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Dry Matter Yield and Quality of 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). Agronomic parameters such as plant height, number of leaves per plant, Leaf to stem ratio, number of branches per plant and forage dry matter yield (DMY) were determined following standard procedures. Feeds chemical compositions were also determined according to the recommended procedures. Intercropping indices such as land equivalent ratio (LER) and relative crowding coefficient (RCC) were also determined. Data were subjected to the ANOVA procedure of the General Linear Model (GLM) of SAS software version 9.3. 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 (154.00 and 85.33 cm) were obtained from T10 and T5 respectively. Dry matter yield of vetch was affected ($P<0.05$) by the treatments. The highest and the lowest dry matter yield of vetch (2.56 t ha^{-1} and 1.28 t ha^{-1}) were obtained from T8 and T10 respectively. 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 LER varied from 0.77 to 1.16. In the present study, land equivalent ratio 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. The result of this study is important for food-feed feed production strategy.
Keywords: Finger millet, Vetch species, seeding ratios, dry matter yield
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1. INTRODUCTION

Ethiopia owns the largest livestock population among African countries and they were estimated to be 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 (CSA, 2018). The livestock sector has been contributing a significant portion to the economy of the country, and still promising to play its role in the economic development of the country. At the family level, livestock play a substantial role as sources of food and family income for smallholder farmers and pastoralists (Wodajo *et al*., 2020). Hence, livestock remains as a mainstay for food security, human nutrition and economic growth of the country (Shapiro *et al.*, 2015). However, the productivity of animals is lagging behind its population due to some technical and management related bottle-necks.

Feed shortage, both in quantity and quality, is among the technical problems that need great attention. In countries where crop-livestock mixed farming is a main agricultural production system, food/feed production strategy can be the best option in producing both food crops and forages as complementary entities. Crop-livestock interaction may be complementary or competitive. Complementarity occurs when one sector provides production contributions to the other (Szymczak *et al*., 2020). This can be explained as the use of manure and draft power for crop production, and the use of crop residues, weeds from crop fields, and crop processing by-products as animal feed. Production of grass or grain or tree legumes as relay crops or in association with regular crops may also give rise to complementarity by enhancing both crop and livestock yields. Thus, harmonizing the two sectors, livestock and crop production, systematically and productively, with no doubt, is mandatory. In Ethiopian, even though livestock play a significant role in crop production, grazing land is being shrunken from time to time to produce food crops to feed the people. However, in recent years, agricultural growth in some countries like China has accelerated remarkably by increased yield per unit area rather than by expansion of the cultivated area (Fan *et al*., 2012).

Intercropping, which is defined as the growing of two or more crop species simultaneously in the same field during one growing season (Ofori and Stern, 1987), is important for the development of sustainable food production systems, particularly in cropping systems with limited external inputs. Intercropping of food cereals with forage legumes could be an important management practice to fill the production gaps of foods and feeds both in quantity and quality for human food and animal feeds, and increase the profitability and sustainability of the system in tropical regions. Intercropping forage legumes with grasses/cereals present the potential to increase productivity, herbage nutritive value, and resource use efficiency (Kiwia *et al*., 2019). Farmers of low-income countries like Ethiopia could not afford to use industry-based concentrates and chemicals as supplements to improve the utilization of roughages. Lucky enough, leguminous forage crops can improve the utilization of low-quality roughages and they are being used more extensively throughout the world (Assefa and Ledin, 2001). In various production systems, legumes are capable of enhancing both crop production through sustained soil fertility and livestock production through increased availability of high-quality feed. One of the potential approaches to reduce the existing livestock nutritional constraint is intercropping of cereals- with forage legumes (Zhang *et al*., 2015).

Finger millet (*Eleusine coracana*) is a small-seeded cereal grown in low rainfall areas of the semi-arid tropics of the world under rain-fed conditions. It is a hardy crop capable of providing reasonable grain yield under circumstances where other crops give negligible yield. Finger millet is a staple food crop in drought-prone areas of the world and is often considered a component of food security strategies. In Africa, finger millet is grown by small-scale farmers often intercropping with cereals, legumes, or vegetables. It is also important for its nutritive and cultural value especially in traditional low-input cereal-based farming systems (Mafongoya *et al*., 2006). In Ethiopia the current national average grain yield of this crop is 2.10 tons ha^{-1}, ^{and} at Bako 2.34 to 2.98 and 2.30 to 2.98 tons ha^{-}1 on research field, and on farmers' field respectively (Kebede *et al*., 2019). Vetch is an annual forage legume well adapted and more promising as short-term fodder crops and widely adapted to the highlands and mid altitudes of Ethiopia. Furthermore, some research reports also reveal that it is possible to produce vetch from sea level to an altitude of 3000 m, and is suited to a wide range of rainfall – typically anything above 400 mm per annum (Gebrehiwot and Tadesse, 1985). Forage legumes including vetch are rich sources of N for livestock with cheaper prices compared to concentrates especially in developing countries (Jabessa *et al*., 2020). Due to its high value, vetch is used as a protein supplement for ruminants on low-quality diets. In order to alleviate the feed shortage in study area, intercropping of cereals crops with forage legumes is feasible.

