Tropical Grasslands-Forrajes Tropicales (2021) Vol. 9(2):216–224
doi: 10.17138/TGFT(9)216-224

Research Paper

Effects of inter-cropping lablab (*Lablab purpureus*) with selected sorghum (*Sorghum bicolor*) varieties on plant morphology, sorghum grain yield, forage yield and quality in Kalu District, South Wollo, Ethiopia

*Efectos de intercalar lablab (*Lablab purpureus*) con variedades seleccionadas de sorgo (*Sorghum bicolor*) en la morfología de las plantas y el rendimiento y calidad del forraje en Kalu District, South Wollo, Etiopía*

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Abstract

An experiment was conducted to determine effects of inter-cropping lablab (*Lablab purpureus*) with 3 selected early-maturing sorghum (*Sorghum bicolor*) varieties (Teshale, Girana-1 and Misikir) on plant morphology, sorghum grain and forage yield and quality plus yield and quality of lablab forage, and to assess farmers' perceptions of the crops in Kalu District, South Wollo, Ethiopia. Seven treatments, namely: T1 - sole lablab (SL); T2 - Teshale + lablab (TL); T3 - Girana-1 + lablab (GL); T4 - Misikir + lablab (ML); T5 - sole Teshale (ST); T6 - sole Girana-1 (SG); and T7 - sole Misikir (SM), were used with 3 replications in a randomized complete block design. The data collected from sorghum varieties were: plant height, number of leaves per plant, leaf area, dry biomass yield and grain yield; and for lablab was: plant height, number of leaves per plant, leaf area, number of branches per plant, number of nodules per plant and dry biomass yield. Grain yield was determined on sorghum at maturity, while lablab was harvested at 50% flowering. Inter-cropped Girana-1 produced yields of both grain and stover and lablab forage similar to those for pure stands of the 2 crops, while inter-cropping of Teshale and Misikir with lablab reduced height, grain and stover yields of sorghum and yields of lablab forage ($P<0.05$). However, crude protein concentration in sorghum stover was enhanced when grown as an inter-crop with lablab ($P<0.05$). Land equivalent ratios for inter-crop treatments were 54–87% higher than those for pure stands. Farmers readily identified the combination Girana-1 + lablab as superior to the other associations. While farmers can improve productivity of their farms by inter-cropping these sorghum varieties, preferably Girana-1, with lablab, more studies should be conducted to determine benefits from sowing other legumes with sorghum. Any improvements in soil N levels from planting the legumes should be quantified.

Keywords: Cropping system, forage biomass, forage cropping, farmers' perceptions.

Resumen

Se realizó un experimento para determinar los efectos de intercalar lablab (*Lablab purpureus*) con 3 variedades seleccionadas de sorgo (*Sorghum bicolor*) de maduración temprana (Teshale, Girana-1 y Misikir) sobre la morfología de la planta, el

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rendimiento y la calidad del grano, calidad del forraje, más el rendimiento. y la calidad del forraje de lablab, y evaluar las percepciones de los agricultores sobre los cultivos en el distrito de Kalu, South Wollo, Etiopía. Siete tratamientos, a saber: T1 - lablab solo (SL); T2 - Teshale + lablab (TL); T3 - Girana-1 + lablab (GL); T4 - Misikir + lablab (ML); T5 - solo Teshale (ST); T6 - solo Girana-1 (SG); y T7 - solo Misikir (SM), se utilizaron con 3 repeticiones en un diseño de bloques completos al azar. Los datos recolectados de las variedades de sorgo fueron: altura de planta, número de hojas por planta, área foliar, rendimiento de biomasa seca y rendimiento de grano; y para lablab fue: altura de planta, número de hojas por planta, área foliar, número de ramas por planta, número de nódulos por planta y rendimiento de biomasa seca. El rendimiento de grano se determinó en sorgo en la madurez, mientras que el lablab se cosechó al 50% de floración. El cultivo intercalado de Girana-1 produjo rendimientos tanto de grano como de rastrojo y forraje de lablab similares a los de los rodales puros de los 2 cultivos, mientras que el cultivo intercalado de Teshale y Misikir con lablab redujo la altura, los rendimientos de grano y rastrojo de sorgo y los rendimientos de forraje (P <0.05). Sin embargo, la concentración de proteína cruda en el rastrojo de sorgo aumentó cuando se cultivó como una siembra intercalada con lablab (P <0.05). Las proporciones de equivalentes de tierra para los tratamientos entre cultivos fueron 54–87% más altas que las de los rodales puros. Los agricultores identificaron fácilmente la combinación Girana-1 + lablab como superior a las otras asociaciones. Si bien los agricultores pueden mejorar la productividad de sus fincas intercalando estas variedades de sorgo, preferiblemente Girana-1, con lablab, se deben realizar más estudios para determinar los beneficios de sembrar otras leguminosas con sorgo. Se debe cuantificar cualquier mejora en los niveles de N del suelo por la siembra de leguminosas

Palabras clave: Biomasa de forrajes, cultivo de forrajes, percepción de los agricultores, sistema de cultivo.

