Straw dry matter yield and quality of finger millet intercropped with selected vetch species at different seeding ratios in western Oromia, Ethiopia

Wakgari Keba a,*, Taye Tolemariamb, Abdo Mohammedb

a Bako Agricultural Research Center, PO Box 03, Bako, Ethiopia
b Jimma University, PO Box 378, Jimma, Ethiopia

ARTICLE INFO

Keywords:
Chemical composition
Dry matter yield
Finger millet
Seeding ratio
Vetch species

ABSTRACT

This study was conducted to evaluate the straw dry matter yield and quality of finger millet intercropped with three species of vetch (Vicia sativa, Vicia villosa and Vicia atropurpurea) at different seeding ratios in western Oromia, Ethiopia. The experimental design was Randomized Complete Block Design (RCBD) arranged factorially in three replications. The treatment consisted of three vetch species and three seeding ratios (25:75, 50:50 and 75:25% finger millet: vetch respectively) and one pure stand of each as a control. The dry matter yield (DMY) of finger millet straw was different (P < 0.05) for the tested treatment combinations and the highest DMY of finger millet straw (5.85 t ha⁻¹) was obtained from T10. The crude protein yield of finger millet straw was also influenced by the main effect and interaction effects of species and seeding ratio (P < 0.05). According to this study, T10 gave the highest (0.50 t ha⁻¹) crude protein yield of finger millet straw. In general, vetch intercropping with finger millet has improved overall dry matter yield and quality of the intercrops. Thus, T10 was found to be the best treatment tested in terms of dry matter yield and quality to be used in a food/feed production strategy in a mixed crop-livestock production system to alleviate food/feed shortages in Bako and similar agro-ecologies.

1. Introduction

Ethiopia is at the top of the list of livestock among African countries (CSA, 2018). The livestock sector has made a significant contribution to the country’s economy and still promises to play its role in the country’s economic development. As a result, livestock production remains a cornerstone of food security, human nutrition and economic growth in the country (Shapiro et al., 2015). However, livestock productivity is lagging behind its population due to some technical and operational bottlenecks. A shortage of feed, both quantitatively and qualitatively, is one of the technical problems that deserve great attention. In countries where mixed-crop livestock farming is the main agricultural production system, a food/feed production strategy may be the best option to produce both food crops and feed as complementary units. Therefore, a systematic and productive harmonization of the two sectors of livestock and crop production is undoubtedly imperative.

Intercropping is the growing of several crop species simultaneously on the same plot during a single growing season (Ofori and Stern, 1987). It is essential to the development of sustainable food/feed production, mainly in cropping systems with scarce external inputs. Intercropping forage legumes with cereals/grains increases the potential for increasing productivity. Farmers from low-income countries like Ethiopia couldn’t afford to use industry-based concentrates and chemicals as dietary supplements to improve roughage utilization. Fortunately, legume forage plants can improve the utilization of poor quality roughage through nitrogen fixation and sharing it with companion cereals/grasses. Forage legumes can improve the utilization of inferior roughage and are increasingly used worldwide (Osuji and Odenyo, 1997). Although livestock farming plays a significant role in crop production in Ethiopia, pasture land is reduced from time to time to grow food crops to feed the family.

Finger millet (Eleusine coracana) with a considerable food and fodder value is currently widely accepted by small farmers and does better than other crops even with poor soil fertility. Gashu et al. (2014) also suggested that finger millet straw is consumed indiscriminately by farm animals, including small ruminants. Finger millet is a cereal grain that is widely grown in Ethiopia in various agroecologies (Kebede et al., 2019). In Africa, finger millet is grown by smallholders often intercropping with
cereals, legumes or vegetables (Mulualem and Melak, 2013). Forage legumes, including vetch, are rich sources of nitrogen for livestock at cheaper prices compared to concentrate, especially in developing countries (Mpairwe et al., 2003). In addition, vetch can be used as a protein supplement for ruminants on inferior roughage. To alleviate the feed shortage in the study area, the intercropping of finger millet with vetch is essential to improve the nutritional value of finger millet straw. Some information has been generated on the intercropping of vetch with other cereals (Lithourgidis et al., 2007; Dhimma et al., 2007). Finger millet has also been intercropped with legumes other than vetches such as Desmodium uncinatum and Desmodium intortum (Midega et al., 2010) in other areas. However, only limited information is available on the effect of intercropping of vetch with finger millet on dry matter yield and nutritional value in the study area. Hence, this study was designed to assess the straw dry matter yield and quality of finger millet mixed with three vetch species (Vicia sativa, Vicia villosa and Vicia atropurpurea) with finger millet in different seeding ratios in Western Oromia, Ethiopia.

