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Participatory evaluation of lupine genotypes on biomass and grain yield performance and nutritional value in the highland of Ethiopia

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ABSTRACT

A study was conducted to evaluate the adaptability, yield performance and nutritional value, and to identify farmers preferred lupine genotypes. Four lupine genotypes were evaluated using participatory approach at Arbegona and Bule districts of Ethiopia on the farmer's plots. The experimental layout followed a randomised complete block design with four replications. Farmers as well as researchers gave the first rank for accession No. 239042 and accession No. 239047 and least for Sanabor (Accession No. 144) in overall performance. Moreover, according to the results of the current study, accession No. 239004 and 239042 were the best lupine genotypes, which gave the greater grain yield, forage dry matter production and nutritive value than the other accession tested. Based on the laboratory evaluation, sweet lupine forage and seed can be used as homegrown protein source in livestock feeding. Farmers preferred all the tested lupine genotypes for their after assessing its grain yield. Even though Sanabor (Accession No. 144) was inferior in its grain yield, the farmers preferred the Sanabor mainly due to their early maturity, short growth habit, lodging tolerance, despite its high vegetative growth. Thus, the consideration of farmers' preference for forage crops is crucial for increased adoption of improved forage crops.

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Farmer's preference; grain yield; lupine genotypes; nutritional value; participatory

Introduction

In the highland areas of Sidama Regional State and Southern Nations, Nationalities, and Peoples' Region State of Ethiopia livestock production is inseparably linked with crop production because of the mixed crop livestock farming system. Crop and livestock are closely integrated throughout the highlands in a complex of competitive and complementary ways (CSA 2017). The major feed resources in these areas are natural pasture and crop residues. However, due to the high rate of human population growth, natural pasture is being cultivated and converted into a cropland. On the other hand, crop residues especially cereals have a very poor feeding value with poor metabolisable energy, negligible available protein, and seriously deficient in mineral and vitamins (Solomon 2001). Agro-industrial by-products are high in nutritive value, but they are expensive and less accessible to the smallholder farmers in rural areas. Therefore, looking for other alternative home-grown protein supplements is crucial to improve livestock production and productivity. Growing and using legume crops, as sweet lupine that have high nutritive value is one option to solve this

problem (Yenesew et al. 2015). Therefore, to solve the burden of feed shortage under the existing situation in the mixed crop livestock farming system, it is very important to look for a multipurpose, highly productive and less labour demanding leguminous crop so that it can be used to develop efficient feeding system in the area and easily adopted by farmers.

White Lupine is a traditional crop in Ethiopia. It is grown in the North-Western part of the country (Nigusie 2012) by smallholder farmers in the Amhara and Benshangul Gumuz Regions and local white lupine in Ethiopia is a very important traditional multipurpose crop and is grown in mixed crop livestock farming systems (Yeheyis et al. 2010). Yeheyis et al. (2010) also noted that under traditional management systems the average grain yield potential of the crop was 1.2 t/ha. However, the use of the crop as human food and as livestock feed is limited due to its bitter taste attributed to its relatively high alkaloid content (1.43%) (Yeheyis et al. 2011). In parts of Africa, adaptation trials have shown that it is possible to grow sweet lupine in high potential areas of Africa (Riga et al. 2021). Lupine (locally in Amharic known as 'Gibto' in Ethiopia) is widely used to describe the seeds of different

domesticated lupine species. Lupines are members of the genus *lupineus* L. in the legume family (Fabaceae). Taxonomically, lupine belongs to the class of Magnoliophyta (Angiosperm), subclass Magnoliatae (Dicotyledoneae) and order Fabales (Kurlovich 2002). Lupine is a cool season crop, relatively tolerant to spring frost, adapted to well drained, coarsely textured and neutral to acidic soils (Putnam et al. 1992). Its seeds are employed as a protein source for animal and human nutrition in various parts of the world (Kohajdova et al. 2011). Lupine grain contains high amount of protein (32.2%), fibre (16.2%), oil (5.95%) and sugar (5.85%) (Tadele et al. 2014).