Introduction

In Ethiopia, the dominant farming system is a crop-livestock system (Assefa et al. 2016), in which both crop and livestock production are economically important. In the country, natural pasture is the primary feed source, which has low biomass yield and nutritional value because of mismanagement (CSA 2018). In addition, grazing land is being converted to crop production to provide food for the rapidly increasing human population in the nation. Consequently, the major feed resource for livestock during the dry season is crop residues (CSA 2018), which have low nutritive value, resulting in poor animal performance unless concentrates or conserved hay is fed (Tolera 2008). The average land holding of households is less than a hectare in different areas of Ethiopia (Gedefaw et al. 2019), so integrated usage of land by inter-cropping of food and forage crops would provide efficient resource utilization (Tarekegn and Zelalem 2014). Inter-cropping legumes with cereal crops has multiple advantages in terms of improving biomass yield, nutritive value and land equivalent ratio (Jensen et al. 2020). In an investigation of the diverse potential of a multi-purpose legume, lablab [*Lablab purpureus* (L.) Sweet], for smallholder production systems, increased biomass yield and nutritive value of forage were recorded (Nord et al. 2020). Shehu et al. (2001) reported that inter-cropping of sorghum with lablab improved the protein concentration in cereal stem as well as leaf yield.

Lablab is adapted to most tropical environments (Grotelüschen 2014), producing high yields of fodder with crude protein (CP) in whole plants of 15–21% (Murphy and Colucci 1999). It is resistant to drought, diseases and pests and improves soil fertility; shade tolerance allows it to be grown successfully with tall cereal crops, including maize (Grotelüschen 2014).

However, the local sorghum varieties are becoming less relevant because of unprecedented climatic variability. Moreover, these local varieties are not highly productive and are failing to meet the alarmingly increasing human population´s food demand. The improved early-maturing sorghum varieties, Teshale, Girana-1 and Misikir, are adapted to the study area as reported by several authors (Tesfaye 2013) and are commonly grown in farming systems.This early-maturing feature of sorghum leads to the possibility of sustainable production in moisture-deficient areas. To the best of our knowledge, no studies have been conducted where these sorghum varieties have been inter-cropped with lablab. Among the commonly available improved lablab accessions is cultivar Highworth (lablab accession ILRI 147). A report by Grotelüschen (2014) showed that ILRI 147 had higher protein concentration than 3 other lablab accessions. The growth habit of ILRI 147 is shorter and more horizontally spreading than cultivar Rongai Noir (ILRI 11609) and cultivar Jhansi (ILRI 6529) (Hunegnaw et al. 2016). This growth habit may makes ILRI 147 more compatible than other accessions for inter-cropping with Teshale, Girana-1 and Misikir sorghum varieties, which have shorter plant height than local sorghum landraces. Hence, we initiated this study to determine the outcomes from inter-cropping these sorghum varieties with lablab to improve productivity of cropping land on farms in the area.

Materials and Methods

Climate

The field experiment was conducted in Kalu district of South Wollo Zone at Harbu Agricultural TVET (Technical Vocational Education and Training) College (10°55' N, 39°46' E; 1,484 masl). The daily mean minimum and maximum temperatures are 8.1 and 23.2 °C, respectively, and average annual rainfall is 1,091 mm (National Meteorology Agency, Kombolcha Branch 2018). The average monthly minimum and maximum temperatures and monthly rainfall for the experimental site during the study are presented in Figure 1.

Soil characteristics

To evaluate the physico-chemical properties of the soil, a Vertisol, at the experimental site, soil samples were taken randomly before planting from 5 spots diagonally across the site to a depth of 20 cm and mixed to make a composite sample. The composite soil sample was air-dried, lightly crushed with a wooden pestle and mortar and screened through a 2 mm sieve for analysis of physical and chemical properties, i.e. soil texture, electrical conductivity, organic carbon, soil pH, cation exchange capacity, total nitrogen and available phosphorus (Olsen) at Sirinka Agricultural Research Centre Soil Laboratory (Table 1).

Trial design

A randomized complete block design was used to conduct the field experiment with 3 replications. Each plot measured 3.75 m long and 3 m wide (11.25 m^2) and the gross area used in the experiment was 370.5 m^2. Each plot of inter-cropping consisted of 5 rows of sorghum and 4 rows of lablab.

