	1	1	1	1.50^{a}	1	1	2	1	1.25^{b}	1	1.25	1
Propor	1	1	1	1.50^{a}	1	1	2.5	1	1.5^{b}	1	2	1
Walala	1	1	1	1^{b}	1	1	2	1	1.5^{b}	1	1.5	1
Sanabor	1	1	1	1^{b}	1	1	2.25	1	2.75^{a}	1	1.25	1
Mean	1	1	1	1.20	1	1	2.25	1	1.65	1	1.5	1
CV	0	0	0	26.4	0	0	31.9	0	35.4	0	38.9	0
LSD	0	0	0	0.48	0	0	1.11	0	0.9	0	0.9	0
P-Value	NS	NS	NS	*	NS	NS	NS	NS	**	NS	NS	NS

Q/Segeria = Quni Segeria FTC, A/Rakate = Arba Rakate FTC

3.5. Seed Per Pod and Pod Per Plant

There were significance (P<0.05) variation of seed per pod at on station and Quni Segeria during second year but there were no statistical (p>0.05) variation between the varieties at Arba Rakate FTC both years and on station and Quni Segeria second trial year (Table 6). Seed per pod varied from 3.73 to 5.1 at on station, from 3.55 to 5.3 at Quni segeria FTC and from 3.7 to 4.2 at Arba Rakate FTC. The highest seed per pod were produced during the second experimental year at all locations that might be due to rain fall differences. Different scholars reported different seed per pod of different lupines varieties. [3] reported from 4.10 to 7.34, from 4 to 5.3 as reported by [22, 10]. The present finding of seed per pod of different lupines varieties were similar with different scholars.

There were a significant (p<0.05) variation for pod per plant of lupine varieties across all location except second year at Arba Rakate FTC during second year (Table 6). Pod per plant for on station ranged from 11.2 to 24.9 at on station, for Quni Segeria, it was varied from 12.4 to 126.1 and at Arba Rakate FTC, it was ranged from 10.45 to 33.45. The tested varieties were produced more pod per plant during the second year at all locations. Bora and Sanabo varieties produced higher pod per plant than the other tested varieties. [27, 3, 22] reported significance variation among lupines varieties in terms of pod per plant ranged from 17.3 to 33.1, 24.85 to 48.10 and 9.67 to 25 respectively.

Table 6. *Mean Seed per Pod and Pod per Plant of Lupines varieties tested across locations.*

	Seed per Pod						Pod Per Plant					
Treatments	**On station**		**Q/Segeria**		**A/Rakate**		**On station**		**Q/Segeria**		**A/Rakate**	
	2021	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
Vitabor	4	5.1a	3.8	5b	4.2	4.2	11.2^{b}	15.7b	12.4^{b}	78.8^{b}	14.08^{b}	28.9
Bora	3.83	4.8^{ab}	3.55	4.9^{bc}	4.1	4.1	11.65^{b}	21.4^{ab}	15.7^{a}	126.1^{a}	14.4^{ab}	28.35
Propor	4.12	4.6^{b}	4.3	5.3^{a}	3.95	3.95	11.55^{b}	20.1^{ab}	14.1^{ab}	95^{b}	13.95^{b}	28.15
Walala	3.83	4.2^{c}	3.95	4.8^{c}	3.7	3.7	14.25^{a}	24.9^{a}	12.8^{b}	90.6^{b}	10.45^{c}	33.45
Sanabor	3.73	4.75^{b}	3.6	4.8^{c}	3.85	3.85	11.55b	23.5^{a}	14.8^{a}	103.2^{ab}	16.4^{a}	27.45
Mean	3.9	4.67	3.84	4.92	3.96	3.96	12.04	21.12	13.96	98.72	13.92	29.26
CV	10.54	4.16	15.37	3.1	15.56	15.56	13.69	21.57	8.05	18.84	11.78	23.22
LSD	0.63	0.29	0.91	0.24	0.95	0.95	2.54	7.02	1.73	28.7	2.52	10.47
P-Value	NS	*	NS	*	NS	NS	*	*	**	**	**	NS

Q/Segeria = Quni Segeria FTC, A/Rakate = Arba Rakate FTC

3.6. Plot Cover and Leaf-Steam Ratio

The result of plot cover and leaf-steam ratio is present in (Table 7). There were no statistical (p>0.05) difference between the varieties both for plot cover and leaf steam ratio but statistical (p<0.05) variation was recorded for plot cover at on station both years. Walala and Bora varieties produced better plot cover at on station second and first experimental year respectively. Plot cover increases from mid to high land for all tested lupines varieties.

