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RESEARCH ARTICLE

Pre-extension demonstration of inter-cropping of improved forages with food and cash crops at Semen Bench Woreda, Southwest Ethiopia

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Abstract
Pre-extension demonstration study was conducted in the North Bench district, Bench Sheko Zone, South-western Region, Ethiopia, in 2020/2021 main cropping season. The objective of the study was to demonstrate fodder production from improved forage legumes intercropped in food and cash crops and to evaluate the nutritional quality and compatibility of forage legumes. Three forage legumes, namely lablab, vetch, and cowpea, intercropped in maize, whereas alfalfa and desmodium intercropped in coffee. The demonstration was laid out in a randomized complete block design with ten replications on a farmer's farm field with a participatory approach. The legumes were intercropped in maize three weeks after maize planting. The results revealed that maize plant height, maize grain yield, and maize stover biomass yields were not significantly ($p > 0.05$) different among treatments. However, significantly higher legume biomass yield and total biomass yield were obtained from maize-lablab-based intercropping as compared to maize-vetch and maize-cowpea-based intercropping systems. Similarly, the maize-lablab-based intercropping system recorded a significantly ($p < 0.05$) higher crude protein yield. The lower legume biomass yields were obtained from desmodium and alfalfa intercropped in coffee. Participant farmers were also very interested in forage production from maize-lablab-based intercropping systems as compared to maize-vetch, maize-cow pea, desmodium-coffee, and alfalfa-coffee-based intercropping systems. Therefore, farmers are recommended to intercrop lablab in maize to overcome the animal feed shortage in the study area.

Keywords: Animal feed shortage, Biomass yield, Crude protein, Forage legumes, Intercropping.

Introduction

In many developing countries, livestock play an important role in the livelihoods of most small-scale farmers as sources of food in the form of meat and milk, cash income, and manure. Similarly, livestock production is an important economic activity that produces both food and non-food commodities in most sub-Saharan countries (Sere *et al*., 2008).

The Ethiopian livestock sub-sector contributes about 10% to total export earnings, primarily through the export of ruminant animals, 45% of agricultural GDP, including economic values and non-marketed services, and 37 to 87% of household income (FAO, 2019). Despite its significant contribution, livestock productivity in Ethiopia is lower than the African average, mainly due to a shortage of feed. Hence, to exploit the potential of livestock, the use of improved forages is one of the key strategies to improve the income of smallholder farmers.

Ethiopia has the largest livestock population of any country in Africa, which is estimated to be about 55.3 million cattle, 27.35 million sheep, 28.16 million goats, 1.96 million horses, 6.95 million donkeys, 0.36 million mules, 1.1 million camels, and 51.35 million poultry (CSA, 2015). Even though the country has a lot of livestock resources, it is not using them properly due to various problems, such as a shortage of feed resources and poor quality, which remain the major bottlenecks to livestock production in the mid-and highlands of Ethiopia.

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The major feed resources in Ethiopia are grazing pasture, crop residue, improved feed, hay, by-products, and others (CSA, 2021). However, the area of grazing land is decreasing from time to time due to poor management and the increment of crop cultivation (FAO, 2004). Thus, improved forage grass and legume species with high biomass yield and nutritional value are important (Tolera *et al*., 2012). Lemma *et al*. (2010) state that only 0.15% of smallholder farmers practice on-farm improved forage production. Land shortage, low access and, high cost of seed and planting materials, and lack of awareness of their importance and production are major impediments to smallholder farmers' low practice of improved forage production (Mengistu *et al*., 2021).

Residues from cereals are the main source of forage, but these are low in protein and have poor digestibility. Removing them from the fields also reduces the soil's organic matter content, degrading soil structure and increasing the erodibility of cropped land. Introducing and subsequently utilizing high-yielding, improved forage crops could solve the country's animal feed shortage problem. Moreover, it has been reported that the introduction of forage crops (legumes) into mixed farming systems through intercropping with cereal and cash crops increases farm income and reduces pressure on land resources (Zekarias, 2016). Hence, feed shortage problems in the livestock production system could be alleviated by the integration of improved forage crops with other crops into the farming system. This is highly important and appropriate in areas where land scarcity is a problem and the agricultural production system is a subsistence system.