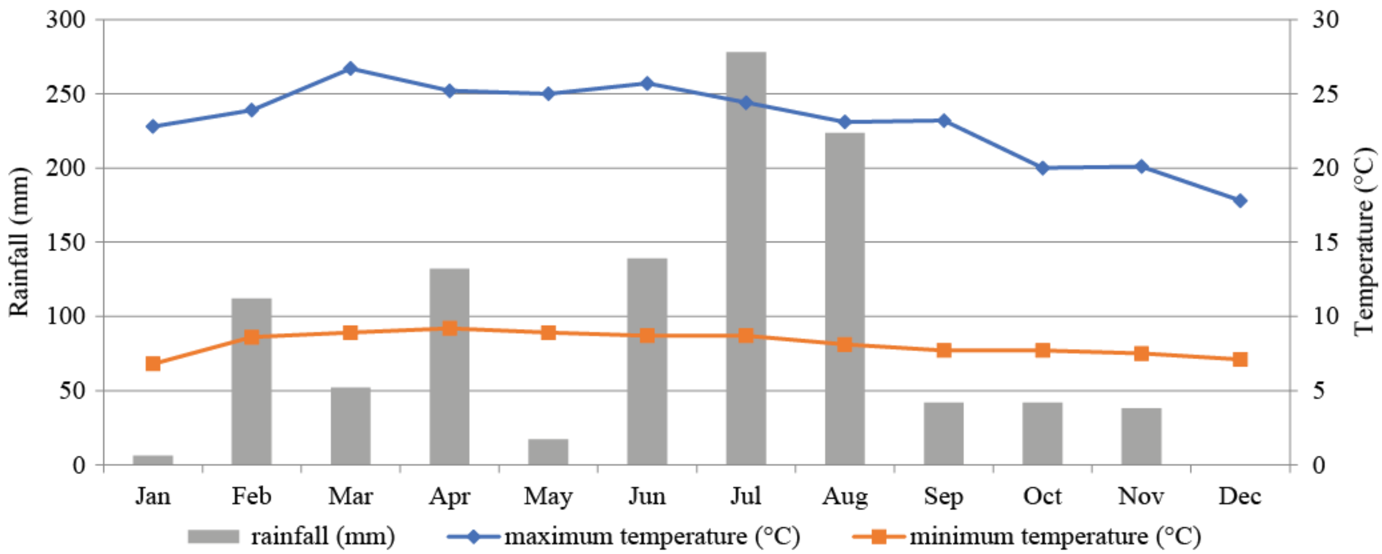

Figure 1. Mean monthly minimum and maximum temperature (°C) and rainfall distribution (mm/month) during 2018 in Kalu district at Harbu. Source: Annual report, National Meteorology Agency, Kombolcha Branch 2018.

Table 1. Physico-chemical properties of the soil at the experimental site before sowing.

Parameter	Value	Rating
Particle size distribution		
Sand (%)	28.3	
Silt (%)	39.2	
Clay (%)	32.5	
Textural class	Silty clay loam	
pH	6	Slightly acidic
Cation exchange capacity (cmol$_{(+)}$/kg soil)	23.2	High
Electrical conductivity (dS/m)	2.33	Low
Total N (%)	0.16	Medium
Available P (ppm)	23.6	High
Organic carbon (%)	1.16	Medium
Organic matter (%)	2	Medium

Spacing between plots and blocks were 1 and 1.5 m, respectively. Three sorghum varieties (Teshale, Girana-1 and Misikir) were inter-cropped with lablab accession ILRI 147 (which was adapted to and recommended for the area), while pure stands of the sorghum varieties and lablab were also grown. This provided 7 treatment combinations consisting of: lablab (LL) only (T1); Teshale + lablab (TL) (T2); Girana-1 + lablab (GL) (T3); Misikir + lablab (ML) (T4); Teshale (TT) only (T5); Girana-1 (GG) only (T6); and Misikir (MM) only (T7).

The land was ploughed 3 times to provide a good seedbed and divided into plots. Sorghum varieties were sown into holes within rows with 75 cm between rows and 25 cm between plants within rows; pure lablab was also sown at the same spacing (Mpairwe et al. 2002). Fifteen days after emergence sorghum plants were thinned to a single healthy plant per hole. Inter-cropped lablab was sown down the center of the sorghum inter-row spaces, i.e. 37.5 cm from the rows of sorghum; with 20 cm between plants, at 18 days after sorghum was sown. All plots of sorghum received a basal application of 100 kg N:P:S fertilizer (19:38:7) per ha at sowing and were top-dressed with 50 kg urea/ha when knee-high (40 days after sowing), while all plots were weeded at 45 days after sowing. Sole lablab plots received a basal application of N:P:S (19:38:7) at 46 kg/ha at sowing according to FAO (2012) recommendations.