Some pieces of information have been generated on intercropping of vetch with other cereals (Lithourgidis *et al*., 2007 and Dhima *et al*., 2007). Finger millet has also been intercropped with legumes other than vetches like *Desmodium unicenatum*, and *Desmodium intortum* (Midega *et al*., 2010) in other areas. However, there is no piece of information available in the study area on the effect of intercropping vetch species with Finger millet on forage dry matter yield and nutritive value. Therefore, this study was designed to determine the effect of intercropping three vetch species *(Vicia sativa, Vicia villosa,* and *Vicia atropurpurea)* with Finger Millet (*Eleusine coracana*) at different seeding ratios on herbage yield, chemical composition, digestibility, and compatibility of vetch.

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) which is located in Oromia Regional State, West Shoa Zone, and Bako Tibe district at about 250 km away from the capital city Addis Ababa on the way to Nekemte town. It is at about 8 km from Bako town and 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 (Figure 1).

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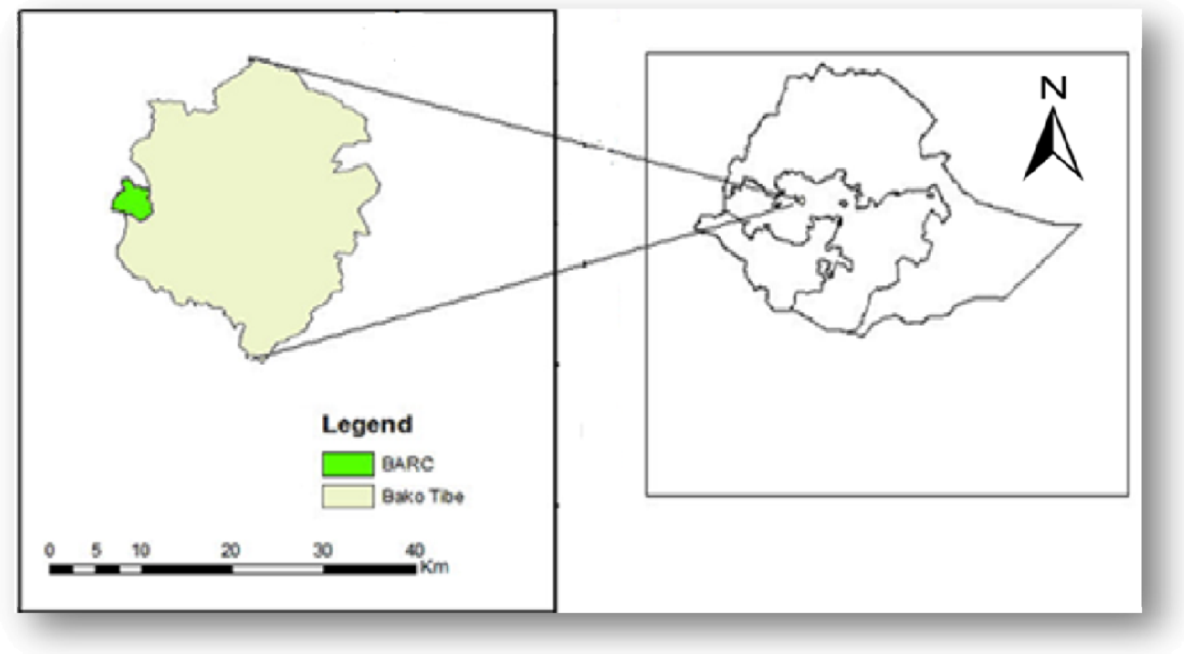

Figure 1 Map of the study area, Bako Agricultural Research Center (BARC)