Intercropping is the growing of two or more crops simultaneously on the same field to increase the productivity per unit of land for sustainable food production. Farmers can plant multiple crops in intercropping, increasing total yield and profit by combining cash crops with beneficial companion plants (Huss *et al*., 2022). Including forage legumes like desmodium, lablab, vetch, cowpea, and alfalfa in intercropping systems can provide a more sustainable nitrogen source through biological nitrogen fixation. In addition, using forage legumes intercropped with maize and cash crops directly benefited the farmer with food and animal feed (Mengistu *et al*., 2017). Disodium is grown on various land uses as a mixed pasture, with multiple advantages over the monoculture of forage grasses. Desmodium's common benefits include forage production, nitrogen fixation, and soil erosion control (Mengistu *et al*., 2017 and Mazzafera *et al*., 2021). Cowpeas (*Vigna unguiculata*) and lablab (*Lablab purpureus*) are fast-growing, annual forage legumes. They are excellent quality crops for fattening sheep and cattle and are also regarded as good feed for milking cows (Cook, 1994; Chinma *et al*., 2008). Vetch (*Vicia* spp.) is a versatile plant with various applications in agriculture. Vetch is one of the adapted forage legumes in mid- and highland areas. It has a high-quality of hay, either grown alone or mixed with grains (Saidi *et al*., 2010). Like other grain legumes, alfalfa is a significant herbaceous forage primarily used as feed for livestock due to its high protein content and digestible fibers.

Maize is one of the important crops used in human diets and animal feed. It has the potential to supply large amounts of energy-rich forage for animal diets, and its fodder can safely be fed at all stages of growth without any danger (Dahmardeh *et al*., 2010). Maize can be intercropped with legumes for various reasons.

The livestock production system in Southwest Ethiopia is diverse, ranging from mixed farming to agro-pastoral and pastoral systems. Livestock feed resources in the Bench-Sheko Zone mainly include natural pasture and crop residues (Aleme and Mengistu, 2023). Livestock production is one of the agricultural activities in most rural areas of Bench-Sheko Zone in general and the Semen Bench district in particular. Even though the Woreda has great potential, the production and productivity of livestock are very low, mainly due to a shortage of feed. Semen Bench is one of the Woredas in the Bench-Sheko Zone of southwest Ethiopia, where there is high population pressure and grazing lands are limited.

The level of adoption of improved forage crop technology can be accelerated through the strengthening of pre-extension demonstrations. A participatory approach uses existing local skills and knowledge as a starting point. Many of the previous studies pointed out that farmers who participated in on-farm trials, demonstrations, and field day events adopted improved agricultural technologies more than others did (Chandio and Yuansheng, 2018). Undertaking participatory pre-extension demonstration, evaluation, and validation of agricultural technologies or research outcomes with the participation of farmers and other stakeholders in the study area is important to familiarize the farmers with different forage technologies. This helps to enhance the acceptability of the technology in order to solve the forage scarcity gap. Therefore, this technology transfer project was initiated to enhance forage crop production and productivity by establishing an agricultural technology village through appropriate technology transfer with full production packages and evaluating the technology preferences of the smallholder farmers and experts in the study area.

Materials and Methods

Description of Study Area

The field demonstration took place in Semen Bench woreda (Endekel and Dakin kebeles) of the Bench-Sheko zone during the 2020/2021 main cropping season. The site is located in South Nations, Nationalities, and Peoples Regional State, in the sub-humid tropical region of South-Western Ethiopia. Geographically, the study site is located at 6°09'N latitude and 35°0'E longitude, at an altitude of 1400 m above sea level. The area receives annual rainfall ranging from 1801 to 2000 mm, with mean minimum and maximum temperatures of 15.01 and 25°C, respectively. The rainfall pattern is bi-modal, with the "Belg" rain (short rains) happening from January to May and the "Meher" rain season extending from June to November. Major crops grown in this area are enset, banana, faba bean, maize and coffee, and cabbage. Natural pasture is the primary source of animal feed in areas where farmers employ intense pastureland grazing with high stocking rates, resulting in poor natural pastureland management. In addition, in the Semen Bench district, several grass species and forage species are cultivated to support livestock production. These species play a crucial role in providing nutritious feed for animals.