2. Materials and methods

2.1. Description of the study area

The experiment was carried out at Bako Agricultural Research Center (BARC); located in western Ethiopia during the main rainy season (June to November) in 2020. The area is located at an altitude of 1650 m above sea level, and receives an annual rainfall of 1605.1 mm mainly from May to October with maximum rainfall in the months of May to September.

2.2. Experimental materials

Improved finger millet variety (Bako-09) and vetch species (Vicia sativa, Vicia villosa and Vicia atropurpurea) were used as test species for the study. The finger millet variety was launched in 2017 by the Bako Agricultural Research Center and is characterized by its upright growth. Vetch species were introduced into BARC from Holeta and Sinana Agricultural Research Centers and adapted to Bako conditions.

2.3. Treatments and experimental design

Treated included three vetch species, Vicia sativa (common vetch), Vicia villosa (hair vetch) and Vicia atropurpurea (lilac vetch) and three seeding ratios (25%:75%, 50%:50% and 75%:25% finger millet: vetch, respectively) in a three-replicate randomized complete block (RCBD) design. The vetch species were sown between rows of finger millet and sole vetch was sown based on their respective recommended seed rates of 25 kg ha⁻¹ for Vicia villosa and Vicia atropurpurea and 30 kg ha⁻¹ for Vicia sativa while the sole finger was sown at a seed rate of 25 kg ha⁻¹. The experiment consisted of three replications; each contains 13 experimental units resulting in 39 plots. The spacing between the plots and the replicates is 1 m and 1.5 m, respectively, and the plots in each replicate were randomly assigned to the thirteen treatments using the SAS software randomization method. The vetches were sown after two weeks of planting finger millet according to the recommendation by Alemu (2016).

2.4. Land preparation and planting

The land was ploughed and fined with tractors and finally levelled by day labourers to fine the soil. Before laying out the trial plots, fine seedbed plots were laid out. The recommended fertilizer rate of 100 kg ha⁻¹ NPS and 64 kg ha⁻¹ UREA (Kebbede et al., 2019) was used for all experimental units during setup (sowing). Seeds of finger millet and three vetch species (Vicia sativa, Vicia villosa and Vicia atropurpurea) were sown in alternate rows (Agza et al., 2018) according to their seed percentage on well-prepared soil. Weeding was done by hand to eliminate the regrowth of unwanted plants.

2.5. Data collection procedures

2.5.1. Biomass yield determination

The total straw yield per finger millet plot was weighed and determined after the grain harvest. Harvesting was made by hand with a sickle, leaving a stubble height of 8 cm above the bottom according to recommended practice (Balehegn et al., 2020). The harvested fresh biomass was weighed and recorded immediately within the field using a top-loading scale. Fresh subsamples of roughly 250–300 g were taken from each plot and weighed, which was then crushed into small pieces of 2–5 cm to work out the dry matter. Finally, the fresh samples were oven dried at 65 °C for 72 h and therefore the partial dry weight is recorded to estimate the dry matter biomass production.

\[
DMY (\text{tha}) = 10^4FSW \times (\text{HA} \times \text{FWS})
\]

(1)

where: 10 = constant for conversion of yields in kg/m² to ton/ha; FW = fresh weight from harvesting area (kg); DWS = dry weight sub-sample (g); HA = harvest area (m²), and FWS = fresh weight sub-sample (g).

Crude protein yield decided by the multiplication of dry matter yield with the crude protein content of the feed samples. Besides, a chopped and sun-dried forage sample of every plot was prepared and reserved for laboratory chemical analyses.

2.5.2. Analysis of feed chemical composition

Samples of finger millet straw were taken from each plot and dried in a forced draft oven at 65 °C for 72 h and ground using a Wiley mill to pass through a 1 mm sieve for chemical analysis. The AOAC (1990) method was used to determine DM, ash and nitrogen. Dry matter content was determined by oven drying at 65 °C for 72 h (Schmid et al., 1970). Ash was determined by completely burning the feed samples in a muffle furnace at 600 °C overnight according to the method of AOAC (1990). Organic matter was determined by subtracting the ash component from 100. Total nitrogen (N) is determined by the Kjeldahl method of AOAC (1990). Crude protein (CP) was calculated as nitrogen (N)*6.25. The plant structural components such as neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were analyzed using the detergent extraction method. Hemicellulose was calculated by subtracting ADF from NDF content and cellulose was calculated by subtracting ADL from ADF content.