The area has a warm humid climate with annual mean minimum and maximum temperature of 14.4 and 29.3°C, respectively. The area receives an annual rainfall of 1605.1 mm 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 according to rating done by Jones (2003). Being located at tepid to cool sub humid mid high lands (SH_2) agro-ecological zone, the area is a mixed farming zone, encompassed by Gibe River and abundant natural vegetation. The area is known for its mixed crop-livestock farming system in which cultivation of maize (*Zea mays* L.), finger millet (*Eluesine coracana*), niger seed (*Guzoita abyssinica*, L.), hot pepper (*Capsicum annuum* L.), soybean (*Glycine max* L.), common bean (*Phaseolus vulgaris* L.), mango (*Mangifera indica* L.), banana (*Mussa* spp), sugar cane (*Saccharrum officinarum* L) are common (Dabesa and Tana 2021).

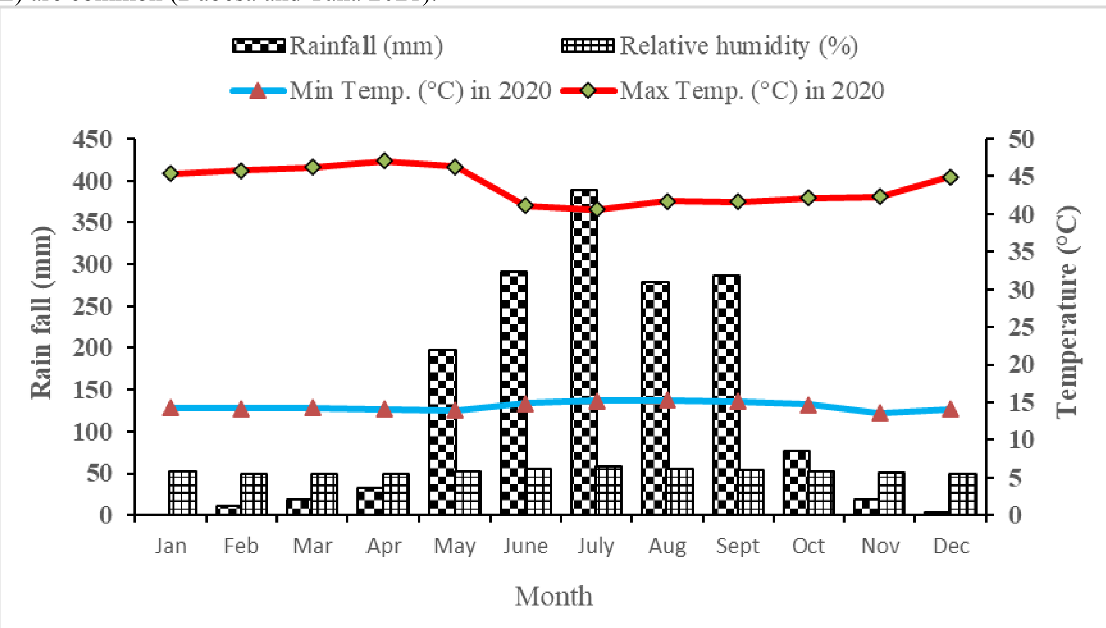

Figure 2 Monthly total rainfalls (mm), relative humidity (%), mean minimum and maximum temperatures (°C) of experimental station in 2020.

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 and is characterized by erect growth habit. It is highly adaptable to mid and low altitude areas (Kebede *et al*., 2019). 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 vilosa* and *Vicia atropurpurea,* and 30 kg ha^{-1} for *Vicia sativa* (Gezahagn *et al.,* 2013), and Finger Millet 15 kg ha^{-1} (Kebede *et al*., 2019). 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 (Alemu, 2016). 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 made fine with tractors and finally leveled by daily laborers to make the soil fine. Fine seedbed plots were prepared before the experimental plots were laid out. The recommended fertilizer rate of 100 kg ha^{-1} of NPS and 64 kg ha^{-1} UREA (Kebede *et al*., 2019) was applied during establishment (planting) for all experimental units. Seeds of Finger Millet (*Eleusine coracana)* and three vetch species (*Vicia sativa*, *Vicia villosa*, and *Vicia atropurpurea*) were sown in alternate rows (Diriba and Diriba, 2013) according to their seed rate proportions on well-prepared soil. Weeding was done by hand to eliminate the regrowth of undesirable plants and to promote the growth of the intercrops by increasing soil aerations. The plots were kept weed-free throughout the growth period.