The majority of grass species in the area were desho grass (*Pennisetum pedicellatum*), rhodes grass (*Chloris gayana*), elephant grass (*Pennisetum purpureum*), Phalaris grasses (*Phalaris* spp.), and among the legumes species included green leaf (*Desmodium intortum*), sesbania (*Sesbania* spp.), and alfalfa (*Medicago sativa*). Two representative Kebeles (Endekel and Dakin) from the site (Semen Bench Woreda) were selected purposively. Potential Kebeles were selected in collaboration with zonal, Woreda and Kebele agricultural experts and experts. Accordingly, the district was selected due to their potential for forage crops (lablab, vetch, cowpea, desmodium and alfalfa) production as demonstration sites of the technology. Maize (BH546) variety was used as main crop for the cropping system.

Farmers Selection, Treatments, and Experimental Design

A total of 20 farmers (15 men and 5 women) were purposefully selected out of those who were willing to allocate 0.05 ha of their lands with an average steepness of about 10% for the field demonstration in 2020/2022 main cropping season (Figure 1). Adequate land (minimum of 0.05 ha), locality to roads so as to facilitate the chance of being visited by many farmers, initiatives to implement technologies, good skill in field management and willingness to explain the technologies to others were used as criteria to select the participant farmers. All participating farmers had cash crops (coffee) and food crops (maize) in the exiting land for intercropping of the improved forage crops. A total of 1-ha (0.75 ha of maize) was intercropped with lablab, vetch and cowpea and 0.25 ha of coffee land was underplanted with desmodium and alfalfa forage plants.

The demonstration fields were cleared and plowed by oxen plow according to farmers' practice. Maize was planted at a 25 kg/ha seed rate with 75 cm of space between rows and 30 cm between the plants. NPS blended fertilizer at a rate of 100 kg/ha was applied at planting as nationally recommended for the crop whereas urea (46 kg/ha) was applied in split application, 1/3 at planting and the remaining

Table 1: Descriptions of the experimental treatments used in the study area

Treatments (T)	*Descriptions*
T1	Sole maize and sole coffee
T2	Lablab intercropped with maize
T3	Vetch intercropped with maize
T4	Cowpea intercropped with maize
T5	Desmodium intercropped with coffee
T6	Alfalfa intercropped with coffee

Figure 1: A picture taken during the farmers selection process

2/3 is applied after three weeks from planting. Then, after three weeks, five improved forage legume technologies were intercropped with maize and coffee for the demonstration process by using each farmer's field as a replication, i.e., the demonstration activity was conducted on 10 farmers per activity per kebele, for a total of 20 farmers in both kebeles The treatments description are listed in Table 1. The technologies were planted on farmers' land with a simple plot design (30 x 30 m) in the 2020/21 main cropping (Meher) season with full recommended management packages.

Training for Forage Technology Demonstration and Knowledge Transfer Techniques

Training (theoretical and practical) is very important for awareness creation and improving technology transfer to fill knowledge, skill, and attitude gaps. The training was mainly focused on forage crop establishment, general management, harvesting, storage, and feeding systems. Hence, training was given to the participating farmers to implement the forage technology demonstration process in a proper manner on their field. In addition, awareness creation was given to stakeholders through consultation meeting and training, such as zone, Woreda, and kebele agricultural experts to support and participate in the demonstration practice. Farmers research group (FRGs) members and other follower farmers were encouraged to participate in different extension and promotional events organized at each demonstration site. These are mechanisms used to enhance farmer-to-farmer learning and information exchange, such as trainings, field visits/tours, and experience sharing. Therefore, a field visit was arranged to create awareness and have farmers share their experience and knowledge. Regular joint monitoring and evaluation (follow-up actions) and provision of technical advice were undertaken at different crop stages based on necessary emerging knowledge and skills and technical advice needs. Field day motivates people to adopt new practices by showing what has already been achieved under field conditions. In other words, it is to show new practices/technologies' performance and profitability and convince them of their applicability. Besides, it is a way of facilitating people's access to new technology for the purpose of mass mobilization. Thus, mini-field days were organized at the demonstration site to involve key stakeholders and enhance linkage among relevant actors. Discussion session and result communication forum were also organized.

