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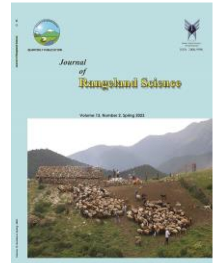

Research and Full Length Article:

Potential of Oat (*Avena sativa*), Vetch (*Vicia villosa*) and their Mixtures as Fodder in the Ethiopian Highland

Alemayehu Jambo[A], Kassa S. Retta[B*], Habtamu Lemma[C]
[A] Wolaita Zone Trade and Marketing Department, Wolaita Sodo, Ethiopia
[B] Assistant Prof. Department of Animal Sciences, College of Agriculture and Natural Resources, Mekdela Amba University, South Wollo, Ethiopia, *(Corresponding author), Email: kassashawel@gmail.com
[C] Associate Prof. Department of Animal and Range Sciences, College of Agriculture, Wolaita Sodo University, Wolaita Sodo, Ethiopia

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Abstract. The objective of this study was to evaluate the performance of oat (*Avena sativa; variety*-CI-8237), vetch (*Vicia villosa*) and their mixtures under irrigation conditions in the Ethiopian highland. This mixed cropping is a mixture of legume and cereal, it was done to fulfills a variety of functions, including complementary use of growth factors, such as soil nutrients, light, and water; reduced pest and disease incidence, reduced soil erosion, more total biomass production, more yield stability, and more household food security. Treatments were included: sole oat (T_1), sole vetch (T_2), 85% oat + 15% vetch (T_3), 70% oat + 30% vetch (T_4), 55% oat + 45% vetch (T_5) and 40% oat + 60% vetch (T_6). Experimental plots were laid out in a Randomized Complete Block Design (RCBD) with three replications in Damot Gale District, Wolaita Zone, Southern Nations Nationalities and Peoples Region, Ethiopia. Data collected for emergence date, plant height, and number of leaves per tiller, total fresh yield, dry matter yield and chemical composition in two consecutive years (2018-19 and 2019-20). The greatest and shortest days to emergence with 19 and 13 days were recorded in 100% vetch and 100% oat, respectively. The highest Dry Matter (DM) yield was obtained from the mixture of 55% oat and 45% vetch (6.75t/ha). The highest Land Equivalent Ratio (LER) was obtained in 55% oat and 45% vetch mixture. Similarly, this treatment had lower Neutral Detergent Fiber (NDF) (45.77%), Acid Detergent Fiber (ADF) (8.01%) and Acid Detergent Lignin (ADL) (1.31 g per kg) concentrations and highest *In Vitro* Dry Matter Digestibility (IVDMD) (73.14%). Overall, it is recommended that in the highlands of Ethiopia, smallholder farmers can use 55% oat and 45% vetch to increase the quantity and quality of fodder.

Key words: Chemical composition, Mixed cropping, Oat, Yield parameters, Vetch

Introduction

Feed availability and quality is one of the impediments of livestock production in crop-livestock systems in southern Ethiopia. It is mainly due to expansion of cultivated lands, high population growth, increased land degradation and reduced pasture lands (Funte *et al.*, 2009). The reduction in grazing areas and consequently shortage of feed to livestock significantly influenced livestock holdings and production in general. The problem of feed shortage in crop-livestock production system could be alleviated by integration of improved forage crops into the farming system is important (Getnet *et al.*, 2003). The inclusion of productive annual forages like oat and mixtures with legumes could provide more sustainable source of N through biological N fixation of vetch (Crews and Peoples, 2004). Improved fodder production combined with appropriate post-harvest handling practices is believed to solve some of the critical feed shortages and quality problems.

In forage crop production systems, grass-legume mixtures are preferred due to their several advantages over monoculture. Cultivation of oat/vetch mixture is important since oats-vetch is suitable for intercropping to supply feed shortage both in quantity and quality (Alemu *et al.*, 2007). Vetch (*Vicia villosa*) is reputed for their beneficial compatibility with annual oat when they grow in the mixture (Negash *et al.*, 2017). Reports indicated that mixtures containing 25-50% legume produces more quality forage and yield per unit area compared with pure stands. Forage species such as vetch (*Vacia sativa*) and oat grass (*Avena sativa*) are high productive feed species to fill the gap of feed shortage (Negash *et al.*, 2017).

Investigating the potential productivity under various environments and agronomic condition is crucial to these species. To alleviate feed shortage in highly populated areas like Damote Gale Woreda of Wolaita zone, establishment of forage crops and legumes under irrigated condition is feasible. Therefore, the objective of this research was to evaluate the compatibility, biomass yield and nutritive value of oat and vetch mixed cropping under irrigation condition in the study area.