Participatory Research is a research to action approach that emphasises direct engagement of local priorities and perspectives (Cornwall and Jewkes 1995). A deliberate choice of participatory research methods can help researchers more deeply engage stakeholders and communities at each step of the research process. Such engagement allows research to benefit from the collective wisdom of both researchers and communities, which in turn creates more findings that are meaningful translated to action (Vaughn and Jacquez 2020).

So far, livestock feed is a critical problem in Ethiopia and lupine has a potential to meet nutrient needs by incorporating either the seed or the forage into ruminant diets (Ruiz and Sotelo, 2001). Both the seeds and forage have been utilised for ruminant diets worldwide however, lupine genotype were not introduced and evaluated for their adaptability in Sidama regional state and Southern Nations, Nationalities, and Peoples' Region State of Ethiopia. Participatory principles provide farmers' views, their acceptance of the intervention and information on the compatibility of the intervention within the farming system and an opportunity to refine further (Anwar et al. 2012). The aim of the study was to evaluate the adaptability, yield performance and nutritional value of lupine genotypes, and to identify farmer who has preferred lupine genotypes at Arbegona district of Sidama regional state and Bule district of Southern Nations, Nationalities, and Peoples' Region State of Ethiopia.

Materials and methods

Description of the study area

The experiment was conducted on the farmer's plots for the two consecutive years (2016 and 2017) at Arbegona district of Sidama Regional State and Bule district of Gedeo Zone in Southern Nations, Nationalities and Peoples Regional State of southern Ethiopia (Table 1) during the main cropping season. The test locations represent the highland areas ranging in altitude from 2521

Table 1. Description of the study area for geographical position and physico-chemical property of the soils.

Parameter	Districts (locations)	
	Arbegona	Bule
Latitude	6° 41' North	6°18' North
Longitude	38° 43' East	38° 24' East
Elevation (metre above sealevel)	2521	2793
Annual rain fall	1400	1187
Soil type	Nitosol	Nitosol
Soil class	Loam	Loam
pH (1:1 H ₂ O)	4.36	4.74
Total organic matter (%)	2.02	3.53
Total available Nitrogen (%)	0.32%	0.17
Available phosphorus (ppm)	18.3 ppm	22.6

Note: ppm = parts per million, % = .percentage.

to 2793 metre above sea level. The farming systems of the study areas is mixed crop livestock production. The rainfall pattern is characterised by two rainy seasons (the main and short rainy seasons). The main rainy season extends from June to October, whereas the short rainy season from March to April.

Treatments and experimental design

The experiment was laid out in a randomised complete block design with four replications. The experimental materials consisted of the four sweet lupine genotypes: Accession No. 239004 (T1), Accession No. 239042 (T2), Accession No. 239047 (T3) and Sanabor (T4). These four lupin genotypes were selected for their higher grain yields and nutritive values. The seeds were obtained from the Amhara Agricultural Research Institute, Ethiopia and Ethiopian Biodiversity Institute. A plot size was 1.2 m * 4 m = 4.8 m² was allocated for sweet lupine production from each participating farmer. Seed rate was 80 kg ha⁻¹. The inter row spacing was 30 cm, while the intra row spacing was 7 cm. The land was prepared by a tractor and mould-board plow used for final plots preparation and levelled by human power at the start of the rainy season (June). The trial was planted at the beginning of the main rainy season (June) and the experiment was established at two locations in Arbegona and Bule districts of Ethiopia. Planting was done by hand on a well-prepared seedbed and fertiliser was not applied. Weeding was done manually twice, at seedling and just before flowering stages.