Plant height, leaf area and number of leaves, branches and nodules of lablab were assessed on 10 randomly selected plants from the middle 2 rows of each plot at 50% flowering stage (at about 3 months after sowing) (ILRI 2013). Plant height, leaf area and number of leaves of sorghum varieties were taken from 10 randomly selected plants from the middle 3 rows of each plot at milk stage (about 15 days after flowering). Leaf area was calculated as Leaf area = leaf length × maximum width × 0.75 using the method described by Stickler et al. (1961).

When sorghum seed-heads were mature, 10 plants were selected at random from the middle rows. Seed-heads were harvested by hand using sickles, were sun-dried and threshed and the grain was weighed to estimate grain yields. After grain harvesting sorghum stove was harvested by cutting at 10 cm above ground level. Similarly, the whole plot of lablab was harvested at 5 cm above ground level for biomass yield determination. Harvested material was weighed fresh using a balance with sensitivity of 0.1 g. Sub-samples (500 g) were taken from each plot, chopped into small pieces and air-dried until constant weight was recorded.

Dried forage samples from each plot were ground and subjected to chemical analyses at Debre Birhan Agricultural Research Center, Animal Nutrition Laboratory to determine: ash concentration by combusting in a muffle furnace at 500 °C for 6 hours; N concentration by Kjeldahl method; and neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) by the procedures of Van Soest et al. (1991).

The land equivalent ratio (LER) for inter-cropping was calculated, using the formula:

LER = (IYS/SYS) + (IYL/SYL) (Mead and Willey1980), where:

SYS = yield of pure sorghum; IYS = inter-cropped yield of sorghum; IYL = inter-cropped yield of lablab; and SYL = yield of pure lablab.

Farmers were invited to visit the experimental area during the vegetative stage to form their views and perceptions about the forages when inter-cropped. The perceptions of 8 male and 4 female farmers were recorded through participation using 6 evaluation criteria set by farmers themselves. The criteria were: biomass yield; speed of growth; compatibility of sorghum with lablab; drought tolerance; grain yield; and ability to stay green.

Data analysis

Analysis of variance was used to analyze data on morphological characteristics, forage dry matter yield and chemical composition, grain yield and LER. Fisher's LSD test ($P<0.05$) was employed for separation of means carried out using the procedure of SAS (2002).

The model used for data analysis was:

$Y_{ij} = \mu + B_i + T_j + e_{ij}$,

where:

Y_{ij} = all dependent variables;

μ = overall mean;

B_i = effect of i^{th} block;

T_j = effect of j^{th} treatment; and

e_{ij} = the random error.

Results

With the exception of Girana-1, sorghum varieties and lablab were affected morphologically by inter-cropping (Table 2).

Girana-1 outperformed Teshale and Misikir in terms of plant height, number of leaves/plant and total leaf area, whether grown as a pure stand or when inter-cropped with lablab ($P<0.01$; Table 2). Similarly, height and number of leaves per plant for Girana-1 were not affected by inter-cropping with lablab ($P>0.05$), while both parameters for Teshale and Misikir were reduced by growing in association with lablab ($P<0.01$). Surprisingly leaf area of Girana-1 was not affected when grown with lablab ($P>0.05$), while leaf area was reduced in the case of Teshale and Misikir (P<0.01). For lablab, inter-cropping with Teshale or Misikir reduced plant height and total leaf area per plant (P<0.01). Number of branches per plant and number of nodules per plant for lablab were reduced when lablab was grown with any of the sorghum cultivars (P<0.01).

Both grain and stover yields of Teshale and Misikir were reduced (P<0.001) by inter-cropping with lablab (Table 3; P<0.001). Sowing lablab with sorghum reduced forage yields of lablab but differences were significant (P<0.05) only for Teshale and Misikir.

Inter-cropping of sorghum varieties with lablab increased both ash and CP concentrations in sorghum stover but lowered NDF, ADF and ADL concentrations (P<0.001; Table 4). Crude protein levels in stover of Girana-1 reached 7% when grown with lablab.

Inter-cropping lablab with sorghum varieties significantly (P<0.001) increased ash concentration but reduced CP, NDF, ADF and ADL concentrations of lablab (Table 5).

While land equivalent ratios (LERs) for biomass yield (non-grain component) for inter-cropping lablab with sorghum varieties were less than unity for each species, the combined LERs were significantly (P<0.001) greater than unity, with increases of 54–87% (Table 6). Girana-1 + lablab produced the greatest yield advantage over pure stands.

Farmers' perception of the inter-cropping technology was assessed during a field day. Farmers preferred inter-cropping to planting pure stands of sorghum and lablab and ranked Girana-1+ lablab as the preferred option (data not presented). They said that: Girana-1 inter-cropped with lablab had largest heads and seed size; its superior plant height provided physical support for climbing lablab; and it was more suitable for lablab growth and development as compared with Teshale and Misikir.