2.5. Data Collection Procedures

2.5.1. Agronomic Parameters

The agronomic parameters of vetch like number of branches per plant and number of leaves per plant were counted from five randomly selected plants, and plant height was measured by measuring tape from five plants that were selected from the middle rows of each plot at forage harvesting stage. The leaf to stem ratio of vetch was determined at optimum harvesting stage by cutting plants from two randomly selected inner rows, separated into leaves and stems, dried, and weighed. Higher leaves to stem ratio is an indication of better nutritional value of the crop (Casler and Vogel, 1999).

2.5.2. Biomass Yield Determination

Vetch species were harvested at 50% flowering stage based on continuous visual observation (Muir *et al*., 2008). Harvesting was done by hand using a sickle, leaving a stubble height of 8 cm above the ground according to recommended practice (Leta *et al*., 2013). The fresh biomass harvested was weighed and recorded in the field immediately by using a top-loading balance scale. Fresh subsamples of about 250-300 grams were taken from each plot and weighed and then chopped into small pieces of 2-5 cm for dry matter determination. Then the fresh samples were oven-dried at 65ºc for 72 hours and the partial dry weight is recorded to estimate the dry matter biomass production according to (Mutegi *et al*., 2008)

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

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

From each plot, samples of each vetch species intercropped at different seeding ratios and sole vetch species were taken and dried in a forced draft oven at 65ºc for 72 hours and ground using Wiley mill to pass through a 1mm sieve screens for chemical analysis. The AOAC (1990) procedure was used for the determination of DM, Ash, and nitrogen. The DM content was determined by oven drying at 65 º c for 72 hours. Ash was determined by the complete burning of the feed samples in a muffle furnace at 600^{0}C overnight according to the procedure of AOAC (1990). Total nitrogen (N) was determined by the Kjeldahl procedure (AOAC, 1990). Crude protein (CP) was calculated as nitrogen (N) x 6.25. The structural plant constituents such as neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) were analyzed using the detergent extraction method. Hemi cellulose was calculated by the subtracting ADF from NDF content, and cellulose was calculated by subtracting the 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 taken for *in-vitro* dry matter digestibility (IVDMD). The two-stage rumen inoculates pepsin method of Tilley and Terry (1963) was used to determine IVDMD. Rumen liquor was collected from three rumen of fistulated steers and then transported to the laboratory using a thermos flask that was pre-warmed to 39 ºc. Rumen liquor was taken in the morning before animals were offered with feed. A duplicate sample of about 0.5 grams of each was incubated with 30 ml of rumen liquor in a 100 ml test tube in a water bath at 39^{O}C for 48 hours for microbial digestion. This was followed by another 48 hours of enzyme digestion with acid pepsin solution. Blank samples containing buffered rumen fluid only were also incubated in duplicates for adjustment. Drying of sample residues was done at 60 ^{O}C for 72 hours. The chemical analysis and *in -vitro* dry matter digestibility *(*IVDMD) was conducted at Holeta Agricultural Research Center. IVDMD was calculated (Tesfaye and Zewdu, 2021) as:

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

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

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

Where OM = DM- Ash (measured after ignition of feed or residue)

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

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

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

Data collected from experimental plots were summarized using Microsoft Excel 2013 and bar graphs were also used to sketch some results of the study. Summarized data were subjected to 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 5 % significance level or 95% confidence interval. The statistical model for the analysis of data was:

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

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.

Pearson correlation analysis (Cleophas and Zwinderman, 2018) was performed to determine the association between the plant morphological parameters (plant height, number of leaves per plant, number of branches per plant and leaf stem ratio) with yield and selected chemical composition of vetch.

3. RESULTS AND DISCUSSION

3.1 Agronomic Performance of Vetch

3.1.1 Plant height.

Plant height of vetch was significantly affected (P<0.05) by species, seeding ratios and intercropping at forage harvested stage (Table 2). Vetch species intercropped with finger millet had higher plant height as compared to their corresponding sole crops. This indicates that the intercropped legumes make movement towards sunlight which is crucial for photosynthesis. The present result disagrees with the report of Ojo *et al.* (2013) who noted that the plant height of *Panicum maximum* intercropped with *Lablab purpureus* was not significantly different from the sole at 14 weeks after planting. The difference between the results could be attributed to such factors as the type of soil, legume and grass considered, date of harvesting and other management conditions.