2.5.3. In vitro dry matter digestibility (IVDMD)

The two-step rumen inoculation pepsin method of Tilley and Terry (1963) was used to determine in-vitro dry matter digestibility (IVDMD). Rumen liquor was collected from three rumen fistulated steers and then transported to the laboratory using a thermost flask pre-warmed to 39 °C. Rumen juice was taken in the morning before the animals were fed. A duplicate sample of about 0.5 g each was incubated with 30 ml of ruminal fluid in a 100 ml test tube in a water bath at 39 °C for 48 h for microbial digestion. This was followed by another 48-hour enzyme digestion with acidic pepsin solution. Blanks containing only buffered rumen fluid were also incubated in duplicate for adjustment. The sample residues were dried for 72 h at 60 °C. Chemical analysis and IVDMD were performed at Holeta Agricultural Research Center. IVDMD was calculated as:

\[
IVDMD = \frac{\text{Dry sample weight} - (\text{Residue} - \text{Blank})}{\text{Dry sample weight}} \times 100
\]

(2)

The sample was ashed to estimate In vitro OM digestibility as:

\[
IVOMD = \frac{\text{DOM in the feed} - (\text{OM in residue} - \text{Blank})}{\text{OM in the feed}} \times 100
\]

(3)

(Tesfaye and Zewdu, 2021)
where OM = DM- Ash (measured after ignition of feed or residue) (Forejtová et al., 2005).

The Metabolizable Energy (ME) content was estimated using the equation:

\[ ME (MJ kg DM) = 0.15 \times IVOMD (Pikrton, 2005) \]  

(4)

2.5.4. Statistical analysis

Data collected from experimental plots were summarized using Microsoft Excel 2013 and data were subjected to the ANOVA procedure by using the General Linear Model (GLM) of SAS software (2002) version 9.3. Significance differences among treatment means were separated and compared using the Least Significant Difference (LSD) test at a 5% significance level or 95% confidence interval. The statistical model for the analysis of data was:

\[ y_{ijk} = \mu + a_i + j_j + (aj)_{ij} + e_{ijk} \]  

(5)

The \( a_i \) and \( j_j \) parameters represent the main effects and have the same general interpretation as the effect in a one-way ANOVA does. The \( (aj)_{ij} \) represents an interaction effect. The \( e_{ijk} \) represents a random error.

3. Results

3.1. Straw dry matter yield finger millet

Vetch species, seeding ratio and their intercropping had a significant effect (\( P < 0.05 \)) on the DMY of finger millet straw (Table 1). The analysis of variance showed that the highest DMY of finger millet straw (5.85 t ha\(^{-1}\)) was obtained from T10 and it was only beaten by the sole finger millet (T1).

3.2. Crude protein yield of finger millet straw

The Crude protein yield (CPY) of finger millet straw is presented in Table 1. CPY of finger millet was influenced by the main effect and the interaction effects of the species and the seeding ratio (\( P < 0.05 \)). Accordingly, T10 produced the highest (0.50 t ha\(^{-1}\)) crude protein yield of finger millet straw. The CPY of Finger millet straw has increased as the seeding ratio of all vetch species used in this experiment decreased.

3.3. Chemical composition of finger millet

The present result revealed that the interaction effect of species and seeding ratio had significantly varied (\( P < 0.05 \)) for the chemical composition of finger millet except for dry matter content (Table 2). Generally, this study showed that the higher the seeding ratio of the vetch in the intercropping system, the higher the crude protein, fiber fractions and the content of the straw. In this study, the highest ash content (9.02%) was obtained from T8. The lowest ash content (6.50%) was obtained from T5. This value is 27.94% lower than the highest ash content in the treatment combination. Similarly, the highest CP content of finger millet straw (11.56%) was obtained from T8, followed by T11 (10.52%), and T12 (10.51%). The maximum CP content was 20.16% higher than the CP content of sole finger millet. Accordingly, the lowest NDF content (61.56%) was obtained from T13 while the highest (65.32%) was from T8.

In the present study, T5 had significantly the lowest ADF content (40.45%) followed by T11 (41.29%). These values are below the ADF content of the sole finger millet (43.7%). ADL values of finger millet straw in this study were significantly varied among the treatments. T13 gave the lowest (6.75%) ADL values from the intercropped treatments, as well as from the sole. Sole finger millet had higher cellulose content (37.27%) than finger millet mixed with vetch (32.91%) from a treatment combination of 25% finger millet +75% Vicia villosa.

3.4. In vitro digestibility and metabolizable energy values of finger millet straw

3.4.1. In vitro dry matter and organic matter digestibility

According to the current study, the interaction of the vetch species and the seeding ratios were significantly different for in-vitro dry matter digestibility (IVDMD) (Table 3). The highest IVDMD of finger millet straw (63.39%) was recorded from T13, while the lowest (60.56%) was recorded from T11. This lowest IVDMD value is, however, 12.53% higher than the pure stand of finger millet straw. The highest and lowest IVOMD (56.75% and 54.96%) were recorded from T13 and T7, respectively. All of the treatment combinations had IVOMD values greater than the pure stands of finger millet straw (45.23%).