Sampling and sample processing

During sampling, each plot was divided in half crosswise with an effective plot size of 1.2 m × 2 m. One-half was used for forage sampling and the other for seed sampling. Forage sampling was done when the plants reached around 50% flowering stage and seed sampling at maturity. In both the cases the sampling was done

from the middle two rows, excluding the border rows. Forage was harvested from the centre of the plots in an area equivalent to $1.1 \text{ m} \times 1 \text{ m}^2 = (1.1 \text{ m}^2)$. Harvesting was done by manually using a sickle, leaving a stubble height of 5 cm, and the harvested herbage was weighed fresh in the field. Representative fresh forage samples of 500 g were taken from each plot and oven-dried at 60 °C for 48 h to determine chemical composition. For dry matter yield determination, samples were dried at 105 °C overnight. The seed samples were air-dried till constant weight. After drying, both the forage and seed samples were ground using a hammer mill to pass through a 1-mm stainless steel sieve and stored in airtight plastic bags for chemical analyses.

Chemical composition analyses

Total ash content was determined by combusting the samples in a muffle furnace at 550°C for 6 h. Nitrogen was determined by the Kjeldahl method (AOAC 1990) and crude protein (CP) content was calculated as $N \times 6.25$. The neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) contents were determined according to Van Soest and Robertson (1985). The *in vitro* organic matter digestibility (IVOMD) was determined by the method of Tilley and Terry (1963) as modified by Van Soest and Robertson (1985).

Famer's participation

The trial farmers participated in all the processes of forage evaluations, starting from land preparation to harvesting. The information on farmers' perceptions on the lupin species was collected using ranking and scoring tools (preference ranking) with a group of 30 farmers (20 males and 10 females) in each district. The major farmers' criteria considered in the evaluation of lupin species were vegetative growth, biomass yield, branches/plant, pod/plant, palatability, seed size, seed colour, fast growing condition, early maturity, seed dispersion condition and not logging ability. The farmers have been demonstrated how to rank the criteria in order of importance using ranking cards numbered 1–4, where seven is signed the highest preference and one is the lowest.

Data analysis

Differences among treatments were tested using analysis of variance procedures of Statistical Analysis System (SAS, 2002) general linear model to compare treatment means. Least significant difference at 5% significance level was used for comparison of means. The model used for data analysis was $Y_{ijkl} = \mu + A_i + B_j + L_k + Y_l + AL_{ik} + AY_{il} + LY_{kl} + ALY_{ijk} + e_{ijkl}$. Where: Y_{ijkl} is the response; μ is the overall mean; A_i is the *i*th treatment effect; B_j is the block *j*th effect, L_k is the *k*th location; Y_l is the *l*th year of harvesting effect. AL_{ik} , AY_{il} and LY_{kl} are the interaction of treatment, location and year effect. e_{ijkl} is the experimental random error.

Results and discussion

Agronomic performance, yield and yield component of sweet lupine

Analysis of variance showed that there was a significant difference between lupin genotypes for plant height, branch per plant, pod per plant, dry matter and grain yield (Table 2). Sanabor (Accession No. 144) had significantly ($P < 0.05$) shorter plant height than Accession No. 239004 and Accession No. 239042. Among the tested genotypes, Accession No. 239042 and Sanabor (Accession No. 144) gave a significantly higher branch per plant. Sanabor (Accession No. 144) had significantly ($P < 0.05$) lower grain yield than the other lupine genotypes due to its high seed disappearing before harvest. Accession No. 239004, Accession No. 239042 and Accession No. 239047 were late maturing, taking a mean of 170 days to maturity. However, Sanabor (Accession 144) was the earliest and took 120 days to maturity. In the current study, the mean yield and yield components varied among lupine genotypes are consistent with the findings of Mulugeta et al. (2015) who reported that landraces in general were late maturing, i.e. took a mean of 179 days to mature. The earliest local accession (Acc12) took 168 days to mature, which was still a long time. However, Sanabor (Acc144) was the earliest and took 131 days to maturity. Farmers complained about the late-maturing lupine genotype, due to difficulty to

Table 2. Mean of agronomic trait, dry matter and grain yield of lupin species at Arbegona and Bule districts of Ethiopia.