Table 2. Plant morphology of 3 sorghum varieties and lablab sown alone or inter-cropped.

Treatment	PH (cm)		NLPP		LA (cm^2)		NBPP	NNPP
	Sorghum	Lablab	Sorghum	Lablab	Sorghum	Lablab	Lablab	Lablab
SL	-	238a[1]	-	58.4a	-	138a	11.9a	17.4a
TL	189c	198b	10.5c	45.5c	602c	118b	6.4bc	13.8b
GL	245a	231a	11.3a	52. 0b	631a	127ab	8.4b	14.2b
ML	176e	172c	9.6e	41.8c	579e	103c	4.4c	10. 0c
ST	192b	-	10.9b	-	608b	-	-	-
SG	247a	-	11.4a	-	633a	-	-	-
SM	183d	-	10.0d	-	595d	-	-	-
LSD	3.5	26.0	0.16	6.35	6.4	8.22	1.85	1.96
Prob.	***	**	***	**	***	**	**	***

[1]Within columns means followed by different letters differ significantly (P<0.01; P<0.001). SL = sole lablab (T1); T L = Teshale + lablab (T2); GL = Girana-1 + lablab (T3); ML = Misikir+ lablab (T4); ST = sole Teshale (T5); SG = sole Girana-1 (T6); SM = sole Misikir (T7); PH = plant height; NLPP = number of leaves per plant; LA = leaf area; NBPP = number of branches per plant; and NNPP = number of nodules per plant.

Table 3. Forage yields of lablab plus stover and grain yields of sorghum sown alone or inter-cropped.

Treatment	Dry biomass (t DM/ha)		Grain yield (quintal/ha)
	Sorghum stover	Lablab	Sorghum
SL	-	5.65a	-
TL	7.75c[1]	4.08b	54.6c
GL	9.08a	5.01a	59.5a
ML	5.84e	3.47b	49.1 e
ST	7.90b	-	56.6b
SG	9.08a	-	59.5a
SM	6.24d	-	52.5d
LSD	0.005	0.635	0.365
Prob.	***	**	***

[1]Means within columns followed by different letters differ significantly (P<0.01; P<0.001). 1 quintal = 100 kg. SL = sole lablab (T1); TL = Teshale + lablab (T2); GL = Girana-1 + lablab (T3); ML = Misikir + lablab (T4); ST = sole Teshale (T5); SG = sole Girana-1 (T6); SM =sole Misikir (T7).

Table 4. Chemical composition (%) of stover from sorghum varieties sown alone or inter-cropped with lablab.

Treatment	Ash	CP	NDF	ADF	ADL
TL	12.1a	5.8b	52.5d	39.1d	10.1d
GL	12.1a	7.0a	51.0e	37.6e	7.9e
ML	11.2b	5.8c	53.2c	40.9c	10.2c
ST	9.1d	3.5e	68.8a	50.5a	12.1b
SG	9.4c	5.6d	63.4b	47.2b	12.1b
SM	8.0e	2.2f	68.8a	50.5a	12.2a
LSD	0.0048	0.0041	0.0217	0.0079	0.0043
Prob.	***	***	***	***	***

Means within columns with different letters differ significantly ($P<0.001$). CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; ADL = acid detergent lignin; SL = sole lablab (T1); TL =Teshale + lablab (T2); GL = Girana-1 + lablab (T3); ML = Misikir + lablab (T4); ST = sole Teshale (T5); SG =sole Girana-1 (T6); SM = sole Misikir (T7).

Table 5. Chemical composition (%) of lablab forage sown alone or inter-cropped with sorghum varieties.

Treatment	Ash	CP	NDF	ADF	ADL
SL	8.7b	15.9a	35.4a	27.8a	6.4a
TL	9.8a	14.8c	32.2c	24.3c	6.1c
GL	9.8a	15.6b	32.2c	24.3c	6.1c
ML	9.8a	14.5d	33.3b	25.8b	6.3b
LSD	0.012	0.2	0.0067	0.0046	0.01
Prob.	***	***	***	***	***

Means within columns with different letters differ significantly ($P<0.001$). CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; ADL = acid detergent lignin; SL = sole lablab (T1); TL = Teshale + lablab (T2); GL = Girana-1 + lablab (T3); ML = Misikir + lablab (T4); ST = sole Teshale (T5); SG = sole Girana-1 (T6); SM = sole Misikir (T7).

Table 6. Land equivalent ratio for biomass yield (non-grain component) of inter-cropping sorghum varieties with lablab.