3.4.2. Metabolizable energy of finger millet straw

In this study, an interaction effect of the treatment combinations showed that about 56% of the treatments had not shown statistically significant differences in metabolizable energy values (Table 3). Numerically, the highest ME of finger millet straw (8.54 MJ kg\(^{-1}\)) was recorded when 25% finger millet was intercropped with 75% Vicia atropurpurea.

4. Discussion

4.1. Finger millet straw yield

The dry matter yield of finger millet straw as an animal feed was one of the features of interest in this study. The analysis of variance showed
that the highest dry matter yield (DMY) of finger millet was obtained from 10. This could be due to Vicia vilosa’s contribution to nitrogen fixation, which promotes biomass yield and quality of finger millet and could also be due to the higher seeding ratio of finger millet compared to the companion legume. The significant difference between treatments observed in the current study for forage DMY was supported by the results of others (Assefa and Ledin, 2001; Alemu et al., 2007) in oat and vetch mixtures. Geleti (2000) also reported that grasses in the Intercrops ports of others (Assefa and Ledin, 2001; Alemu et al., 2007) in oat and vetch mixtures. Geleti (2000) also reported that grasses in the Intercrops

4.2. Crude protein yield (of finger millet)

Diriba (2014) suggested that crude protein yield (CPY) is the product of the total forage dry matter yield and the crude protein content of a plant. According to this study, 75% finger millet +25% Vicia vilosa produced the highest CPY of finger millet straw. The CPY of finger millet straw was increased as the seeding ratio of finger millet was increased, and the plant densities of all vetch species used in this experiment were decreased. So when the seeding ratio of vetch decreased, that of finger millet was increased, increasing both dry matter yield (DMY) and CPY of finger millet. This could be due to the positive impact of legume/vetch in nitrogen fixation which in its turn enhanced dry matter and crude protein yield production of the grass/finger millet component.

4.3. Chemical composition of finger millet

The ash content of finger millet straw varied among the treatment combinations. The highest ash content was obtained from T8 (25% finger millet +75% Vicia vilosa). This maximum ash content is assumed to be due to the highest seeding ratio and creeping nature of Vicia vilosa associated with the lowest seeding ratio of finger millet with which it was intercropped to be liable to fall and form contact with the soil. The mixed cultivation of grasses with legumes can improve the forage quality concerning the CP content compared to sole grass. This study showed that the higher the seeding ratio of the vetch species, the higher the CP content of Finger millet straw. This was related to the highest crude protein content of finger millet straw obtained from T8. The CP content of finger millet straw obtained in this study is higher than the 7.5% crude protein content reported by Madibela and Modiakgotla (2004) from three landraces of finger millet tested in Botswana. This could be due to the contribution of legumes in improving straw quality through nitrogen fixation. The result of this study also corresponds to the results of Eskandari et al. (2009), who reported that grasses that were grown in mixed culture with legumes contained a higher CP content than grasses that were harvested from the cultivated monoculture. This suggests that legumes grown alongside non-legume plants increase the N uptake of companion plants by removing the atmospherically fixed N by legumes on the non-nitrogen fixing plants grown in connection with them. Ojo et al. (2013) also reported higher CP values of Panicum maximum mixed with Lablab purpureus. The present result is also in agreement with the finding of Taye et al. (2007) who reported that Napier grass intercropped with Lablab and Desmodium resulted in higher CP levels than Napier grass alone.

The lowest NDF levels were found in vetch grown with finger millet than in the sole finger millet because legumes fix nitrogen in the soil, which helps improve the nutritional values of grass. The highest NDF content of finger millet straw obtained in this study was compared and found to be superior in feed quality to that reported by Madibela and Modiakgotla (2004) in Botswana. This variation is mainly due to a difference in the cropping system (monoculture/intercropping), which in our case can be explained as the contribution of the vetch species to improving the nutritional value of finger millet straw by reducing the

Table 2. Chemical compositions of finger millet straw as affected by intercropped vetch species, seeding ratios and their interaction.