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 (154.00 and 85.33 cm respectively) were obtained from T10 and T5. Analysis of variance revealed that with increasing seeding ratio of finger millet there was a decrease in plant height of vetch for all the tested species. This could be due to the suppressive effect of the cereal over the companion legume. Generally earlier research reports have pointed out that plant height is the major attributor involved in the forage yield of grass and legumes associated with growth and biomass.

3.1.2 Leaves per plant

Leaf number determines the photosynthetic capacity of a plant. Leaves per plant of vetch was significantly affected (P<0.05) by species, seeding ratios and their interaction at forage harvest stage (Table 2). The leaves per plant of three vetch species intercropped with finger millet at different seeding ratios was lower than leaves per plant of their respective sole crops of each species. Number of leaves per plant of vetch for all the tested species was declined with an increasing seeding ratio of Finger millet. This shows that leaf development of intercropped vetch was hampered by dominance of finger millet in nutrients, moisture and sun light utilization. Analysis of variance for an interaction effect of variety and seeding ratio showed that T5 had produced the highest (35) leaves per plant, while the lowest leaves per plant (20.33) was obtained from T13. Contrary to the current result, the finding of Yegrem *et al.* (2019) reported that a higher number of leaves per plant D*esho* grass intercropped with green leaf *Desmodium* than the sole.

3.1.3 Leaf to stem ratio and branches per plant

Leaf to stem ratio is an important factor that determines the quality of plants as leaves are more digestible and favorite food for animals than stems. Analysis results revealed that there was no statistically significant difference (P>0.05) on leaf to stem ratio of vetch species (Table 2). The number of branches per plant of vetch species was significantly affected (P<0.05) by variety, seeding ratio, and their interaction. The number of branches per plant of the vetch species varied between 2.13 and 3.35 with a mean value of 2.71. Maximum number of branches per plant (3.34) was recorded from T9. This could be due to the balanced population of the two intercrops which enabled the legume to get optimum soil nutrients, moisture, space, and light to establish well and produce the maximum branches. Alemu *et al*., (2014) reported the mean number of branches higher than the results obtained in this study. The possible difference could be cropping system, agro ecology, soil fertility, soil moisture, management practices, and other growth plant factors.

3.1.4 Vetch herbage dry matter yield

Dry matter yield (DMY) of vetch was affected (P<0.05) by species, seeding ratio, and their interaction (Table 2). The highest and the lowest dry matter yield of vetch (2.56 t ha^{-1} and 1.28 t ha^{-1}) were obtained from T8 and T10 respectively. This study revealed that the DMY of vetch was increased as the seeding ratio increased. Pure stands of vetch (*Vicia sativa, Vicia vilosa,* and *Vicia atropurpurea)* were also compared and the highest dry matter yield

(6.82 t ha^{-1}) was obtained from sole *Vicia vilosa,* but the lowest dry matter yield (5.06 t ha^{-1}), was harvested from *Vicia sativa.* This result is similar to the finding of Alemu (2014) where the highest and the lowest dry matter yield was obtained from *Vicia villosa* and *Vicia sativa* respectively.

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)*

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 (2017) in which *Vicia vilosa* intercropped with maize gave the highest yield among other tested vetch species.

3.2 Chemical Composition of Vetch

The chemical composition of vetch species intercropped with Finger millet and the pure stand was given in Table 3. The result showed that species, seeding ratio, and their interaction had significantly (P<0.05) affected the dry matter (Dm %) content of vetch. Highest dry matter (93.99%) was obtained from T10. This could be due to higher moisture utilization and the higher seed proportion of Finger millet which utilized maximum moisture from the soil. DM concentration of all the treatment combinations was above 92.47%, indicating good drying to conserve as hay. This result is in line with the finding of Bingö *et al*., (2007) who reported similar value in a vetch-barley mixture.

The ash content is the concentration of minerals in the forages. The higher ash content indicates a high concentration of minerals. Variation in concentration of minerals in forages induced by factors like varieties (Gezahegn *et al.,* 2014), plant developmental stage, morphological fractions, climatic conditions, soil characteristics and fertilization regime has been reported (Jukenvicius and Sabiene, 2007). McDonald *et al*. (2002) also reported that mineral concentration declines with age and is also influenced by soil type, soil nutrient levels and seasonal conditions. Among the treatment combinations of this study, the highest and the lowest ash content (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 possibility of contact with ground surface/soil that in its turn increases the ash content of forages. Whereas, *Vicia sativa* has an erect growth habit that reduces the possibility of spoilage by soil. Moreover, this result is similar to the finding of Fantahun, (2017) which indicated an intermediate to late maturing vetch species (*Vicia atropurpurea*) had relatively higher ash content than early maturing vetch species (*Vicia sativa*), which could be due to differences in proportions and composition of morphological fractions.