Treatment	Land equivalent ratio of dry biomass			Yield advantage (%)
	Sorghum	Lablab	Total	
TL	0.98b	0.72b	1.70b	70
GL	0.99a	0.88a	1.87a	87
ML	0.93c	0.61b	1.54c	54
LSD	0.0014	0.143	0.1417	-
CV	0.0623	8.5101	3.6486	-
Prob.	***	*	**	-

Means within columns with different superscripts differ significantly ($P<0.05$). TL = Teshale + lablab; GL = Girana-1 + lablab; ML = Misikir + lablab; SL = sole lablab (T1); TL =Teshale + lablab (T2); GL = Girana-1 + lablab (T3); ML = Misikir + lablab (T4); ST = sole Teshale (T5); SG = sole Girana-1 (T6); SM = sole Misikir (T7).

Discussion

This study has shown the substantial benefits in terms of total yields of forage to be obtained from inter-cropping lablab and sorghum in comparison with sowing the 2 crops as pure stands. Not only was total DM yield of forage increased but also the CP concentration in the sorghum stover was increased. It was of interest that growth of Girana-1 was not significantly affected by being grown in association with lablab, while both Teshale and Misikir suffered depression in yields of both stover and grain. This finding was in spite of the fact that Girana-1 was the tallest sorghum accession but did not significantly suppress the growth of lablab in terms of plant height or total leaf area, although it did reduce the number of branches per plant. Musa et al. (2012) reported that dry forage and grain yields of sorghum varieties (S1007, Pioneer and local Shahlaa) varied between varieties when inter-cropped with cowpea.

This finding of an overall lack of response of Girana-1 to inter-cropping with lablab is in contrast to the results with Teshale and Misikir, which behaved according to results from other published studies. Shehu et al. (2001) found that inter-cropping of lablab with sorghum caused a marked reduction in yields of sorghum stem, leaves and grain, while Isaacs et al. (2018) found a reduction in height of maize following inter-cropping with lablab. Similarly, significant reduction of number of leaves and leaf area of sorghum was shown when inter-cropped with legumes (Arshad et al. 2014). This suppresion in growth would normally be expected when two crops are inter-planted because of increased competition for light, nutrients and moisture.

The increased CP concentration in sorghum stover when inter-cropped with lablab is in agreement with the findings of Akhtar et al. (2013) and Mbahi et al. (2017), who reported increases in CP concentration in sorghum when inter-cropped with lablab and groundnut, respectively. This response is probably due to increased soil N availability resulting from atmospheric N fixation by rhizobia on lablab root nodules. Significantly higher CP concentration in Girana-1 than in Teshale and Misikir, regardless of whether pure stands or inter-cropped with lablab, suggests that Girana-1 had better ability to extract nitrogen from soil than the other varieties, as it also presented higher grain and stover yields.

The lower NDF, ADF and ADL concentrations in inter-cropped sorghum stover were in line with reports that showed inter-cropping sorghum with lablab significantly reduced NDF concentration in forage produced (Mpairwe et al. 2002; Amole et al. 2015), while ADF concentration in sorghum was lower when inter-cropped with groundnut and lablab than when sorghum was grown as pure stands (Zhang et al. 2015). Zhang et al (2015) and Amole et al. (2015) reported lower fiber levels in sorghum inter-cropped with legumes than in pure sorghum.

The consistently lower concentrations of NDF and ADF in Girana-1 than in Teshale and Misikir, regardless of whether grown as pure stands or inter-cropped with lablab, is further evidence of the superiority of this variety over Teshale and Misikir.

The reduction in number of leaves per plant and number of branches per plant for lablab when inter-cropped with sorghum conforms with the findings of Redfearn et al. (1999) and Iqbal et al. (2018) that inter-cropping sorghum with soybean reduces the number of leaves and branches of soybean, respectively. Similarly, Ngongoni (2007) found that inter-cropping maize with lablab and cowpea significantly reduced number of nodules per plant of both legumes.

The reduction in biomass yield of inter-cropped lablab relative to pure lablab might be a function of competition for light, soil moisture and nutrients. Growth of lablab was depressed more by competition with sorghum than sorghum growth was depressed by competition with lablab, indicating that sorghum was more competitive than lablab under the conditions of the study. Since sorghum was much taller than lablab, one might suspect that competition for light played a significant role in differences which occurred.

Inter-cropping lablab with the 3 sorghum varieties was more advantageous than sole cropping, since 54–87% more land would be required with sole cropping to produce a similar quantity of dry forage as obtained with inter-cropping. This finding is in line with reports that LER values greater than 1 occurred when sorghum was inter-cropped with cowpea and rice bean (Singh Pal et al. 2014). The highest LER value obtained with inter-cropped Girana-1 + lablab is further evidence of the benefits of planting sorghum and lablab under an inter-cropping system in this environment. In a study of inter-cropping of maize with vetch, berseem clover and beans, LER exceeded 1 in combinations of both maize hybrids studied (704 and 301) and vetch (Ozpinar 2009).