Treatments	Plant height (cm)	Branch/Plant	Pod/plant	Dry matter yield (t/ha)	Grain yield (t/ha)
1. Accession No. 239004	111a	13 ^{bc}	33 ^c	0.52 ^d	2.57 ^a
2. Accession No. 239042	110a	16 ^{ab}	27 ^d	1.34 ^b	2.36 ^a
3. Accession No. 239047	107a	11 ^c	38 ^a	1.36 ^a	2.46 ^a
4. Sanabor (Accession No. 144)	72b	20 ^a	35 ^b	0.84 ^c	0.37 ^b
LSD (5%)	16	4	3	0.009	1.10
p-value	0.0001	0.0004	0.0001	0.0001	0.0010

^{a, b, c}Mean followed by different superscript letters within columns indicate significant differences ($p < 0.05$) for treatments, LSD = least significant difference.

Table 3 Mean chemical composition of lupine genotype tested at Arbegona and Bule districts of Ethiopia.

Treatments	Ash	NDF	ADF	ADL	CP	IVOMD
1. Accession No. 239004	15.28 ^a	48.25 ^a	36.39 ^b	5.38 ^b	23.38 ^a	68 ^a
2. Accession No. 239042	15.21 ^a	47.25 ^b	35.94 ^c	5.41 ^b	22.50 ^b	67 ^b
3. Accession No. 239047	15.01 ^a	48.06 ^a	36.09 ^{bc}	5.46 ^b	22.50 ^b	66 ^c
4. Sanabor (Acce. No. 144)	14.64 ^b	46.75 ^c	38 ^a	5.79 ^a	23.88 ^a	65 ^d
LSD (5%)	0.29	0.47	0.36	0.23	0.57	0
<i>p</i> -value	0.0001	0.0001	0.0001	0.0041	0.0001	0.0001

^{a, b, c}Mean followed by different superscript letters within columns indicate significant differences ($p < .05$) for treatments, LSD = least significant difference, CP = crude protein, NDF = neutral detergent fibre, ADF = acid detergent fibre, ADL = acid detergent lignin, IVOMD = *in vitro* organic matter digestibility.

keep from aftermath free grazing of livestock, just after harvesting of other early-matured field crops.

The lupine genotypes were evaluated for their adaptability, yield performance and nutritional value, and to identify farmers preferred lupine genotypes. There was a significant difference in plant height, seed per pod, pods per plant, dry matter yield and grain yield among the lupine species (Table 2). Three genotypes i.e. Accession No. 239004, Accession No. 239042 and Accession No. 239047 were late in days to maturity (170 days) than the remaining Sanabor species. The broad-leafed lupin genotypes, Accession No. 239004, Accession No. 239042 and Accession No. 239047 were significantly taken higher days to maturity, which was more than six months. On the contrary, Sanabor was extra early to mature. This indicated that the farmers mainly due to difficulty to keep from aftermath free grazing of livestock just after harvest of other field crops during the dry period complained the late-maturing species. In the farming, system there is always free grazing of animals on the stubble residue after harvest. In the same way, the long maturing species were significant with maximum plant height than the earlier species and cause lodging of the plant. This could be a probability due to the morphological divergence of the species. The highest pod per plant was obtained from lupine genotype, Accession No. 239047 and the lowest pods per plant was obtained from Sanabor (Accession No. 144). This may have a significant impact on the yield of the lupine genotypes. This study revealed that there was a proportional relationship with days to flowering, maturity, plant height and pods per plant among the genotypes.

In the current study of sweet lupine genotypes, Accession No. 239047 gave the highest forage dry matter yield (1.36 t/ha) while Sanabor (Accession No. 144) sweet lupine genotypes had the lowest forage dry matter yield (0.84 t/ha). The result of this study disagreed with Riga et al. (2021), who reported a mean forage dry matter yield of 3.84 t/ha from the Sanabor (Accession No. 144) when harvested at three months of age. However, the forage dry matter yields were lower than reported by Fraser et al. (2005) (8.45 t/ha) from narrow-leafed lupine in the United Kingdom. On the contrary, the forage dry matter

yields were similar as reported by Tessema (2017) (1.4 t/ha) from narrow-leafed sweet lupine in Ethiopia. This variation in forage dry matter yield could be due to differences in the growth environment.