Agronomic Data Collection

Data collected included crude protein yield, biomass yield advantage, plant height, forage dry matter yield, Stover dry matter yield, and maize grain yield were recorded at the maturity stage.

According to Abera (2020), crude protein yield was determined from total dry matter yield. The biomass yield advantages of the forages were determined by comparing the biomass yield obtained from forage intercropped (maize-lablab, maize-vetch, and maize cowpea) and sole maize farming practices using the following formula:

$$\text{Biomass yield advantage} = \frac{(\text{Yield of intercrop (t/ha)} - \text{Yield sole (t/ha)})}{\text{Yield of sole (t/ha)}} x\ 100$$

Statistical Data Analyses

Both qualitative and quantitative data were collected using appropriate data collection methods such as focused group discussion (FGD), direct field observation, and measurements. The perceptions of farmers, extension workers, and other stakeholders who participated in field visits and field days were recorded. Feedback assessments were collected on farmers' preferences for the demonstrated varieties (likes and dislikes). Data was also collected from forage species intercropped with coffee and maize and were analyzed by ANOVA to determine if there were significant differences between means of the various forage species intercropped with cash and food crops using SAS 9.1 (SAS, 2008). The Tukey HSD- test was used for mean separation. Descriptive statistics were employed to assess farmers' perceptions, with the means compared using the t-test independent samples test and Levene's test for equality of variance.

Table 2: Grain and biomass productivity of maize as pure stand, intercropping with legumes and legumes biomass productivity when intercropped with coffee at Semen Bench districts

Treatments	*PH (cm)*	*MGY (t/ha)*	*MBY (t/ha)*	*LBY (t/ha)*	*TBY (t/ha)*
Sole Maize	191.05	3.801	0.491	-	0.491[b]
Maize + Lablab	191.3	4.05	0.531	0.168[a]	0.699[a]
Maize + Vetch	190.9	3.92	0.502	0.045[b]	0.547[b]
Maize + Cow pea	190.5	3.805	0.499	0.043[bc]	0.533[b]
Coffee + Alfalfa	-	-	-	0.026[c]	0.026[c]
Coffee + Desmodium	-	-	-	0.032[bc]	0.032[c]
Mean	190.94	3.892	0.506	0.063	0.390
SEM	0.65	2.5	0.89	0.13	0.73
p - value	0.08	0.14	0.76	<.0001	<.0001

Where: PH = Plant height, MGY = Maize grain yield, MBY = Maize biomass yield, LBY = Legume biomass yield and TBY = Total biomass yield; Values within a column that bear the same letter are not statistically different ($p < 0.05$)

Results

Effect of Intercropping on Growth and Yield Parameters of Maize and Forage Crops

The mean values of plant height, maize grain yield, maize biomass yield, legume biomass yield, and total biomass yields are presented in Table 2. Under sown forage legume in maize did not significantly ($p > 0.05$) affect maize plant height, grain yield, or biomass yields. The values of mean grain yield and maize biomass yield are ranged from 3.801 to 4.050 t/ha and 4.91 to 5.31 t dry matter per ha, respectively. This study showed that the under-sowing of forage legumes did not significantly ($p > 0.05$) affect maize grain yield. However, compared to sole maize stands, stands under sown with lablab and vetch increased the grain yield of the maize by 6.6 and 3.3%, respectively, although the value of cowpea was unchanged.

The increase in grain yield observed when maize stands were intercropped with lablab and vetch can be attributed to lablab and vetch are leguminous plants that have the ability to fix atmospheric nitrogen through their symbiotic relationship with nitrogen-fixing bacteria (rhizobia). This nitrogen fixation process increases soil nitrogen availability, benefiting neighboring crops like maize, especially during the grain-filling stage. Cowpea is also leguminous, but its impact on maize yield was unchanged. This might be the timing of cowpea growth and maize growth might not have been well-matched. Likewise, the highest grain yield was observed when maize was under sown with lablab (4.05 t/ha), followed by vetch under sown (3.920 t/ha). The lower maize grain yield was observed when planted in a pure stand (3.801 t/ha). Correspondingly, similar trends were obtained for biomass yield in the order of lablab, vetch, cowpea, and sole maize in declining order.