Materials and Methods

Description of the Study Area

This experiment was conducted in Damot Gale District, Wolaita Zone, Southern Nations Nationalities and Peoples Region (SNNPR), located at 311 Km south of Addis Ababa in Adde Sibaye Kebele. Geographically, it is located between 6° 57' 42.6" north latitude and 37° 49' 41.52" east longitude at an altitude of 2005 m above sea level. The average temperature of the area varies between 12^0C and 24^0C and Mean annual rainfall ranges between 400 and 900 mm (Biruk, 2015).

Experimental Design and Treatments

The oat and vetch mixture were sown on December 2018-19 and 2019-20 in the dry season up to maturity (95 days). Field preparation was carried out on a well-prepared seedbed, and water diversion ditches were made for irrigation. Vetch and Oat seeds were obtained from Areka Agricultural Research center, Ethiopia. Both species were planted as mono crops and mixtures. Four levels of mixtures of vetch *(Vicia villosa.)* and oat (*Avena sativa L.)* sole oat (T_1), 0% oat +100% vetch (T_2), 85% oat + 15% vetch (T_3), 70% oat + 30% vetch (T_4), 55% oat + 45% vetch (T_5) and 40% oat + 60% vetch (T_6) were considered in a randomized complete block design (RCBD) with three replications. The recommended rates for oats and vetch were 90 kg/ha and 30 kg/ha, respectively (Melkamu *et al.*, 2016).

Table 1. Description of treatment combination

Treatments	Treatment combination	Amount seed sown (g)
T_1	100% oats	152 g oats
T_2	100% vetch	54 g vetches
T_3	85% oats +15% vetch	137.7 (oats) + 8.1 (vetch)
T_4	70% oats +30% vetch	113.4 (oats) + 16.2 (vetch)
T_5	55% oats +45% vetch	89.1 (oats) + 24.3 (vetch)
T_6	40% oats +60% vetch	64.8 (oats) + 32.4 (vetch)

The gram of seed sown for each plot is given in Table 1. The 1000 seed weight of oat and vetch were 30.6g and 86.01g, respectively. The total land area of 285m^2 was prepared including the spacing between blocks and plots. The spacing between blocks and plots were 1.5m and 1m, respectively, while the planting depth was 3 cm. The plot size of each experimental unit was 6 m^2 (3×2 m). In each plot there were 10 rows for sole oat and 6 rows for sole vetch and other mixed cropping plots and seeds planted by drilling. Two rows within plots were considered as borders and were not harvested to remove border effect and the middle 8 rows of oat and 4 rows of full vetch and mixed cropping of oat and vetch varieties were harvested. Planting was done considering the recommended rates of oats and vetch which is 90 kg/ha and 30 kg/ha, respectively. 30 cm and 20 cm between rows planting were used for sole oat and vetch varieties respectively. Weeding was done by hand two times, at the early seedling and mid of vegetative growth stage.

Seed bed preparation

Soil samples were collected before commencing the trial using a soil auger at two soil depths: the upper layer at 0- to 10-cm depth and lower layer at 11- to 20-cm depth. Samples were collected from five positions located randomly along crisscrossed diagonal lines on the experimental field. Soil samples were collected from each plot and bulked by treatment to assess preliminary soil physical and chemical properties and tested at Horticoop-Ethiopia (Horticulture) PLC, soil and water analysis laboratory (Table 2).

Table 2. Pre-soil physicochemical analysis results of the experimental site

Parameters	**Soil Depth**	
	0-10 cm	**11-20 cm**
pH-H_2O (0-14)	5.51	5.936
Sand (%)	23	23.6
Clay (%)	31	30.8
Silt (%)	46	45.6
Textural Class	Clay-loam	Clay-loam
Calcium Cmol (+) /Kg	3.12	3.80
Mg Cmol (+)/Kg	0.50	0.60
K(Cmol (+))/Kg	0.80	0.94
Na(C mol (+)/Kg	0.39	0.44
Available P(Mg/Kg)	18.95	8.22
Sulfur (Mg/Kg)	27.56	16.54
Organic Carbon (%)	1.53	1.24
Total Nitrogen (%)	0.13	0.12
Carbon: Nitrogen Ratio	11.61	10.43

The land was selected, plowed two times for proper aeration and easy preparation of plots, seedbed were well prepared, and protected by fencing. The experimental plots are clay-loam soil. All necessary agronomic practices (cultivation, weeding, etc.) were done uniformly for all plots. Then, selected oat and vetch varieties were sown. Two times a day i.e., 15 liter it the morning and 15 liter water in the afternoon per plot were applied up to emergence (15 days). After emergence, plots were irrigated in the evening with 20 liter of water up to maturity every other day (Worku *et al.*, 2021).

