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Forage Yield and Quality Evaluation of Selected Vetch Species Intercropped with Finger Millet at Different Seeding Ratios in Western Oromia, Ethiopia

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Abstract

This study was conducted to evaluate dry matter yield and quality of three vetch species (Vicia sativa, Vicia vilosa, and Vicia atropurpurea) intercropped with finger millet at different seeding ratios in western Oromia, Ethiopia. The experimental design was Randomized Complete Block Design (RCBD) with three replications. The treatment consisted of three vetch species, five seeding ratios (0:100, 25:75, 50:50, 75:25 and 100:0% Finger millet: Vetch respectively). Most measured parameters revealed significant ($P<0.05$) difference among the treatments. The interaction of species and seeding ratios showed a significant difference ($P<0.05$) for plant height at forage harvesting stage. The maximum and minimum plant heights were obtained from T10 (154 cm) and T5 (85.33 cm) respectively. Dry matter yield of vetch was affected ($P<0.05$) by the treatments. The highest and the lowest dry matter yield of vetch were obtained from T8 (2.56 t ha^{-1}) and T10 (1.28 t ha^{-1}) respectively. Crude protein (CP) content of vetch had shown significant variation ($P<0.05$) for the tested treatments and the highest value was obtained from T12 (19.16%). The land equivalent ratio (LER) varied from 0.77 to 1.16. In the present study, LER values greater than 1.0 are recorded from T10 (1.16), T9 (1.08) and T11 (1.03). The highest forage dry matter yield of vetch, which can be supplemented in ruminant ration, was obtained from T8. Thus, it can be concluded that in a mixed crop-livestock production system of Bako and similar agro ecologies vetch can be integrated with Finger millet production in a food-feed production strategy to alleviate the existing feed shortage.

Keywords: Finger millet, vetch species, seeding ratios, dry matter yield

1. Introduction

Ethiopia has the largest livestock population among African countries and they have been estimated at about 60.39 million cattle, 31.30 million sheep, 32.74 million goats, 2.01 million horses, 8.85 million donkeys, 0.46 million mules, 1.42 million camels and 56.06 million poultry [1]. The livestock sector has contributed a significant part to the country's economy and still promises to play its role in the country's economic development. At the family level, livestock production plays an essential role as a source of food and family income for small farmers and pastoralists [2]. Therefore, livestock farming remains a mainstay for the country's food security, human sustenance, and economic growth [3]. However, the productivity of the animals lags behind the population due to some technical and managerial bottlenecks.

Forage scarcity, both in quantitative and qualitative terms, is one of the technical issues that deserve close attention. In countries where arable-livestock is the main agricultural production system, the food/feed production strategy may be the best option for the production of food and forage crops as complementary units. The interaction between crops and livestock can be complementary or competitive. Complementarity occurs when one sector provides production contributions to the other [4]. This can be explained by the use of manure and draft power for crop production and the use of crop residues, crop field weeds and crop processing by-products as animal feed. Production of grass or cereals or tree legumes as catch crops or in conjunction with regular crops can also lead to complementarity by increasing both crop and livestock yields. Therefore, a systematic and productive harmonization of the two sectors animal husbandry and crop production is undoubtedly imperative. Even though livestock play a significant role in crop production in Ethiopia, the rangeland is shrunk from time to time to grow food crops to feed the people. However, in recent years, agricultural growth has accelerated significantly in some countries, such as China, through higher yield per unit area rather than an increase in acreage [5].

Intercropping, defined as the simultaneous cultivation of two or more crop species in the same field during a growing season [6], is important for the development of sustainable food production systems, especially in cropping systems with limited external inputs. The intercropping of food crops with forage legumes could be an important management practice to fill the production gaps of food and feed in both quantity and quality for human food and animal feed and increase the profitability and sustainability of the system in tropical regions. Intercropping of forage legumes with grasses/cereals offers the potential to increase productivity, herb nutritional value and resource use efficiency [7]. Farmers in low-income countries like Ethiopia could not afford to use industry-based concentrates and chemicals to supplement roughage to better utilize it. Fortunately, legume forages can improve the use of poor quality roughage and are used more widely around the world [8]. In different production systems, legumes are able to improve both crop production through sustained soil fertility and animal production through increased availability of high-quality forage. One of the possible approaches to reduce the existing dietary restrictions in livestock is the intercropping of cereals with forage legumes [9].