| Factors | Chemical composition |
|---------|----------------------|
| Vspps1  | DM (%)  | Ash (%)  | CP (%)  | NDF (%)  | ADF (%)  | ADL (%)  | HC (%)  | Cell (%) |
| Vspps2  | 92.43   | 6.50     | 7.53    | 7.34     | 64.70    | 43.25     | 7.51     | 21.32 |
| Vspps3  | 92.33   | 7.29     | 8.95    | 65.32    | 42.78    | 7.51      | 21.55      | 36.26 |
| Vspps4  | 92.59   | 6.50     | 7.53    | 64.70    | 43.25    | 7.51      | 21.55      | 36.26 |
| Vspps5  | 92.33   | 9.02     | 11.56   | 63.15    | 40.45    | 7.51      | 22.70      | 32.91 |
| Vspps6  | 92.59   | 8.59     | 10.52   | 62.50    | 41.50    | 7.32      | 20.99      | 34.18 |
| Vspps7  | 92.33   | 7.29     | 8.95    | 64.70    | 43.25    | 7.51      | 21.55      | 36.26 |
| Vspps8  | 92.43   | 6.50     | 7.53    | 64.70    | 43.25    | 7.51      | 21.55      | 36.26 |
| Vspps9  | 92.59   | 7.29     | 8.95    | 64.70    | 43.25    | 7.51      | 21.55      | 36.26 |
| Vspps10 | 92.33   | 9.02     | 11.56   | 63.15    | 40.45    | 7.51      | 22.70      | 32.91 |
| Vspps11 | 92.59   | 6.50     | 7.53    | 64.70    | 43.25    | 7.51      | 21.55      | 36.26 |
| Vspps12 | 92.33   | 9.02     | 11.56   | 63.15    | 40.45    | 7.51      | 22.70      | 32.91 |
| Vspps13 | 92.59   | 6.50     | 7.53    | 64.70    | 43.25    | 7.51      | 21.55      | 36.26 |
| Vspps14 | 92.33   | 9.02     | 11.56   | 63.15    | 40.45    | 7.51      | 22.70      | 32.91 |
| Vspps15 | 92.59   | 6.50     | 7.53    | 64.70    | 43.25    | 7.51      | 21.55      | 36.26 |
| Vspps16 | 92.33   | 9.02     | 11.56   | 63.15    | 40.45    | 7.51      | 22.70      | 32.91 |
| Vspps17 | 92.59   | 6.50     | 7.53    | 64.70    | 43.25    | 7.51      | 21.55      | 36.26 |
| Vspps18 | 92.33   | 9.02     | 11.56   | 63.15    | 40.45    | 7.51      | 22.70      | 32.91 |
| Vspps19 | 92.59   | 6.50     | 7.53    | 64.70    | 43.25    | 7.51      | 21.55      | 36.26 |
| Vspps20 | 92.33   | 9.02     | 11.56   | 63.15    | 40.45    | 7.51      | 22.70      | 32.91 |
| Vspps21 | 92.59   | 6.50     | 7.53    | 64.70    | 43.25    | 7.51      | 21.55      | 36.26 |
| Vspps22 | 92.33   | 9.02     | 11.56   | 63.15    | 40.45    | 7.51      | 22.70      | 32.91 |
| Vspps23 | 92.59   | 6.50     | 7.53    | 64.70    | 43.25    | 7.51      | 21.55      | 36.26 |
| Vspps24 | 92.33   | 9.02     | 11.56   | 63.15    | 40.45    | 7.51      | 22.70      | 32.91 |

Note: a,b,c,d,e,f,g,h,i,j,k,l,m,n,o,p,q,r,s means different letters in a column are significantly different (P < 0.05). Vspps = vetch species, SR = seeding ratio, DM = dry matter; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; ADL = acid detergent lignin; HC = hemicellulose; Cell = cellulose; CV = coefficient of variation, and p = probability, Vspps1 = vetch species1 (Vicia sativa), Vspps2 = vetch species2 (Vicia villosa), Vspps3 = Vetch species3 (Vicia aropurpurea).
Table 3. In-vitro and digestibility and metabolizable energy of Finger millet straw as affected by vetch species, seeding ratios and their interaction.

| Factors                  | IVDMD (%) | IVOMD (%) | ME (MJ kg⁻¹) |
|--------------------------|-----------|-----------|--------------|
| Intercropped Vpps        |           |           |              |
| Vpps1                   | 62.28     | 55.91     | 8.39         |
| Vpps2                   | 61.89     | 55.70     | 8.35         |
| Vpps3                   | 62.02     | 55.13     | 8.26         |
| P value                  | 0.6419    | 0.448     | 0.42         |
| Seeding ratios           |           |           |              |
| SR1                     | 63.12     | 56.65     | 8.49         |
| SR2                     | 62.20     | 55.86     | 8.38         |
| SR3                     | 60.87     | 55.23     | 8.28         |
| P value                  | 0.0002    | 0.0019    | 0.0018       |
| Interaction effect       |           |           |              |
| Vpps1*SR1(T5)           | 62.65     | 56.15     | 8.51         |
| Vpps1*SR2(T6)           | 62.80     | 56.04     | 8.41         |
| Vpps1*SR3(T7)           | 61.39     | 54.96     | 8.24         |
| Vpps2*SR1(T58)          | 63.31     | 56.30     | 8.44         |
| Vpps2*SR2(T9)           | 67.72     | 54.55     | 8.32         |
| Vpps2*SR3(T10)          | 60.66     | 55.33     | 8.30         |
| Vpps3*SR1(T11)          | 63.39     | 56.75     | 8.54         |
| Vpps3*SR2(T12)          | 62.09     | 56.09     | 8.41         |
| Vpps3*SR3(T13)          | 60.56     | 55.38     | 8.31         |
| Overall mean             | 61.06     | 55.91     | 8.38         |
| P value                  | 0.0059    | 0.0377    | 0.0348       |
| Sole FM mean(T1)         | 52.97     | 45.23     | 8.37         |