Interaction effect had significant variation (P<0.05) on CP content of vetch. The CP content of vetch obtained from T12 (19.16%) was the highest among the tested treatments. Pure stand vetch specices had higher crude protein content than their respective vetch intercropped with Finger millet. Among the pure stands of vetch sole *Vicia sativa* had the highest CP content (23.55%). This difference was attributed to species or varietal differences among the legumes. This result was in agreement with Rahetlah *et al.* (2010) who reported that pure stand of vetch had higher CP concentration than vetch mixed with oat.

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)*

Most of the herbaceous legumes have CP content of >15%, a level which is usually required to support lactation and growth, which suggests the adequacy of herbaceous legume to supplement basal diets of predominantly low-quality pasture and crop residues (Gezahagn *et al.*, 2014). Therefore, the result of the present study was greater than the required CP for lactation and growth of animals. Analysis of variance showed that interaction of the factors had significant effect on NDF content of vetch and the lowest value (35.24%) was recorded for T7. Meissner *et al.* (1996) reported the NDF contents above the critical value of 60% can decrease voluntary feed intake, feed conversion efficiency and longer rumination time. However, the NDF content of all the tested vetch species was found below this threshold level which indicates higher digestibility. Both the main and interaction effect had a significant effect on ADF content of legumes (Table 3). The lowest ADF content (34.72%) was obtained from T12. Legumes with less than 31% ADF values are rated as having superior quality whereas those with values greater than 55% are considered as inferior quality (Kazemi *et al.,* 2012). Therefore, the ADF content of vetch varieties in the current study was categorized in the medium range of quality. The interaction effect of variety and seeding ratio had significantly affected (P<0.05) the ADL content of vetch. 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 vetch was significantly affected by both species and seeding ratio (Table 4). Among the treatment combinations of vetch species and seeding ratios, the highest (63.40%) IVDMD was obtained from T12. IVDMD of any forage crop varied with harvesting stage, fiber and cell wall constituents (Mustafa *et al.,* 2000); proportions of morphological fractions (Fekede, 2004); soil, plant species and climate (Getnet and Ledin, 2001). This could be the effect of some environmental factors which impose considerable negative impact on forage quality through fastening physiological maturity and thereby increasing structural constituents of the plant. The *in- vitro* organic matter digestibility (IVOMD) of vetch was significantly affected (P<0.05) by 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 might be due to the variety and inherent characteristics difference among the vetch species used. Therefore, in the present study the mean IVOMD values of vetch were higher than the critical threshold level of 50% required for feeds to be considered as having acceptable digestibility (Owen and Jayasuriya, 1989).

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)

3.3.2 Metabolizable Energy of vetch

Analysis of variance revealed that vetch species, seeding ratio, and their interaction had significantly (P<0.05) affected the metabolizable energy (ME) of vetch species used in the current experiment. The highest ME value (8.79 MJ kg^{-1}) was recorded for T12 while the lowest value (8.05 MJ kg^{-1}) was obtained from T6. In general, Metabolizable energy obtained in this study was higher than the critical threshold level of 7.5 MJkg^{-1} for roughages and forages as noted by earlier research reports.

3.4 Biological Compatibility

3.4.1 Land equivalent ratios

Land equivalent ratios of Finger millet and vetch are presented in Table 5. LER of the total dry matter yield from vetch species and Finger millet varied from 0.77 to 1.16.

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.

In the present study, land equivalent ratio values greater than 1.0 are recorded only from T10 (1.16), T9 (1.08) and T11 (1.03). In the current study, as the LER values of only these three treatments were greater than 1, this result is partially in agreement with the finding of Dawit and Nabi (2017) in which all the values of LER of vetch + maize was greater than 1.0. The possible reason for the difference is the cropping systems, types of crops used for intercropping and other environmental conditions.

4. CONCLUSION

The varietal and seeding ratio effects of Finger millet and vetch on yield and quality of vetch as well as the compatibility of Finger millet and vetch were evaluated. The results of the current study shows that it is possible to produce substantial quantity and higher nutritional quality of feed by incorporating vetch with Finger millet in a food/feed production system with efficient use of external resources.

Conflicts of Interest

The authors declare no conflicts of interest.

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