Finger millet (*Eleusine coracana*) is a small-seeded cereal grown in rain-fed conditions in low-rainfall areas of the world's semi-arid tropics. It is a robust crop, capable of giving a reasonable grain yield in circumstances where other plants yield negligibly. Finger millet is a staple in drought-prone areas of the world and is often viewed as part of food security strategies. In Africa, Finger millet is grown by small farmers who often grow it with grains, legumes, or vegetables. It is also important for its nutritive and cultural value, particularly in traditional low-input grain-based farming systems [10]. In Ethiopia, the current national average grain yield of this crop is 2.10 tons ha-1 and in Bako 2.34-2.98 and 2.30-2.98 tons ha-1 in the research field and the farmer field, respectively [11].

Vetch is an annual forage legume crop that is well-adapted and more promising as short-term forage crops, and is widely adapted to the highlands and mid-elevations of Ethiopia. In addition, some research reports also show that it is possible to produce vetches from sea level to an altitude of 3000 m and that it is suitable for a wide range of rainfall, typically anything over 400 mm per year [12]. Forage legumes including vetch are rich N sources for livestock with cheaper prices compared to concentrates, especially in developing countries [13]. Because of its high value, vetch is used as a protein supplement for ruminants on poor diets. In order to alleviate the scarcity of fodder in the study area, mixed cultivation of grain crops with fodder legumes is possible.

Some information has been generated on intercropping of vetch with other cereals [14, 15]. However, no information is available in the study area on the effect of mixed cultivation of vetches with Finger millet on dry matter yield and nutritional value. Therefore, this study was designed to determine the effect of intercropping three species of vetch (Vicia sativa, Vicia villosa, and Vicia atropurpurea) with finger millet (*Eleusine coracana*) at different sowing ratios on herbage yield, chemical composition, digestibility, and compatibility.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was carried out during the main rainy season (June to November) in 2020 at Bako Agricultural Research Center (BARC) located in western Oromia, Ethiopia. The area is located at an altitude of 1650 m above sea level, and at 09^0 6’00” N latitude and 37^0 09’00” E longitudes.

The area has a warm humid climate with annual mean minimum and maximum temperature of 14.4 and 29.3°C (Figure 1), respectively. The area receives an annual rainfall of 1605.1 mm (Figure 1) mainly from May to October with maximum precipitation in the month of May to September (Meteorological station of the center, 2020). The predominant soil type of the area is *Nitosols* which is characteristically reddish brown and clay in texture with a pH that falls in the range of very strongly acidic to strongly alkaline.

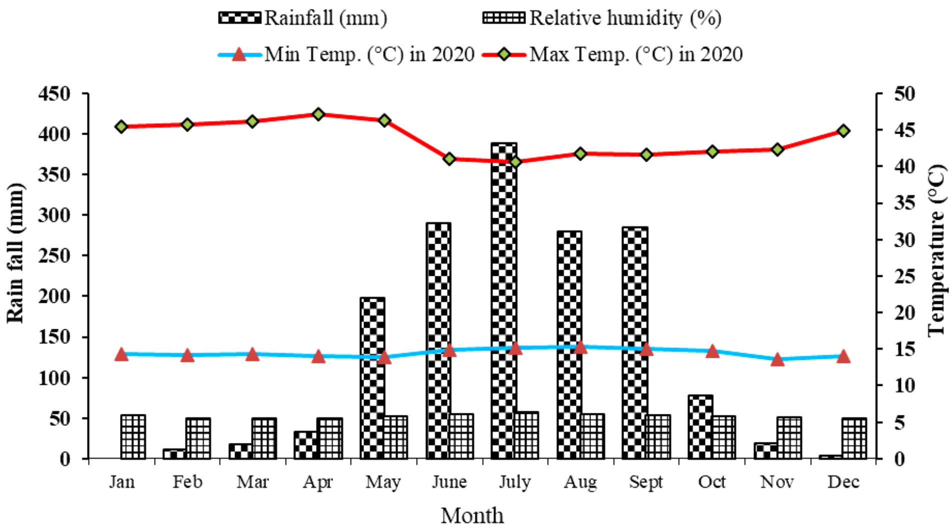

Fig 1: Monthly total rainfall (mm), relative humidity (%), mean minimum and maximum temperatures (°C) of experimental station in 2020.

2.2. Experimental Materials

Improved Finger Millet variety (Bako-09) and Vetch species (*Vicia sativa, Vicia villosa,* and *Vicia atropurpurea*) were used as test crops for the study. The Finger millet variety (Bako-09) was released by Bako Agricultural Research Center (BARC) in 2017.Vetch species were introduced to BARC from Holeta and Sinana agricultural research centers and adapted to Bako condition.