Forage legume biomass yield and total biomass (maize biomass + forage legumes) were significantly ($p < 0.05$) affected by treatments. Accordingly, higher (0.168 t/ha.) legume biomass yield was recorded for maize lablab intercropping, and a lower biomass yield (0.026 t/ha) was obtained from coffee intercropped alfalfa. Similarly, higher (0.699 t/ha) total biomass yield was obtained from maize intercropped with lablab as compared to maize intercropped with vetch, cowpea, and sole maize plants.

Biomass Yield Advantages

The biomass yield advantages of maize lablab, vetch, and cowpea intercropping practices were 11.10, 2.50, and 0.50%, respectively, at the study area. The highest values of biomass yield advantages calculated for lablab indicate that the under-sowing of lablabs with maize was more advantageous than vetch, cowpea, and sole maize cropping. The biomass yield advantages calculated for lablab suggest that undersowing lablab with maize provides greater benefits compared to vetch, cowpea, and sole maize cropping. This indicates the advantages of sowing lablab with maize stem from its nitrogen-fixing ability, complementary growth patterns, soil enrichment, pest management, and overall ecosystem benefits.

Crude Protein Yield

The values of forage legumes, crude protein yield of maize Stover, legumes, and total fodder are presented in Table 3. The forage legume crude protein yield significantly ($p < 0.05$) varied among treatments. The highest crude protein yield was obtained from lablab (0.26 t/ha) under sown in maize as compared to vetch and cowpea (0.06 t/ha).

Table 3: Crude protein yield of maize Stover, legumes and total fodder grown when under sown with legumes

	Crude protein t/ha		
Treatments	*Maize stover*	*Legumes*	*Total*
Sole maize	0.35	-	0.35[b]
Maize + Lablab	0.37	0.26[a]	0.63[a]
Maize + Vetch	0.36	0.06[b]	0.42[b]
Maize + Cow pea	0.36	0.06[b]	0.42[b]
Mean	0.36	0.13	0.46
SEM	0.36	0.02	0.06
p-value	0.96	<.0001	<.0001

Values within a column that bear the same letter are not statistically different ($p < 0.05$)

Treatments did not significantly affect the maize Stover crude protein yield ($p > 0.05$). However, the crude protein contents of maize under sown with legumes were in the highest range of 0.36 to 0.37 t/ha, whereas the crude protein yield of Stover from pure stand maize was the lowest at 0.35 t/ha. The total fodder (maize Stover + legumes) crude protein significantly ($p < 0.05$) varied among treatments. Higher total crude protein is obtained from forage legumes under sown in maize. Significantly higher total crude protein (0.63 t/ha) was obtained from the combination of maize-lablab-based cropping systems as compared to maize-vetch, maize-cow pea, and sole maize cropping. The significantly higher total crude protein yield obtained from the combination of maize-lablab-based cropping systems compared to maize-vetch, maize-cowpea, and sole maize cropping can be attributed to when lablab intercropped acts as a living mulch, suppressing weeds and reducing competition for nutrients. Thus, the taller maize plants benefit from this reduced competition and utilize the available nitrogen for protein production.

Farmer perception towards demonstrated forage technologies compared to local practices

Farmers' evaluation criteria for technology demonstration and evaluation for forage crops purposes are shown in Table 4. The technologies were demonstrated, evaluated at the crop maturity stage, and validated by farmers, zonal and Woreda agricultural experts, development agents, researchers, and other stakeholders based on the selection criteria stated in Table 4. Farmers carried out a qualitative evaluation of the forage intercropping system through matrix ranking (Figure 2). The major criteria considered in the evaluation include vegetative growth, herbage yield, multipurpose use, soil erosion protection, palatability, drought tolerance, compatibility with maize or coffee, and maintenance of soil fertility.