*Means with different letters in a column significantly different (P < 0.05). Vpps = Vetch species, SR = seeding ratio, IVDMD = in-vitro dry matter digestibility; IVOMD = in vitro organic matter digestibility, ME = metabolizable energy, MJ = megajoule; kg⁻¹ = kilogram per hectare, CV = coefficient of variation. Vpps1 = vetch species1 (Vicia sativa), Vpps2 = vetch species2 (Vicia villosa), Vpps3 = Vetch species3 (Vicia atropurpurea).

4.4. In vitro digestibility and metabolizable energy values of finger millet straw

4.4.1. In vitro dry matter and organic matter digestibility

The highest IVDMD of finger millet straw was recorded from T13, while the lowest was recorded from T11. This lowest IVDMD value is, however, higher than the pure stand of finger millet. This is consistent with the finding of Njoka-Njiru et al. (2006) who found that Napier grass mixed with Seca stylosanthes was significantly more digestible than the sole Napier grass. This is because when grasses are intercropped with legumes there is a decrease in fibre fractions, resulting in increasing the IVDMD of grasses (Tessema, 2000; Njoka-Njiru et al., 2006). Owen and Jayasuriya (1989) found that the critical threshold of IVDMD for feed is 50% to be considered acceptable digestibility. Therefore, the IVDMD of finger millet straw obtained from the mixed crop system of the current study after the grain harvest fits the digestibility of most tropical grasses and could be considered acceptable.

All of the treatment combinations in this study had an in-vitro organic matter digestibility (IVOMD) value greater than the pure stand of finger millet. This is in line with Taye et al. (2007), who noted that intercropping Napier grass with Desmodium/Lablab results were significantly higher in IVOMD values than sole Napier grass. Intercropping finger millet with vetch improved the IVOMD of finger millet straws indicating that the feeding value of finger millet straws can be enhanced in terms of nutrient content and digestibility. The degree of digestion of finger millet straw in intercrops with vetch was greater than in pure stand and this is in line with the report by Mapiye et al. (2006), who stated that legumes in connection with grasses have a positive effect on the digestibility of the grass, probably due to an increased N content from legumes.

4.4.2. Metabolizable energy of finger millet

In this study, the interaction effect of the treatment combinations showed that about 56% of the treatments had not shown statistically significant differences in metabolizable energy (ME) values. This creates an opportunity to choose any of the suitable treatment combinations based on users’ interest and availability of the vetch species. Among the treatment combinations, the numerically highest ME of finger millet straw (8.54 MJ kg⁻¹) was recorded when 25% Finger millet was intercropped with 75% Vicia atropurpurea. ME obtained in the current study was higher than the findings of Backiyalakshmi et al. (2021) who reported 6.18%–6.89% in the assessment of forage potential of the Global collection of finger millet germplasm conserved at the ICRISAT genebank. The difference could be attributed to the cropping system (cereal-legume intercropping), the variety of finger millet used, soil nutrient, rainfall amount and pattern, and other macro and microenvironments. The ME value of the current study also was higher than the critical threshold hold level of 7.5 MJ kg⁻¹ for roughages and forages as noted by Owen and Jayasuriya (1989).
5. Conclusion

In Ethiopia, the conversion of grazing land to arable land and a sole cropping system is exacerbating forage shortages in a very desperate way. Intercropping of vetch and finger millet has shown that it is possible to achieve significant forage yield in a food/feed production strategy. The result revealed that 75% finger millet +25% Vicia vilosa was found to be the best treatment combination in herbage dry matter yield production among the tested treatments. Hence, it can be concluded that it is possible to produce both finger millet and vetch in a harmonized and complementary way ease the food/feed problem and thereby improve the livelihood of small-scale farmers in Ethiopia.

Declarations

Author contribution statement

Wakgari Keba: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Taye Tolemariam: Conceived and designed the experiments; Performed the experiments; Wrote the paper.

Abdo Mohammed: Conceived and designed the experiments; Wrote the paper.

Funding statement

This work was supported by Oromia Agricultural Research Institute, Ethiopia.

Data availability statement

Data will be made available on request.

Declaration of interest’s statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

Acknowledgements

The authors would like to thank Bako Agricultural Research Center for the provision of experimental areas together with all the necessary inputs for the implementation of the study titled “Straw dry matter yield and quality of finger millet intercropped with selected species of vetch with different seeding ratios in the western Oromia, Ethiopia”.