Table 7. *Plot cover and leaf stem ratio.*

Treatments	Plot Cover						Leaf stem ratio					
	On station		Q/Segeria		A/Rakate		On station		Q/Segeria		A/Rakate	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Vitabor	67.5[ab]	57.5[b]	71.25	96.3	82.75	96.25	1.50	1.71	1.89	1.09	1.52	1.42
Bora	70[a]	62.5[ab]	72.5	97.5	70	96.75	1.92	1.71	1.52	1.65	1.54	1.43
Propor	65[ab]	56.3[b]	73.75	97.5	75	98.5	1.58	1.37	1.70	1.17	1.73	1.49
Walala	53.75[b]	76.3[a]	73.75	96.3	81.25	98.5	1.92	1.29	1.77	1.44	1.59	1.5
Sanabor	66.25[ab]	68.8[ab]	67.5	99	85	98	1.71	1.50	1.61	1.38	1.61	1.25
Mean	64.5	64.3	71.75	97.3	78.8	97.4	1.72	1.52	1.69	1.35	1.59	1.42
CV	15.29	16.1	16.31	2.52	16.13	2.31	24.30	24.97	16.41	33.12	20.99	23.13
LSD	15.19	15.9	18.03	3.77	19.59	3.46	0.65	0.58	0.43	0.69	0.52	0.51
P-Value	*	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Q/Segeria = Quni Segeria FTC, A/Rakate = Arba Rakate FTC

3.7. Variety Adaptability and Stability Analysis

Mean squares of genotypes, environments and GEI were presented in (Table 8). According to AMMI analysis, only environments is highly significant ($p < 0.001$), indicating the existence of differential responses of environments for the varieties. There were no statistical ($p>0.5$) variation between the varieties.

Table 8. *ANOVA table for AMMI model.*

Source	d.f.	s.s.	m.s.	v.r.	F pr
Total	119	196.43	1.651		
Varieties	4	1.37	0.342	0.27	0.8946
Environments	2	63.72	31.861	39.45	<0.001
Block	9	7.27	0.808	0.65	0.7559
Interactions	8	3.87	0.484	0.39	0.9256
IPCA 1	5	3.20	0.640	0.51	0.7670
IPCA 2	3	0.67	0.222	0.18	0.9114
Error	96	120.21	1.252		

Interaction principal component analysis (IPCA) scores and stability values (ASV) presented in (Table 9). Stability analysis methods are often used by breeders to identify genotypes that have stable performance and respond positively to improvements in environmental conditions [16]. AMMI stability value (ASV) indicates the stability of varieties. Varieties having low ASV are considered more stable while those with high values are less stable [12]. Accordingly, both Propor and Walala varieties where scored lowest ASV values for dry matter yield and seed yield indicated that the most stable varieties than the others tested varieties.

Table 9. *IPCA1, IPCA2, ASV and mean dry matter and seed yield of five lupines varieties over three environments.*

Varieties	IPCA1	IPCA2	AVS	Mean DM yield (t/ha)	IPCA1	IPCA2	AVS	Mean seed yield (qt/ha)
Vitabor	0.46052	0.03768	5.629 (5)	2.630	0.52043	0.4871	0.739 (1)	14.71
Bora	0.15940	-0.32996	0.339 (3)	2.837	-0.58494	0.80679	0.911(4)	16.05
Propor	-0.18127	-0.16454	0.259 (1)	2.944	-0.5548	-0.41866	0.846 (2)	17.00
Walala	0.14883	0.07508	0.304 (2)	2.785	0.44069	-0.86592	0.894(3)	17.62
Sanabor	-0.18748	0.38174	0.393 (4)	2.885	1.07862	0.39069	3.003(5)	16.62

Walala followed by Propor varieties were nearly closed to the origin and the most stable with little responsive to the variety environment interaction whereas the rest varieties far from the origin are sensitive to environmental changes and the most unstable (figure 2). Propor variety produced the largest dry matter yield that high yielder and wider stability performance variety is the most desirable for wider area recommendation.