2.3. Treatments and Experimental Design

The treatment comprised of three vetch species *Vicia sativa* (common vetch), *Vicia villosa* (hairy vetch), and *Vicia atropurpurea* (Purple *vetch*) and five seeding ratios (0:100.100:0, 25:75, 50:50, 75:25% Finger millet: vetch respectively) in randomized complete block design (RCBD) with three replications. The vetch species were intercropped between the rows of Finger Millet and sole vetch species and Finger Millet were sown based on their respective recommended seeding rates of 25 kg/ha for both *Vicia villosa* and *Vicia atropurpurea,* and 30 kg ha^{-1} for *Vicia sativa* [16], and Finger Millet 15 kg ha^{-1}[11]. Seeds of both Finger Millet and Vetch were drilled in their respective rows. The experiment consisted of three blocks; each block contained thirteen experimental units (plots) which make thirty-nine plots. The experimental plot size was 3m*4m=12m^2. The distance between plots and blocks (replications) were 1m and 1.5m respectively. Plots in each block were randomly assigned to the thirteen treatments by using the SAS software randomization procedure. The vetch species were sown after two weeks of planting Finger Millet based on the recommendation [17]. The treatments were assigned to each plot as shown in Table 1 below.

Table 1: Treatment arrangements of the experiment

Treatments	Description	Seeding ratios	
		Finger Millet	Vetch
T1	Sole Finger millet(*Eleusine coracana*)	100%	0%
T2	Sole *Vicia sativa*	0%	100%
T3	Sole *Vicia villosa*	0%	100%
T4	Sole *Vicia atropurpurea*	0%	100%
T5	Finger millet + *Vicia sativa*	25%	75%
T6	Finger millet + *Vicia sativa*	50%	50%
T7	Finger millet + *Vicia sativa*	75%	25%
T8	Finger millet *Vicia villosa*	25%	75%
T9	Finger millet+ *Vicia villosa*	50%	50%
T10	Finger millet+ *Vicia villosa*	75%	25%
T11	Finger millet+ *atropurpurea*	25%	75%
T12	Finger millet+ *atropurpurea*	50%	50%
T13	Finger millet+ *atropurpurea*	75%	25%

2.4. Land Preparation and Planting

The land was plowed and fined with tractors and finally leveled by day laborers to fine the soil. Before planting the trial plots, plots with a fine seedbed were prepared. The recommended fertilizer rates of 100 kg ha-1 NPS and 64 kg ha-1 UREA [11] were applied during setup (planting) for all experimental units. Seeds of Finger millet (*Eleusine coracana*) and three species of vetches *(Vicia sativa, Vicia villosa* and *Vicia atropurpurea*) were sown in alternating rows [18] according to their seeding percentages on well-prepared soil. Weeding was done by hand to eliminate regrowth of unwanted plants and encourage cover crop growth by increasing soil aeration.

2.5. Data Collection Procedures

2.5.1. *Agronomic Parameters*

The agronomic parameters of vetch such as the number of branches per plant and the number of leaves per plant were counted from five randomly selected plants, and plant height was measured by tape measure from five plants selected from the middle rows of each plot at the forage harvest stage. The leaf-stem ratio of vetch was determined at the optimal harvest stage by cutting plants from two randomly selected inner rows, separating into leaves and stems, drying and weighing.

2.5.2. *Biomass Yield Determination*

Vetch species were harvested 50% at the flowering stage based on continuous visual observation [19]. Harvesting was done by hand with a sickle, leaving a stubble height of 8 cm above the ground according to recommended practice [20]. The harvested fresh biomass was weighed and recorded immediately in the field using a top-loading scale. Fresh subsamples of approximately 250-300 grams were taken from each plot and weighed and then chopped into small pieces of 2-5 cm for determination of dry matter. Then the fresh samples were oven dried at 65°C for 72 hours and the partial dry weight is recorded to estimate the dry matter biomass production according to [21].

$$DMY\left({}^{t}/_{ha}\right) = 10 * TFW * \left(\frac{DWSs}{HA * FWSs}\right) \ldots\ldots\ldots\ldots (1)$$

Where: 10 = constant for conversion of yields in kg/m^2 to ton/ ha;
TFW = total fresh weight from harvesting area (kg);
SSDW = sub-sample dry weight (g);
HA = harvest area (m2), and
SSFW = sub-sample fresh weight (g).

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

2.5.3. *Analysis of Feed Chemical Composition*

Samples of each vetch species intercropped at different seeding ratios and sole vetch species were taken from each plot and dried in a forced draft oven at 65°C for 72 hours and ground using a Wiley mill to pass through a 1 mm sieve pending for chemical analysis. The AOAC method (1990) was used to determine dry matter (DM), ash and nitrogen. The DM content was determined by oven drying at 65°C for 72 hours. Ash was determined by completely burning the feed samples in a muffle furnace at 600°C overnight according to the method of AOAC (1990). Total nitrogen (N) was determined using the Kjeldahl method [22]. Crude protein (CP) was calculated as nitrogen (N) x 6.25. Neutral detergent fiber (NDF), acid detergent fiber (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.