Table 4: Farmer's criteria for evaluation of legumes under sown in maize and pure maize production practices (High score = 5 and least score = 1) and number of evaluating farmers = 50

Evaluation parameters	*Maize + Lablab*	*Maize+ Vetch*	*Maize + Cow pea*	*Coffee + Desmodium*	*Coffee + Alfalfa*
Vegetative growth	5	1	1	1	1
Herbage yield	5	2	2	1	1
Multipurpose use as food & feed	3	3	3	1	1
Protection of soil	3	3	3	2	1
Palatability	2	2	2	2	2
Drought tolerance	4	4	3	3	3
Compatibility with maize crop/coffee	5	1	1	2	1
Maintenance of soil fertility	5	3	2	2	2
Total score	32	19	17	14	12
Rank	1st	2nd	3rd	4th	5th

Figure 2: First round farmers' evolution for maize - lablab intercropping system at field level

Based on farmers' evaluation criteria, maize intercropped lablab or a combination of maize and lablab was ranked first or had a higher mean score over the other cropping systems based on overall production performance (Table 4) followed by maize intercropped with vetch. In addition, farmers had perceived positively on the simplicity of the technologies when compared with their practice (farmers' practice).

Discussions

Effect of Intercropping on Growth and Yield Parameters of Maize and Forage Crops

Table 2 shows the mean values for plant height, maize grain yield, maize biomass yield, legume biomass yield, and total biomass yields. Under-sown forage legumes in maize had no significant ($p > 0.05$) effect on maize plant height, grain yield, or biomass yields. The mean grain yield and maize biomass yield vary from 3.801 to 4.05 t/ha and 4.91 to 5.31 t/h dry matter per ha, respectively. This study found that under-sowing of forage legumes had no significant effect ($p > 0.05$) on maize grain yield. However, compared to alone maize stands, stands seeded with lablab and vetch enhanced the grain output of the maize by 6.6 and 3.3%, respectively, while the value of cowpea remained unchanged. These findings are consistent with Abera (2012) and Wana *et al*. (2020), who discovered that the inclusion of forage legumes enhanced maize grain production by 5 to 7.4% compared to sole cropping. The increase in grain production seen when maize stands is intercropped with lablab and vetch can be attributed to the fact that lablab and vetch are leguminous plants capable of fixing atmospheric nitrogen through a symbiotic interaction with nitrogen-fixing bacteria (rhizobia). This nitrogen fixation process increases soil nitrogen availability, which benefits nearby crops such as maize, particularly during the grain-filling stage. Cowpea is leguminous, but its impact on maize yield remains unchanged. The time of cowpea and maize growth may not have been well-matched. The same tendencies were observed in experiments undertaken by Geleti *et al*. (2001) and Mengistu (2002), who showed that companion cereal grain output increased by 4.9 to 6.8% when forage legumes were undersown. In contrast, the current study's findings contradict those reported by Mekasha *et al*. (2007) and Mpairwe *et al*. (2002), who found that adding forage legumes reduces companion crop grain production by 3.6 to 9%.

Similarly, maize underplanted with lablab produced the maximum grain production (4.050 t/ha), followed by vetch (3.920 t/ha). As highlighted in Table 2, the maize grain yield was lower when planted in a pure stand (3.801 t/ha). In decreasing order, similar trends were seen for biomass yield in the order of lablab, vetch, cowpea, and single maize. A previous study reported a similar result (Abera, 2012). The higher grain yield and biomass obtained in this study from maize under sown with legumes than sole maize are possibly due to, in addition to N-fixation, having good plot cover that may protect the soil from runoff water and loss of topsoil and increasing infiltration of water into the soil, which enhances the use of available nutrients for maize plant growth (Abera, 2012). The increased grain yield and biomass observed in this research when maize was intercropped with legumes compared to sole maize cultivation may be attributed to several to, in addition to nitrogen fixation, the presence of a dense plot cover likely shields the soil from runoff water and prevents topsoil loss, as well as increasing water infiltration into the soil, which enhances the use of available nutrients for maize plant growth.

Treatments had a substantial effect ($p < 0.05$) on forage legume biomass output and overall biomass (maize biomass + forage legumes). As a result, maize lablab intercropping yielded more legume biomass (0.168 t/ha), but coffee intercropped alfalfa yielded less (0.026 t/ha). Maize intercropped with lablab produced a higher total biomass output (0.699 t/ha) than maize intercropped with vetch, cowpea, or sole maize plants. The lowest legume biomass yield from the legume-coffee base system may be attributed to the shading effect, soil type, and variety of legumes selected for this technology demonstration.