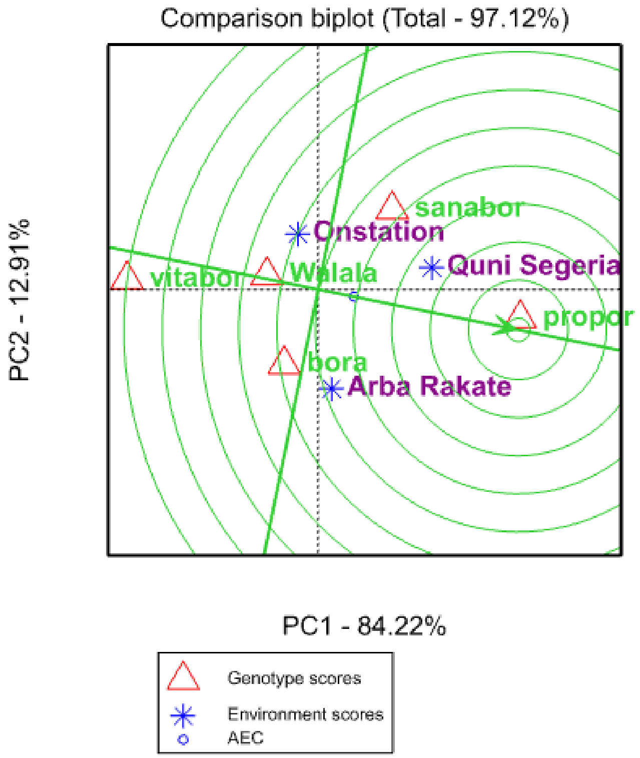

Figure 2. *AMMI GGbiplot for dry matter yield.*

Environments suitability is also classified according their position found in the quadrant. Kuni Segeria and on station found in 1st and 2nd quadrant were favorable environments whereas, Arba Rakate found in 4th quadrant were considered as unfavorable environments for dry matter yield production (figure 3). According to the present study, the ideal environment for sweet lupine production is Kuni segeria followed by on station.

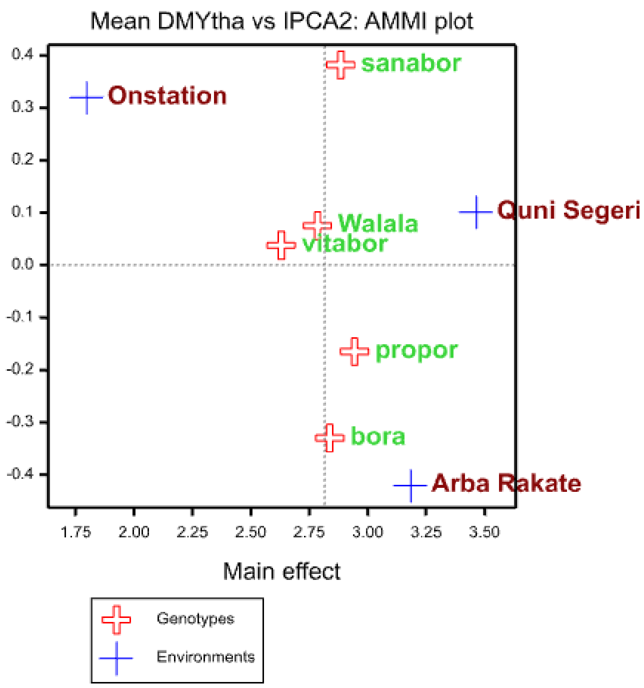

Figure 3. *AMMI GGbiplot ideal environment for dry matter yield.*

4. Conclusion and Recommendation

The present results showed significant differences among sweet lupines for agronomic traits for 50% flowering date, maturity date, seed yield, seed per pod and pod per plant while significance variation was not recorded for mean dry matter yield, pest and diseases, plot cover and leaf stem ration. The mean variation of varieties for seed yield ranged from 17.00 to 17.61qt/ha with a mean seed yield of 16.63qt/ha. The varieties of dry matter yield was ranged from 2.94t/ha to 2.88t/ha with an average of 2.82 t/ha. The highest dry matter was recorded from Propor variety and seed yield was from Walala followed by Propor varieties.

The two varieties were most stable across different agro ecologies. So, it is possible to recommend Walala and Propor varieties as alternative feed resources under smallholder conditions in the study areas and other places of West Hararghe zone of Oromia region with similar climatic and edaphic conditions.

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Data Availability Statement

The Data used to support the results of this work is available from the corresponding author upon request at any time.

Conflicts of Interest

The authors declare no conflicts of interest.

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