2.5.4. *In vitro dry matter (IVDM) and Organic matter (IVOM) digestibility of vetch*

All samples used in the chemical analysis were collected for *in vitro* dry matter digestibility (IVDMD). Rumen juice was collected from the rumen of fistulated oxen and then transported to the laboratory using a thermos preheated 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 water in a 100 ml test tube in a 39°C water bath for 48 hours 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 hours at 60°C. Chemical analysis and *in vitro* dry matter digestibility (IVDMD) were performed at Holeta Agricultural Research Center. IVDMD was calculated [23] as follows:

$$IVDMD = \frac{\text{Dry sample weight} - (\text{Residue} - blank}{\text{Dry sample weight}} \times 100 \ldots\ldots(2)$$

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

$$IVOMD = \frac{\text{DOM in the feed} - (\text{OMin residue} - \text{blank})}{\text{OM in the feed}} \times 100 \ldots\ldots\ldots\ldots(3)$$

Where OM = DM- Ash (measured after ignition of feed or residue)
The Metabolizable Energy (ME) content was estimated using the equation:

$$ME\ (MJ\ kg-1\ DM) = 0.15 * IVOMD \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

2.5.5. *Land equivalent ratio (LER)*

The LER is defined as the amount of land required under monoculture to obtain the same dry matter yield as produced in the intercrop. It is calculated according to the equation proposed by (Baghdadi *et al*., 2016) as follows:

$$LERab = \left(\frac{Yab}{Yaa}\right) + \left(\frac{Yba}{YBB}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

Where, Yaa = sole crop yield of species 'a'; Ybb = sole crop yield of species 'b'; Yab = intercrop yield of species 'a' in combination with species 'b' and Yba = intercrop yield of species 'b' in combination with species 'a'.

2.5.6. *Statistical Analysis*

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

$$yijk = \mu + \alpha i + \beta j + (\alpha\beta)ij + \varepsilon ijk, \ldots\ldots\ldots(6)$$

i = 1. . . I, j = 1. . . J, k = 1. . . nij.
The αi and βj parameters represent the main effects, and have the same general interpretation as the effect in a one-way ANOVA does. The (αβ)ij represents an interaction effect. The εijk represents random error.

3. Results and Discussion

3.1. Agronomic Performance of Vetch

3.1.1. *Plant Height*

Vetch plant height was significantly affected ($P<0.05$) by species, sowing ratio and intercropping at the forage harvest stage (Table 2). Vetch species mixed with finger millet had a higher plant height compared to their corresponding sole crops. This suggests that cover crops are moving toward sunlight, which is critical for photosynthesis. The present result contradicts the finding reported by Ojo *et al.* [24] who found that the plant height of Panicum maximum in cover crops with Lablab purpureus was not significantly different from that of sole 14 weeks after planting. The difference between the results could be attributed to factors such as soil type, legumes and grass, harvest date and other management conditions.

The interaction of species and seeding ratio showed a significant difference ($P<0.05$) for plant height at the stage of forage harvest. Maximum and minimum plant heights (154.00 and 85.33 cm, respectively) were obtained from T10 and T5. The analysis of variance showed that the growth height of the vetch decreased in all tested species with increasing sowing percentage of crabgrass. This could be due to the suppressive effect of the grain over the accompanying legume. In general, previous research reports have indicated that plant height is the main factor affecting forage yield of grass and legumes in relation to growth and biomass.

3.1.2. *Leaves Per Plant*

The number of leaves determines the photosynthetic capacity of a plant. Leaves per vetch plant were significantly affected ($P<0.05$) by species, sowing ratios and their interaction at forage harvest stage (Table 2). The leaves per plant of three vetch species grown with crabgrass at different seeding ratios in intercrops were less than the leaves per plant of their respective single crops of each species. The number of leaves per plant of vetch for all species tested increased with increasing seeding ratios of the Finger Millet decreased. This indicates that cover crop vetch leaf development was hampered by crabgrass dominance in terms of nutrients, moisture and sunlight utilization. Analysis of variance for an interaction effect of cultivar and seeding ratio showed that T5 had produced the highest (35) leaves per plant, while the lowest leaves per plant (20.33) were obtained from T13. Contrary to the current result, the finding of Yegrem *et al.* [25] revealed that a higher number of leaves per plant in Desho grass mixed with green leaf *desmodium* than its sole.