References

Agza, B., Bekele, R., Shiferaw, L., 2018. Quinoa (Chenopodium quinoa, Wild): as a potential ingredient of injera in Ethiopia. J. Cereal. Sci. 82, 170–174.

Alemu, T., 2016. Evaluation of under-sowing vetch in sorghum for intensifying existing production systems: reducing land degradation and farmers’ vulnerability to climate change in the highland dry areas of north-western Ethiopia. In: Technical Report of Experimental Activities, International Center for Agricultural Research in the Dry Areas (ICARDA). Available at. www.icarda.org.

Alemu, B., Melaku, S., Prasad, N.K., 2007. Effects of varying seed proportions and harvesting stages on biological compatibility and forage yield of oats (Avena sativa) and vetch (Vicia villosa R.) mixtures. Livest. Res. Rural Dev. 19 (1), 12.

AOAC, 1990. Official Methods of Analysis of Association of Official Analytical Chemists, fifteenth ed. Washington, DC.

Asefa, G., Ledin, I., 2001. Effect of variety, soil type and fertiliser on the establishment, growth, forage yield, quality and voluntary intake by cattle of oats and vetches cultivated in pure stands and mixtures. Anim. Feed Sci. Technol. 92 (1-2), 95–111.

Backiyalakshmi, C., Naren Reddy, D., Padmakumar, V.P., Prasad, K.V., Azevedo, V.C.R., Verirvvenkash, M., 2021. Assuring forage potential of the global collection of finger millet (Eleusine coracana (L.) Gaertn.) conserved at the ICRI SAT Genebank. Agronomy 11 (9), 1706.

Balchisheg, M., Duncan, A., Toler, A., Ayantunde, A.A., Issa, S., Karimou, M., Zampaligre, N., André, K., Gnanda, I., Varjikshapanickar, P., Kebebe, E., 2020. Improving the adoption of technologies and interventions for increasing the supply of quality livestock feed in low-and-middle-income countries. Global Food Secur. 26, 100372.

CSA (Central Statistical Agency), 2018. Agricultural Sampling Survey Report: Livestock and Livestock Characteristics of Private Peasant Holdings (Statistical Bulletin, 587), Addis Ababa, Ethiopia, pp. 9-20.

Dhima, K.V., Lithourgidis, A.S., Vasilakoglou, I.B., Dordas, C.A., 2007. Competition indices of common vetch and cereal intercrops in two scaling ratios. Field Crop. Res. 100, 249–256.

Diriba, G., 2014. Agronomic and Nutritional Evaluation of Selected Forage Legumes and Locally Available Feedstuff, and Characterization of Forage and Dairy Innovation Systems in Bako and Nekemte Peri-Urban Areas, Oromia, Ethiopia, pp. 87–103.

Eskaardari, H., Ghanbari, A., Javanmard, A., 2009. Intercropping of cereals and legumes for forage production. Not. Sci. Biol. 1 (1), 7–13.

Fantahun, D., 2016. The Effect of Variety and Seed Proportions on Yield, Nutritional Quality and Compatibility of Oats and Vetch Mixtures. Addis Ababa University. Doctorial dissertation.

Forjuttovo, J., Lid, F., Träntén, J., Richter, M., Gruber, L., Doellet, P., Holmola, P., Pavelek, L., 2005. Comparison of organic matter digestibility determined by in vivo and in vitro methods. Czech J. Anim. Sci. 50 (2), 47–53.

Gasu, M., Tamir, B., Urge, M., 2014. Effect of supplementation with non-conventional feeds on feed intake and body weight change of Waræræa Sheep fed urea treated finger millet straw. Greener J. Agric. Sci. 4 (2), 67–74.

Geleti, D., 2000. Productivity and Nutritional Qualities of panicum Coloratum under Varying Stages of Harvest, Different Levels of Nitrogen Fertilizer and in Combination with Stylophanthes Guianensis during the Establishment Year. M.Sc. thesis submitted to Alemany University, Ethiopia.

Gezahegn, K., Fekede, F., Getnet, A., Mengistu, A., Alemayehu, M., Aemro, K., 2016. Chemical composition and in vitro organic matter digestibility of Napier grass (Pennistum purpureum (L.) Schumach) accessions in the mid and highland areas of Ethiopia. Int. J. Livest. Res. 6, 41–59.

Husein, N., Diriba, L., 2021. Cluster Based Oat-Vetch Mixtures for Forage Production in Doolol District of West Ari Zone, Ethiopia.

Kebede, D., Dagnachew, L., Mergesa, D., Chemeda, B., Girma, M., Geleta, G., Gadeta, B., 2019. Genotype by environment interaction and grain yield stability of Ethiopian black seeded finger millet genotypes. Afr. Crop Sci. J. 27 (2), 281–294.