Girana-1 was so superior to other sorghum varieties, in terms of greater height, larger seed heads, largest seed size and compatibility with lablab, that it was not surprising that most participating farmers identified Girana-1 + lablab as the preferred combination.

Conclusion and recommendations

The findings showed that of the 3 sorghum varieties inter-cropped with lablab, Girana-1 was superior to Teshale and Misikir in overall performance. Even when planted as a pure crop Girana-1 was superior to the other 2 varieties and continued to produce at the same level when intercropped with sorghum, while Teshale and Misikir had reduced performance relative to their performance as pure stands. It is obvious that farmers in the area can improve productivity of their land by inter-cropping Girana-1 with lablab. Further studies should be conducted to test findings with other legume species and to quantify any improvements in soil N produced by the legume.

Acknowledgments

The first author acknowledges Bahir Dar University (BDU) for allowing the study to be conducted, and Amhara National Regional State Technical, Vocational and Enterprises Development Bureau for financial support.

References

(Note of the editors: All hyperlinks were verified 16 April 2021.)

Akhtar MF; Ahmad AH; Zamir MSI; Khalid F; Mohsin AU; Afzal M. 2013. Agro-qualitative studies on forage sorghum (*Sorghum bicolor* L.) sown alone and in mixture with forage legumes. Pakistan Journal of Science 65(2):179–185. bit.ly/3xHUPK3

Amole TA; Oduguwa BO; Onifade SO; Jolaosho AO; Amodu JT; Arigbede MO. 2015. Effect of planting patterns and age at harvest of two cultivars of *Lablab purpureus* in *Andropogon gayanus* on agronomic characteristic and quality of grass / legume mixtures. Tropical Agricultural Science 38(3):329–346. bit.ly/3xEgeUq

Arshad M; Nawaz R; Shahnawaz M; Sarfaraz MS; Ahmad S; Ranamukhaarachi SL. 2014. Effect of legume type, nitrogen dose and air quality on biomass and bioethanol production in sweet sorghum-legume Intercropping. Agriculture & Forestry 60(3):257–274. bit.ly/3t55mf3

Assefa G; Mengistu S; Feyissa F; Bediye S. 2016. Animal feed resources research in Ethiopia: Achievements, challenges and future directions. In: Ethiopian Institute of Agricultural Research 50 years of service for ethiopian agriculture. Ethiopian Journal of Agricultural Sciences, Special issue, Addis Ababa, Ethiopia. p. 141–156.

CSA (Central Statistical Agency). 2018. Federal Democratic Republic of Ethiopia Central Statistical Agency, Agricultural sample survey. Volume II. Report on Livestock and Livestock Characteristics. Addis Ababa, Ethiopia.

FAO (Food and Agriculture Organization). 2012. Grassland species index. *Lablab purpureus*.

Gedefaw AA; Atzberger C; Seher W; Mansberger R. 2019. Farmers' willingness to participate in voluntary land Consolidation in Gozamin District, Ethiopia. Land 8(148):1–21.doi: 10.3390/land8100148

Grotelüschen K. 2014. *Lablab Purpureus* (L) Sweet: a promising multipurpose legume for enhanced drought resistance in smallholder farming-systems of eastern Kenya. M.Sc. Thesis. University of Göttingen, Germany.

Hunegnaw B; Mekonen W; Walie M; Amanie A; Tamir S. 2016. Participatory selection of different lablab accessions for under sowing on maize in Western Gojjam, Ethiopia. In: Abegaz S; Yeheyis L, eds. Proceedings of the 9th Annual Regional Conference on Livestock Completed Research Activities, 9–20 March 2015, Bahir Dar, Ethiopia. p. 46–58.

Isaacs KB; Snapp SS; Kelly JD; Chung KR. 2016. Farmer knowledge identifies a competitive bean ideotype for maize–bean intercrop systems in Rwanda. Agriculture & Food Security 5:15. doi: 10.1186/s40066-016-0062-8

ILRI (International Livestock Research Institute). 2013. Lablab (*Lablab purpureus* cultivar Rongai) for livestock feed on small-scale farms (English Version). ILRI, Nairobi, Kenya. hdl.handle.net/10568/1815

Iqbal MA; Iqbal A; Abbas RN. 2018. Spatio-temporal reconciliation to lessen losses in yield and quality of forage soybean (*Glycine max* L.) in soybean-sorghum intercropping systems. Bragantia 77(2):283–291. doi: 10.1590/1678-4499.2017043