Chemical composition and in vitro digestibility of sweet lupine forage

Ash, Neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) content significantly varied among the lupines genotypes (Table 3). lupin genotypes, Accession No. 239004, Accession No. 239042 and Accession No. 239047 gave higher forage ash content than sanabor. Accession No 2309004 and 239047 had higher forage NDF content than Accession No. 239042 and sanabor, whereas sanabor had here ADF and ADL content than other treatments. The present study indicated that forage total ash content increased as the harvesting days of plant advanced. The increment of total ash with maturity in this study might be due to increased absorption of nutrients during the growth and development of plant tissue.

Lupine genotypes, Accession No. 239004 and anabor gave the highest CP content than Accession No. 239042 and Accession No. 239047. This result indicated that the CP content in samples harvested during the experiment period significantly decreased as the age of the plants advanced. The decline in CP content of plant with increasing stage of harvesting, Accession No. 239042 and Accession No. 239047, except Accession No. 239004. 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 (Agza et al. 2013). However, the CP content of this study was lower than the result reported by Yeheyis et al. (2012), who indicated that the sweet lupine Sanabor contains higher CP content 28.56% in the DM basis in Ethiopia. This effect might be due to a shallower depth of rooting or less efficient soil total nitrogen exploitation at the study areas. The highest and the lowest NDF contents were recorded Accession No. 239004, Accession No. 239047 and Sanabor (Accession No. 144), respectively. The highest and lowest mean forage ADL contents were observed

Table 4. Farmers' ranking and criteria for selection of forage crops tested in six mixed farming system districts of southern Ethiopia (Best 4 and least preferred 1), the number of evaluating farmers (60).

Lupine genotypes	Vegetative growth	Biomass & grain yield	Branches/ plant	Seed yield	Seed size	Seed colour	Early maturity	Low seed dispersion	Palatability	Lodging tolerance	Total score	Overall Performance (%)	Researcher rank	Farmer's rank
Accession No. 239004	4	3	4	4	4	4	3	4	4	3	37	92.5	2nd	2nd
Accession No. 239042	4	4	4	4	4	4	3	4	4	3	38	95.0	1st	1st
Accession No. 239047	4	4	4	4	4	4	3	4	4	3	38	95.0	1st	1st
Sanabor (Accession No. 144)	3	3	3	3	3	4	4	2	4	4	33	82.5	3rd	3rd

on Sanabor (Accession No. 144) and others, respectively. Kitaba and Tamir (2007) reported that as maturity advanced, forage yield increased, but CP content dropped by about 40–50%, ADF and NDF levels increased by 15–25%. This may be further changed by environmental situations such as soil fertility, season, temperature, shade and water stress during growth (Norton and Poppi 1995). This indicated that the lower concentration of soluble carbohydrate replaced by the insoluble cell wall part due to early maturity of plants under the narrow spacing in turn increased the lignin content of the plant. This might be because as the plants grow longer, there is a greater need for structural tissue by increased proportion of stem that has higher structural carbohydrates (cellulose and hemicelluloses).

Farmer's perception

Farmers' ranking criteria for selection of the lupin genotypes tested were given in Table 4 and the overall farmers' preference for the lupine species tested is presented in Figure 1. Farmers' ranking criteria were their higher vegetative growth, seed yield biomass yield, branches/plant, palatability, seed size, seed colour, fast growth rate, early maturity, low seed dispersion condition and not lodging tolerance. Farmers as well as researchers gave the first rank for accession No. 239042 and accession No. 239047 and lowest for Sanabor (Accession No. 144) in overall performance.