3.1.3. *Leaf to Stem Ratio and Branches Per Plant*

The leaf-to-stem ratio is an important factor determining the quality of plants, as leaves are more digestible and popular feed for animals than stems. The analysis results showed that there was no statistically significant difference ($P>0.05$) in the leaf-to-stem ratio of the vetch species (Table 2). The number of branches per plant of vetch species was significantly ($P<0.05$) influenced by cultivar, seeding ratio and their interaction. The number of branches per plant of the sweet pea species varied between 2.13 and 3.35 with a mean of 2.71. The maximum number of branches per plant (3.34) was recorded from T9. This could be due to the balanced population of the two cover crops, which allowed the legumes to receive optimal soil nutrients, moisture, space and light to establish well and produce the maximum branches. Alemu *et al.* [26] reported that the average number of branches was higher than the results obtained in this study. The possible difference could be the cultivation system, agro ecology, soil fertility, soil moisture, management practices and other growth crop factors.

3.1.4. *Vetch Herbage Dry Matter Yield*

Dry matter yield (DMY) of vetch was affected by species, seeding ratio and their interaction ($P<0.05$) (Table 2). The highest and lowest dry matter yields of vetches (2.56 t ha-1 and 1.28 t ha-1) were obtained from T8 and T10, respectively. This study found that vetch DMY increased with increasing sowing ratio. Pure vetch stands (*Vicia sativa*, *Vicia vilosa* and *Vicia atropurpurea*) were also compared and the highest dry matter yield (6.82 t ha^{-1}) was from sole Vicia vilosa, but the lowest dry matter yield (5.06 t ha-1) was from Vicia sativa harvested. This result is similar to the result from Alemu [26], where the highest and lowest dry matter yield was obtained from Vicia villosa and Vicia sativa, respectively. The possible reason for the highest dry matter yield of *Vicia vilosa* could be due to varietal difference and the highest plant height which contributed to the highest DMY of *Vicia vilosa* among the tested species. This result is in agreement with findings of Dawit and Nebi [27] in which *Vicia vilosa* intercropped with maize gave the highest yield among other tested vetch species.

Table 2: Effect of vetch species and seeding ratio on plant height (cm), leaves per plant, leaf to stem ratio, branches per plant, pods per plant and seeds per pod of vetch

Factors	plht	Lpp	LSR	Bpp	Dmy (t ha^{-1})
Vspps					
Vspps1	79.11^{c}	31.67^{a}	1.27	1.98^{c}	1.76^{c}
Vspps2	155.67^{a}	24.11^{b}	1.26	3.31^{a}	2.25^{a}
Vspps3	132.44^{b}	22.67^{b}	1.13	2.84^{b}	1.93^{b}
P value	0.0001	0.0001	0.080	0.0001	0.001
Sole vetch species					
Sole Vspps1(T2)	73.67^{c}	36.00^{a}	3.26	1.22	5.06^{c}
Sole Vspps2(T3)	145.33^{a}	30.00^{b}	4.27	1.26	6.28^{a}
Sole Vspps3(T4)	129.67^{b}	29.67^{b}	3.64	1.23	5.61^{b}
P value	0.0001	0.0447	0.072	0.4771	0.0001
Seeding ratios					
SR1	125.00^{a}	28.78^{a}	1.262	2.25^{b}	2.42^{a}
SR2	118.67^{b}	25.67^{b}	1.247	2.91^{a}	2.00^{b}
SR3	115.56^{b}	24.00^{b}	1.248	2.24^{b}	1.51^{c}
P value	0.0052	0.0019	0.624	0.0001	0.0001
Intercrops					
Vspps1*SR1(T5)	85.33^{e}	35.00^{a}	1.23	2.35^{b}	2.41^{b}
Vspps1*SR2(T6)	77.33^{ef}	29.67^{bc}	1.22	2.32^{b}	1.58^{d}
Vspps1*SR3(T7)	74.67^{f}	30.33^{ab}	1.24	2.13^{cd}	1.28^{e}
Vspps2*SR1(T8)	154.00^{a}	26.33^{bcd}	1.28	3.32^{ab}	2.56^{a}
Vspps2*SR2(T9)	146.33^{ab}	24.67^{cde}	1.24	3.35^{a}	2.50^{ab}
Vspps2*SR3(T10)	142.67^{bc}	21.33^{de}	1.25	2.13^{cd}	1.69^{d}
Vspps3*SR1(T11)	135.67^{cd}	25.00^{cde}	1.28	2.19^{bc}	2.30^{b}
Vspps3*SR2(T12)	132.33^{d}	22.67^{de}	1.28	2.16^{cd}	1.93^{c}
Vspps3*SR3(T13)	129.33^{d}	20.33^{e}	1.26	2.15^{cd}	1.54^{d}
Mean	**119.74**	**26.15**	**1.25**	**2.71**	**1.98**
SEM	2.961	1.725	0.021	0.079	0.696
P value	0.0001	0.0002	0.315	0.0001	0.0001
Cv (%)	**4.42**	**11.43**	**2.86**	**5.11**	**5.7**