Jensen ES; Carlsson G; Hauggaard-Nielsen H. 2020. Intercropping of grain legumes and cereals improves the use of soil N resources and reduces the requirement for synthetic fertilizer N: A global-scale analysis. Agronomy for Sustainable Development 40(5):1–9. doi: 10.1007/s13593-020-0607-x

Mead R; Willey RW. 1980. The concept of a land equivalent ratio and advantages in yields from intercropping. Experimental Agriculture 16:217–228. doi: 10.1017/S0014479700010978

Mpairwe DR; Sabiiti EN; Ummuna NN; Tegegne A; Osuji P. 2002. Effect of intercropping cereal crops with forage legumes and source of nutrients on cereal grain yield and fodder dry matter yields. African Crop Science Journal 10(1):81–97.doi: 10.4314/acsj.v10i1.27559

Murphy AM; Colucci PE. 1999. A tropical forage solution to poor quality ruminant diets: A review of *Lablab purpureus*. Livestock Research for Rural Development 11:Article #21. bit.ly/3cbhy8F

Musa EM; Elsheikh EAE; Ahmed IAM; Babiker EE. 2012. Intercropping sorghum (*Sorghum bicolor* L.) and cowpea (*Vigna unguiculata* L.): Effect of *Bradyrhizobium* inoculation and fertilization on minerals composition of sorghum seeds. International Scholarly Research Notices 2012:1–9. doi: 10.5402/2012/356183

National Meteorology Agency, Kombolcha Branch. 2018. Annual Report, Kalu District 2018. Meteorological data.

Ngongoni NT; Mwale M; Mapiye C; Moyo MT; Hamudikuwanda H; Titterton M. 2007. Evaluation of cereal-legume intercropped forages for smallholder dairy production in Zimbabwe. Livestock Research for Rural Development. Volume 19:129. bit.ly/2PR8xta

Nord A; Miller NR; Mariki W; Drinkwater L; Snapp S. 2020. Investigating the diverse potential of a multi-purpose legume, *Lablab purpureus* (L.) Sweet, for smallholder production in East Africa. PLoS ONE 15(1):e0227739. doi: 10.1371/journal.pone.0227739

Ozpinar S. 2009. Tillage and cover crop effects on maize yield and soil nitrogen. Bulgarian Journal of Agricultural Science. 15(6):533–543. bit.ly/33j5QDy

Redfearn DD; Buxton DR; Devine TE. 1999. Sorghum intercropping effects on yield, morphology and quality of forage soybean. Crop Science 39(5):1380–1384. doi: 10.2135/cropsci1999.3951380x

SAS (Statistical Analysis Systems). 2002. SAS Version 9.1. SAS Institute Inc., Cary NC, USA.

Shehu Y;Alhassan WS; Pal UR; Phillips CJC. 2001. The effect of intercropping *Lablab purpureus* L. with sorghum on yield and chemical composition of fodder. Journal of Agronomy and Crop Science 183(2):73–79. doi: 10.1046/j.1439-037x.1999.00338.x

Singh Pal M; Reza A; Joshi YP; Panwa UBS. 2014. Production potential of forage sorghum (*Sorghum bicolor* L) under different intercropping systems. Agriculture for Sustainable Development 2(1):87–91. bit.ly/2Pj64qI

Stickler FC; Wearden S; Pauli AW. 1961. Leaf area determination in grain sorghum. Agronomy Journal 53:187–188. doi: 10.2134/agronj1961.00021962005300030018x

Tarekegn A; Zelalem T. 2014. Evaluation of the performance of herbaceous forage legumes under sown with maize under irrigation condition of Megech, North Gondar, Ethiopia. Livestock Research for Rural Development 26: Article #102. lrrd.org/lrrd26/6/tare26102.html

Tesfaye E. 2013. Adoption of improved sorghum varieties and farmers' varietal trait preference in Kobo District, North Wollo Zone, Ethiopia. M.Sc. Thesis. Haramaya University, Haramaya, Ethiopia.

Tolera A. 2008. Feed resources and feeding management: A manual for feedlot operators and development workers. Ethiopia Sanitary and Phytosanitary Standards and Livestock & Meat Marketing Program (SPS-LMM), USAID, Addis Ababa, Ethiopia.

Van Soest P; Robertson J; Lewis B. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. Journal of Dairy Science 74(10):3583–3597. doi: 10.3168/jds.S0022-0302(91)78551-2

Zhang J; Yin B; Xie Y; Li J;Yang Z; Zhang, G. 2015. Legume-cereal intercropping improves forage yield, quality and degradability. PloS ONE 10(12):e0144813. doi: 10.1371/journal.pone.0144813

(Received for publication 3 May 2020; accepted 13 March 2021; published 31 May 2021)