Lithourgidis, A.S., Dhima, K.V., Vasilakoglou, I.B., Dordan, C.A., Yiakoulaki, M.D., 2007. Sustainable production of barley and wheat by intercropping common vetch. Agron. Sustain. Dev. 27 (2), 95–99.

Madibola, Modikgakgola, 2004. Chemical composition and in vitro dry matter digestibility of indigenous finger millet (Eleusine coracana) in Botswana. Livest. Res. Dev. 16 (4), 2004.

Mapiye, C., Mwale, M., Chikumba, N., Poishiwa, X., Mupangwa, F.J., Mugabe, P.H., 2006. A review of improved forage grasses in Zimbabwe. Trop. Subrop. Agrogcosyst. 6 (3), 125–133.

Midega, C.A., Khan, Z.R., Amudavi, D.M., Pitchkar, J., Pickett, A.A., 2010. Integrated management of Striga hermonthica and cereal stemborers in finger millet (Eleusine coracana (L) Gaertn.) through intercropping with Desmodium intortum. Int. J. Pest Manage. 56 (2), 145–151.

Moore, K.J., Hatfield, R.D., 1994. Carbohydrates and forage quality.. In: Forage Quality, Evaluation, and Utilization, pp. 229–280.

Mparwe, D.R., Sabiti, E.N., Ummuna, N.N., Tegegne, A., Osuji, P., 2003. Integration of finger legumes with cereal crops. I. Effects of supplementation with green forage of lablab hay on voluntary food intake, digestibility, milk yield and milk composition of crossbred cows fed maize–lablab stover or oats–vetch hay ad libitum. Livest. Prod. Sci. 79 (2-3), 193–212.

Mulahalem, T., Melak, A., 2013. A survey on the status and constraints of finger millet (Eleusine coracana L.) production in Mekelle Zone, North Western Ethiopia. Dir. Res. Agric. 27 (1–2), 99–103.

Muthui, J.K., Mugendi, D.N., Vechot, L.V., Kung’a’ J.B., 2008. Combining Napier grass with leguminous shrubs in contour hedgerows controls soil erosion without competing with crops. Agrofor. Syst. 74 (1), 37–49.

Njoka-Njuru, E.N., Njuru, M.G., Abdulrazak, S.A., Mareithi, J.G., 2006. Effect of intercropping herbaecous legumes with Napier grass on dry matter yield and nutritive value of the feedstuffs in the semi-arid region of eastern Kenya. Agric. Tropica Subtropica 39 (4), 255–267.

Olton, F., Stern, W.R., 1987. Cereal–legume intercropping systems. Adv. Agron. 41, 41–90.

Ojo, V.O., Reh, P.A., Anole, T.A., Anele, U.Y., Adeoye, S.A., Hassan, O.A., Olaitise, J.A., Iwunw, O.J., 2013. Effect of intercropping Panicum maximum var, Nchib and Lablab purpureus on the growth, herbage yield and chemical composition of Panicum maximum var. Nchib at different harvesting times. Pakistan J. Biol. Sci. 16 (12), 1605–1609.

Onta, O.P., Odowo, A.A., 1997. The role of legume forages as supplements to low-quality roughages—ILRI experience. Anim. Feed Sci. Technol. 69 (1-3), 27–38.

Owen, E., Jayaasuriya, M.C.N., 1989. Use of crop residues as animal feeds in developing countries. Res. Dev. Agric. 6 (3), 129–138.

Schmid, A.R., Marten, G.C., Goodrich, R.D., 1970. Influence of drying methods and temperatures on in vitro dry matter digestibility of corn and sorghum fodder and silage I. Agron. J. 62 (4), 543–546.

Semben, B.R., Geburu, G., Desta, S., Nigussa, A., Kinger, K., Aboest, M., Mechal, H., 2015. Ethiopia Livestock Master Plan. ILRI Project Report. International Livestock Research Institute (ILRI), Nairobi, Kenya.
Singh, G.P., Oosting, S.J., 1992. A Model for Describing the Energy Value of Straws, XLIV. Indian dairyman, pp. 322–327.
Taye, B., Solomon, M., Prasad, N.K., 2007. Effects of cutting dates on the nutritive value of Napier (Pennisetum purpureum) grass planted sole and in association with Desmodium (Desmodium intortum) or Lablab (Lablab purpureus). Livest. Res. Rural Dev. 19 (1), 2007.
Tilley, J.M.A., Terry, R.A., 1963. A two-stage technique for in vitro digestion of forage crops. J. Br. Grassl. Soc. 18, 114.
Tessema, Zewdu, 2000. Productivity, Chemical Composition and Digestibility of Elephant Grass (Pennisetum Purpureum) as Influenced by the Height of Cutting and Different Sources of Fertilizer Application. An MSc thesis was presented to the School of Alemaya University, Ethiopia, p. 110p.