$^{a-b}$Means with different letters in a column are significantly different (P<0.05. Vspps= vetch species, SR=seeding ratio, Cm= centimeter, Plht= plant height, LPP=leaves per plant, LSR=lef to stem ratio, BPP=branches per plant, Dmy= dry matter yield, t ha^{-1}*=tons per hectare, Vspps1=vetch speciece 1 (Vicia sativa), Vspps 2=vetch speciece 2 (vicia vilosa), and Vspps 3=vetch species 3 (Vicia atropurpurea)*

3.2. Chemical Composition of Vetch

The chemical composition of the vetch species in catch crop cultivation with finger millet and the pure stock is given in Table 3. The result showed that species, sowing ratio and their interaction had significantly (P<0.05) influenced the dry matter content (DM %) of vetch. The highest dry matter (93.99%) was obtained from T10. This could be due to higher moisture utilization and higher seed percentage in crabgrass, which utilized the maximum moisture from the soil. The DM concentration of all treatment combinations was above 92.47%, indicating good drying for preservation as hay. This result agrees with the result of Bingo *et al.* [28] who reported a similar value in a vetches-barley mixture.

The ash content is the concentration of minerals in the feed. The higher ash content indicates a high concentration of minerals. Variations in the concentration of minerals in feed have been reported, caused by factors such as cultivars [29], plant development stage, morphological fractions, climatic conditions, soil properties and fertilization regime [30]. Among the treatment combinations in this study, the highest and lowest ash levels (8.32 and 6.73%) were recorded from T11 and T7, respectively. This could be due to the morphological difference between *Vicia atropurpurea* and *Vicia sativa*. *Vicia atropurpurea* is known to have a creeping growth habit which creates the possibility of contact with the soil surface/soil which in turn increases the ash content of the forage. Whereas *Vicia sativa* has an upright growth habit that reduces the possibility of soil spoilage. Furthermore, this result is similar to the finding of Fantahun [31] who suggested that a mid to late maturing species of vetches (*Vicia atropurpurea*) had a relatively higher ash content than early maturing species of vetches (*Vicia sativa*), which could be due to differences in proportions and composition of the morphological fractions.

The interaction effect showed a significant variation (P<0.05) in the crude protein (CP) content of the vetch. The CP content of the vetch obtained from T12 (19.16%) was the highest among the treatments tested. Pure vetches had higher crude protein content than their respective vetches in catch crop cultivation with finger millet. Among the pure vetch sole stocks, *Vicia sativa* had the highest CP level (23.55%). This difference has been attributed to species or cultivar differences between the legumes. This result agreed with Rahetlah *et al.* [32] who reported that a pure stand vetch had a higher concentration of CP than vetch mixed with oats. Most herbaceous legumes have >15% CP, a level normally required to support lactation and growth, suggesting that herbaceous legumes are suitable to supplement the staple diet of predominantly low-quality pasture and crop residues [29]. Therefore, the result of the present study was greater than the required CP for lactation and growth of the animals. Analysis of variance showed that the interaction of the factors had a significant effect on the NDF content of vetch and the lowest value (35.24%) was recorded for T7. Meissner *et al.* [33] reported that NDF levels above the critical 60% level can reduce voluntary feed intake, feed conversion efficiency and increased rumination time. However, the NDF content of all tested vetch species was below this threshold, indicating higher digestibility.

Table 3: Chemical composition of vetch as affected by species and seeding ratios, and their interaction