Among the lupine genotypes evaluated, farmers gave the highest rank for Sanabor (Accession No. 144) for its early maturity and lodging tolerance. The choice of forages and integration into farming systems also depended on land availability, soil erosion prevalence and livestock husbandry system (Paul et al. 2016). In erosion-prone sites, most farmer's plant grasses for erosion control (Paul et al. 2016); some farmers prefer forage crops that are suitable for intercropping with food crops such as maize and cassava, due to land scarcity. Ba et al. (2014) reported that the main factors that influenced farmers' choice of improved forage varieties were yield, palatability to cattle and ease of establishment. Therefore, the role of forage crops especially in the mixed farming systems requires studying economic importance as related to farmer's benefits, animal performance and the management of natural resources (Kebede et al. 2016).

Overall farmers' ranking scores for the forage crops tested (scores out of $10 \times 4 = 40$ points, higher score indicates higher preference).

Farmers, as well as researchers, gave the first rank for accession No. 239042 and accession No. 239047 and least for Sanabor (Accession No. 144) in overall

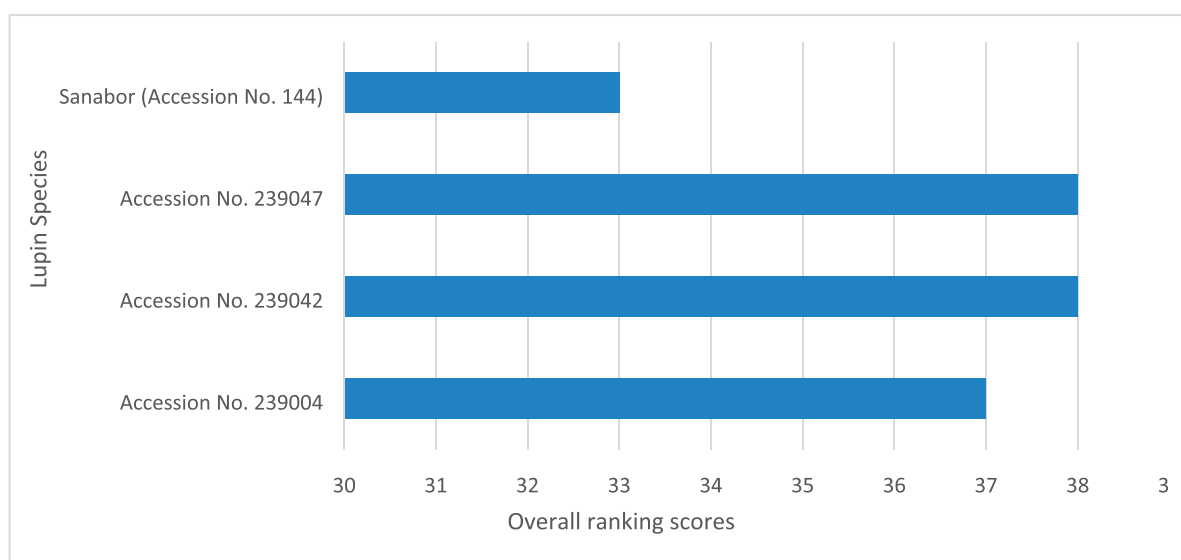


Figure 1. Lupine genotypes and overall score.

performance. Moreover, according to the results of the current study, accession No. 239004 and 239042 were the best lupine genotypes, which gave the greater grain yield, forage dry matter production and nutritive value than the other accession tested. Based on the laboratory evaluation, sweet lupine forage and seed can be used as a homegrown protein source in livestock feeding. Farmers preferred all the tested lupine genotypes for them after assessing its grain yield. Even though Sanabor (Accession No. 144) was inferior in its grain yield, the farmers preferred the Sanabor mainly due to their early maturity, short growth habit, lodging tolerance, despite its high vegetative growth. Thus, the consideration of farmers' preference for forage crops is crucial for the increased adoption of improved forage crops.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

Notes on contributor

Mergia Abera is PhD holder in animal nutrition. He is a senior researcher at Hawassa Agricultural Research Centre under Southern Agricultural Research Institute, Ethiopia. His work

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