Forage legume biomass yield and total biomass (maize biomass + forage legumes) were significantly ($p < 0.05$) affected by treatments. Accordingly, a higher (0.168 t/ha.) legume biomass yield was recorded for maize lablab intercropping, and a lower biomass yield (0.026 t/ha) was obtained from coffee intercropped alfalfa. Higher (0.699 t/ha) total biomass yield was obtained from maize intercropped with lablab as compared to maize intercropped with vetch, cowpea, and sole maize plants. Fu *et al*. (2023) researched maize-legume intercropping and discovered that maize's leaf area index (LAI) and specific leaf weight (SLW) increased significantly when intercropped with soybean. The authors also reported that soybean growth recovered despite being shaded during cohabitation, resulting in enhanced dry matter accumulation. This implies that shade tolerance and recovery mechanisms are critical to intercropping success.

Besides, studies by Huss *et al*. (2022) and Javanmard *et al*. (2023) emphasize the necessity of controlling shade effects in intercropping systems. Maize intercropped with lablab produced a higher total biomass output (0.699 t/ha) than maize intercropped with vetch, cowpea, or sole maize plants might have a different growth pattern or root structure that minimizes competition for resources like water and sunlight with the maize. This allows both plants to thrive and contribute to the total biomass. This finding is in harmony with Atumo (2022) conducted a study on maize-lablab intercropping to evaluate biological yield and parthenium weed control, discovered that maize-lablab intercropping resulted in a higher biomass yield (46.89 t/ha) compared to sole maize.

Biomass Yield Advantages

In the research area, the biomass yield benefits of maize lablab, vetch, and cow pea intercropping methods were 11.10, 2.50, and 0.50%. The highest values of biomass yield advantages calculated for lablab show that under-sowing lablab with maize was more favorable than vetch, cowpea, and solitary maize cropping. The biomass yield advantages calculated for lablab suggest that undersowing lablab with maize provides greater benefits compared to vetch, cowpea, and sole maize cropping. This confirms that the advantages of sowing lablab with maize stem from its nitrogen-fixing ability, complementary growth patterns, soil enrichment, pest management, and overall ecosystem benefits. The studies conducted by Fu *et al*. (2023), Atumo (2022) and Biruk *et al*. (2021) also reflect his evidence that the interaction between leaf traits, nutrient utilization, resource partitioning, and specific crop combinations all contribute to the observed yield advantages in different maize-legume intercropping systems.

Crude Protein Yield

Mean of forage legume values and maize's crude protein yield Table 3 shows the total feed, legumes, and Stover. The crude protein output of forage legumes differed significantly ($p < 0.05$) among treatments. Lablab (0.26 t/ha) grown on maize produced a greater crude protein output than vetch (0.06 t/ha) and cowpea (0.06 t/ha). Treatments had no significant ($p > 0.05$) effect on maize Stover crude protein production. However, the crude protein content of maize grown with legumes were the highest, ranging from 0.36 to 0.37 t/ha, whereas the crude protein yield of Stover from pure stand maize was the lowest, at 0.35 t/ha. The variation in crude protein output was observed when lablab, vetch, and cowpea are intercropped with maize crop primarily from lablab's inherently higher protein content compared to the other two legumes. In addition to the specific lablab genotype used in this study has been particularly productive in terms of both yield and protein content, the intercropping system with maize could have altered nutrient availability and competition, resulting in improved overall productivity. This finding is consistent with that of Bekele *et al*. (2021), who found that among the legumes studied, lablab (Lablab purpureus) outperformed other genotypes in terms of mean forage dry matter and crude protein yields across different sites and years. Similarly, a study by Heuzé *et al*. (2016) shows that lablab's higher inherent protein content contributes to its superior crude protein output when intercropped with maize.