Factors	Chemical composition					
Intercropped Vspps	**DM (%)**	**Ash (%)**	**CP (%)**	**NDF (%)**	**ADF (%)**	**ADL (%)**
Vspps1	93.47^{a}	6.74^{c}	16.22	38.98	39.41^{a}	6.20
Vspps2	93.69^{a}	7.94^{b}	15.51	41.76	39.38^{a}	6.54
Vspps3	92.75^{b}	8.33^{a}	16.42	41.13	36.38^{b}	5.98
P value	0.0001	0.0001	0.6887	0.1916	0.0002	0.0970
Seeding ratios						
SR1	93.61^{a}	7.67	18.89^{a}	40.99	36.38^{b}	6.07
SR2	92.92^{b}	7.67	17.09^{a}	40.86	37.11^{b}	6.12
SR3	93.61^{a}	7.68	12.17^{b}	40.01	41.59^{a}	6.53
P value	0.0001	0.7561	0.0001	0.7893	0001	0.1471
Intercrops						
Vspps1*SR1(T5)	93.57^{b}	6.75^{c}	15.17^{d}	38.64^{c}	35.49^{g}	5.79^{f}
Vspps1*SR2(T6)	92.83^{cd}	6.73^{c}	14.52^{e}	43.05^{ab}	40.03^{c}	6.91^{a}
Vspps1*SR3(T7)	93.99^{a}	6.74^{c}	11.27^{h}	35.24^{d}	42.71^{b}	5.90^{e}
Vspps2*SR1(T8)	93.65^{ab}	7.94^{b}	16.78^{bc}	43.82^{ab}	38.03^{e}	6.49^{c}
Vspps2*SR2(T9)	93.64^{ab}	7.93^{b}	17.57^{b}	40.89^{abc}	36.57^{f}	6.24^{d}
Vspps2*SR3(T10)	93.99^{a}	7.94^{b}	12.21^{g}	40.57^{bc}	43.54^{a}	6.89^{a}
Vspps3*SR1(T11)	92.94^{c}	8.34^{a}	17.04^{dc}	40.53^{bc}	35.62^{g}	5.91^{e}
Vspps3*SR2(T12)	92.47^{d}	8.34^{a}	19.16^{a}	38.64^{c}	34.72^{h}	5.22^{g}
Vspps3*SR3(T13)	92.84^{cd}	8.33^{a}	13.05^{f}	44.23^{a}	38.54^{d}	6.80^{b}
Overall mean	93.30	7.67	16.05	40.63	38.36	6.24
SEM	2.134	1.543	1.654	2.134	1.125	2.235
P value	0.0045	0.001	0.001	0.001	0.0034	0.0001
Sole *Vicia sativa*(T2)	91.46^{b}	7.73	23.55	35.55	31.37	7.06
Sole *Vicia vilosa*(T3)	93.06^{a}	9.39	21.13	36.23	32.00	6.34
Sole *Vicia atropurpurea* (T4)	92.56^{a}	9.14	21.13	35.45	33.42	6.24
P value	0.025	0.071	0.141	0.632	0.197	0.171

$^{a-b}$Means with 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, CV =coefficient of variation. Vspps1=vetch species1 (Vicia sativa), Vspps2= vetch species2 (Vicia vilosa, Vssps3=Vetch species3 (Vicia atropurpurea)

Both the main and interaction effects had a significant impact on the ADF content of legumes (Table 3). The lowest ADF content (34.72%) was obtained from T12. Legumes with less than 31% ADF values are classified as high quality, while those with values above 55% are classified as inferior [34]. Therefore, the ADF content of the vetches was classified in the current study in the medium quality range. The interaction effect of cultivar and sowing ratio had significantly influenced the ADL content of vetch (P<0.05). The ADL of vetch intercropped with Finger millet were ranged from 5.22% to 6.91% with an overall mean of 6.24%.

3.3. *In vitro* Digestibility and Metabolizable Energy Values of Vetch

3.3.1. *In vitro Dry Matter and Organic matter Digestibility of Vetch*

The *in vitro* dry matter digestibility (IVDMD) of vetches was significantly affected by both species and seeding ratio (Table 4). Among the treatment combinations of vetch species and sowing ratios, the highest (63.40%) IVDMD of T12 was obtained. IVDMD of each forage crop varied according to Proportions of morphological fractions [35]; Soil, plant species and climate [8]. This could be the effect of some environmental factors that significantly affect forage quality by consolidating physiological maturity and thereby increasing the structural components of the plant. The *in vitro* organic matter digestibility (IVOMD) of vetch was significantly (P<0.05) influenced by the interaction of species and seeding ratio (Table 4). Among the treatment combinations, T12 gave the highest IVOMD value (54.81%), but the lowest values (50.17%) were from T6. This could be due to the diversity and inherent characteristics of the species of vetch used. Therefore, in the present study, the mean IVOMD values of vetch were higher than the critical 50%

threshold required for feed to be considered acceptably digestible [36].

3.3.2 *Metabolizable Energy of Vetch*

Analysis of variance revealed that vetch species, seeding ratio and their interaction had significantly (P<0.05) influenced the metabolizable energy (ME) of the vetch species used in the current experiment. The highest ME value (8.79 MJkg-1) was recorded for T12, while the lowest value (8.05 MJkg-1) was obtained for T6. In general, the metabolizable energy obtained in this study was higher than the critical threshold of 7.5 MJkg-1 for roughage and forage as noted in previous research reports.