Correspondingly, the total fodder (maize Stover + legumes) crude protein significantly ($p < 0.05$) varied among treatments. Higher total crude protein is obtained from forage legumes under sown in maize. Accordingly, significantly higher total crude protein (0.63 t/ha) was obtained from the combination of maize-lablab-based cropping systems as compared to maize-vetch, maize-cow pea, and sole maize cropping. The significantly higher total crude protein yield obtained from the combination of maize-lablab-based cropping systems compared to maize-vetch, maize-cowpea, and sole maize cropping can be attributed to lablab intercropping, which acts as a living mulch, suppressing weeds and reducing nutrient competition (Atumo, 2022; Biruk *et al*., 2021). Thus, the taller maize plants benefit from this reduced competition and utilize the available nitrogen for protein production**.** The maize-lablab cropping system offers a multiple benefit: increased protein yield, improved soil health, and greater agricultural sustainability. This advantage stems from the way these two crops complement each other, enabling more efficient use of resources and promoting higher protein production (Mthembu *et al*., 2018).

Reflection of Participating Farmer towards the Technology

Participant farmers were evaluated forage legumes under sown in maize and coffee plants. The responses of participating farmers in terms of the benefits and drawbacks of forage production by under-sowing forage legumes in maize crops and coffee plants as compared to sole maize production (monoculture) are shown in Table 4. Among the forage legumes used for under-sowing in maize and coffee plants, participant farmers, Woreda animal feed experts, and development agents found the maize-lablab-based cropping system to be a better strategy for forage and maize production as compared to other legume-based systems and local practices. This is mainly due to the superior benefits obtained from lablab under sown in maize, including higher quality feed production from lablab, soil fertility improvement, soil erosion protection, drought tolerance, and compatibility of the technology with the existing practices. However, the farmers perceived the advantages of the other intercropped forage technologies negatively.

Moreover, all participating farmers were very impressed and interested in growing lablab forage in maize after they realized the superior benefits of lablab-maize-based cropping systems as compared to vetch-maize, cow pea-maize, and sole maize cropping. The farmers also understand that under sown forage technology produces forage crops without competing for land with other crop production. They also developed good knowledge and skills regarding improved forage development and utilization. Farmers were fortified in their contribution to forage production and promoted the adoption of under sown forage development technology in the study area. On the other side, the involvement of the farmers in the research and extension program can increase the realization on the part of research and extension personnel for effective and acceptable technology development. The researchers also benefited from gaining an understanding of farmers evaluation criteria and creating good opportunities to communicate with them. Hence, it is quite evident that farmers in the study area clearly show the advantage of intercropping forage legumes, particularly maize-lablab enhance sustainable fodder production and quality in smallholder rural farming systems in the study area. Therefore, since the farmers have responded well to this new method, it suggests that expanding this practice to other communities or farmers in the district would be beneficial.

Conclusion

The results of the present study indicated that higher grain yield, maize stalk dry matter yield, and legume dry matter yield were obtained from forage legumes intercropped maize-lablab based as compared to maize-vetch, maize-cow pea-based, and sole maize cropping systems. Likewise, higher crude protein yields were also obtained from the maize-lablab-based intercropping system as compared to maize-vetch-based, maize-cowpea-based, and sole maize cropping. Although the amount of fodder yield obtained from maize-vetch and maize-cow pea-based crops was low, the fact that the fodder yield obtained was low without affecting the grain yield makes the technology of forage legumes under sown in maize a better practice. Therefore, those participant farmers obtained more food and animal feed benefits from maize-lablab-based intercropping than from maize-vetch, maize-cow pea, and local practices. The lower legume dry matter yield obtained from both legumes (alfalfa and desmodium) under-sown in coffee plants indicated that the legumes selected for under-sown forage development technology were not suitable in the study area. Participant farmers also voted for maize-lablab-based intercropping technology as the best forage development strategy to solve the animal feed shortage in the study area. However, further studies should be done on varieties of vetch, cowpea, alfalfa, desmodium, and other legume species that are suitable for agro-ecology and evaluated for their compatibility when under sown or intercropped in food and cash crops.

Availability of data and materials

Data used and analyzed for this study are available from the corresponding author on reasonable request.

Author contributions

RB contributed in designing study, conducting a study, statistical data analysis, and manuscript writing. TH contributed in designing a study, supervising the study, statistical data analysis, and manuscript writing.

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