Table 4: *In vitro* digestibility and Metabolizable energy of vetch as affected by species, seeding ratios and their interactions

Factors	IVDMD (%)	IVOMD (%)	ME (MJ kg^{-1})
Intercropped Vspps			
Vspps1	60.19^{b}	51.99^{b}	8.24^{b}
Vspps2	60.39^{ab}	51.62^{b}	8.27^{b}
Vspps3	61.67^{a}	52.99^{a}	8.49^{a}
P value	0.012	0.008	0.012
Seeding ratios			
SR1	61.61^{a}	52.91^{a}	8.48^{a}
SR2	61.27^{a}	52.54^{a}	8.43^{a}
SR3	59.38^{b}	50.51^{b}	8.09^{b}
P value	0.003	0.0002	0.0003
Intercrops			
Vspps1*SR1(T5)	61.84^{c}	53.13^{c}	8.52^{c}
Vspps1*SR2(T6)	59.06^{h}	50.17^{g}	8.05^{h}
Vspps1*SR3(T7)	59.68^{f}	50.72^{f}	8.15^{f}
Vspps2*SR1(T8)	60.80^{e}	52.04^{e}	8.34^{e}
Vspps2*SR2(T9)	61.36^{d}	52.63^{d}	8.44^{d}
Vspps2*SR3(T10)	59.03^{i}	50.18^{g}	8.04^{h}
Vspps3*SR1(T11)	62.18^{b}	53.55^{b}	8.58^{b}
Vspps3*SR2(T12)	63.40^{a}	54.81^{a}	8.79^{a}
Vspps3*SR3(T13)	59.44^{g}	50.62^{f}	8.11^{g}
Overall mean	60.75	51.98	8.34
P value	0.0001	0.0001	0.0001
Sole *Vicia sativa*(T2)	63.52^{b}	55.96	8.89
Sole *Vicia vilosa* (T3)	63.42^{a}	54.58	8.64
Sole *Vicia atropurpurea* (T4)	61.82^{c}	53.68	8.95
P value	0.0001	0.494	0.783
Cv(%)	0.23	3.96	6.29

$^{a-b}$Means with different letters in a column are significantly different (P<0.05). IVDMD=in-vitro dry matter digestibility, *IVOMD= in-vitro organic matter digestibility, ME=Metabolizable energy, Vspps1=vetch species1 (Vicia sativa), Vspps2= vetch species2 (Vicia vilosa, Vssps3=Vetch species3 (Vicia atropurpurea)*

3.4. Biological Compatibility

3.4.1. *Land Equivalent Ratios*

The land equivalent ratios of finger millet and vetch are shown in Table 5. The LER of the total dry matter yield of vetches and finger millet varied from 0.77 to 1.16. In the present study, area equivalent values greater than 1.0 are only recorded from T10 (1.16), T9 (1.08), and T11 (1.03). Since in the current study the LER values of only these three treatments were greater than 1, this result is partially consistent with the results of Dawit and Nabi [27], in which all LER values of vetch + maize were greater than 1.0.

Table 5: Partial land equivalent ratios of vetch and finger millet and total land equivalent ratio as affected by intercropped vetch species and seeding ratios

Treatment	PLERV	PLERFM	Total LER
25%FM + 75% vspps1(T5)	0.47^{a}	0.36^{e}	0.83^{cd}
50% FM + 50% vspps 1(T6)	0.31^{de}	0.47^{d}	0.79^{d}
75%FM + 25% vspps 1(T7)	0.25^{f}	0.66^{c}	0.91^{c}
25%FM + 75% vspps 2(T8)	0.38^{bc}	0.39^{e}	0.77^{d}
50% FM + 50% vspps 2(T9)	0.37^{bc}	$0.72b^{c}$	1.08^{ab}
75%FM + 25% vspps 2(T10)	0.28^{ef}	0.89^{a}	1.16^{a}
25%FM + 75% vspps 3(T11)	0.41^{b}	0.36^{e}	0.77^{d}

50% FM + 50% vspps 3(T12)	0.34[cd]	0.55[d]	0.89[c]
75%FM + 25% vspps 3(T13)	0.28[ef]	0.75[b]	1.03[b]
Mean	0.34	0.57	0.92
SEM	0.016	0.025	0.027
P value	0.0001	0.0001	0.0001
CV (%)	8.3	7.5	5.2

[a-b]Means with different letters in a column are significantly different (P<0.05). FM= Finger millet, Vspps= vetch species, PLERV=Partial Land equivalent ratio of vetch, PLERFM= Partial Land equivalent ratio of finger millet, LER=Land equivalent ratio.

The possible reason for the difference lies in the cultivation systems, the plant species used for intercropping and other environmental conditions.

4. Conclusion

The effects of varietal and sowing ratio of finger millet and vetch on yield and quality of finger millet and compatibility of finger millet and vetch were evaluated. The results of the current study shows that it is possible to produce a significant quantity and higher nutritional quality of feed by integrating finger millet with finger millet in a food/feed production system with efficient use of external resources. The highest forage dry matter yield of vetch, which can be supplemented in ruminant ration, was obtained from T8. Thus, it can be concluded that in a mixed crop-livestock production system of western Ethiopia and similar agro ecologies vetch can be integrated with Finger millet production in a food-feed production strategy to alleviate the existing feed shortage.

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