Data Collection and Sampling Techniques

The developmental process, days to emergence, days to 50% flowering and maturity stage (Fekede, 2009) were recorded starting from date of sowing and counts of plant number, number of leaves per tiller, number of tillers per plant and number of leaves per plant were recorded. Ten plants from each plot in a quadrant (0.25 m^2) were taken to measure number of tillers per plant, number of leaves per plant and number of leaves per tiller. Average results from each measurement were recorded to evaluate the performance (Adeel *et al.*, 2014).

Biomass yield

The data from each plot was sampled using a quadrant of 0.25m^2 (0.5 x 0.5 m) sizes during a predetermined sampling period. The quadrant was randomly thrown on a plot and the average weight of plants from the quadrant was used for determination of biomass yield at 50% flowering and full maturity stage.

Green forage yield is the amount of green herbage harvested/cut, expressed in t/ha. Green forage yield per ha is estimated based on green herbage harvested/ cut from sampling area (three adjacent rows from the center of each plot) and converted to hectare basis (Akililu and Alemayehu, 2007). The fresh harvested biomass was chopped into small pieces using sickle and a sub-sample of 500g was taken and partially dried in an oven at 65°C for 72hrs for further dry matter analysis (Adeel *et al.*, 2014).

Plant height

The average plant height was measured from ground to the tip of the main stem (Gebremedhn *et al.*, 2015). The measurement was done by taking ten random plants at 90 days from each plot.

Land Equivalent Ratio

Land Equivalent Ratio (LER) is the relative land area under sole crops that is required to produce the yields achieved in intercropping. When LER is compared at uniform overall plant density of the sole and intercrops then it is known as Relative Yield Total (Akililu and Alemayehu, 2007).

$$LER = \sum_{i=1}^{n} \frac{Yi}{Yij}$$

Where:

Y_i = the yield of i'1' component from a unit area of intercrop expressed as a fraction of the yield.

Y_{ij} = the yield of that component grown as sole crop over the same area and n is number of crops involved.

Relative Yield Total (RYT)

Relative yield total is the ratio of yields obtained in mixture to that of yields in sole stand. High RYT above unit imply that the two species will not strictly competing for the same limiting factor (Akililu and Alemayehu, 2007).

$$RYT = \frac{Yab + Yba}{Yaa + Ybb}$$

Where:
Y_{ab} = yield of component 'a' in the mixture
Y_{ba} = yield of 'b' in the mixture
Y_{aa} = yield of 'a' in sole stand at 100% population
Y_{bb} = yield of 'b' in sole stand at 100% population

Chemical Analysis

The mixtures were harvested with a sickle at 10cm clipping height above the ground. Following harvesting, the forage samples 500 gm from each plot were weighed, labeled and air dried under shade and kept in separate plastic bags for chemical analysis. One representative oven-dried forage sub-sample (three replications per treatment) from each plot was taken to nutrition laboratory for chemical analysis. The samples were dried in an oven at 65-72 ^{o}C for 48 hours and ground using Willey mill to pass through 1mm sieve.

The chemical analyses of forage were done using standard analytical methods. The DM content was determined by oven drying at 105 °C overnight and while the ash content was determined by combusting in a muffle furnace at 500°C for 6 hours, CP content was determined by determining N and calculating as N x 6.25 (AOAC, 1995). The neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined according to the procedures of (Van Soest and Robertson, 1985). The *in-vitro* dry matter digestibility (IVDMD) of the samples were determined using the modified two stages (Tilly and Terry, 1963) as modified by (Van Soest and Robertson, 1985)

Statistical Analysis

The data were analysed using the General Linear Model (GLM) procedure of ANOVA in SAS version 9.2 (2008). Duncan Multiple Range Test was used to determine the statistical significances between treatment means at the 5 % level of significance.

Results and Discussion

Phenological traits

As pure and mixed stands date of emergence, 50% flowering and date of maturity was significantly differed among the treatments (Table 3). The result revealed that, legumes took more days to emerge compared to oat. The shortest dates to emergence were recorded by sole oat (T_1) (13) compared to the other treatments. Emergence date ranges around 13-19 days in all plots. The days to 50% flowering was highest in sole oat (T_1) (84 days) whereas, sole vetch took the least (64) days to flower. The earlier the maturity is the better escape of drought period. Days of maturity of sole vetch (T_2) (81) matured earlier and sole oat (T_1) and 85% oat + 15% vetch (T_3) (94) matured late compared to the rest treatments.

The current result is in line with Amanuel *et al.* (2018) who reported the emergence date and 50% flowering in oats variety ranges as 14-21 and 62-89 days, respectively. Hellewell *et al.* (1979), attested that the major difference in maturity among oat cultivars related to differences in the length of the vegetative growth stage (sowing to flowering stage), not the grain filling period (heading to grain maturity stage) and thus the fast growth of early maturing cultivars is explained in terms of a shortened vegetative growth stage rather than a shortened grain filling period. The present report agrees with Assefa and lendin (2001). Average emergences of the intercropping were 65% at first week and above 97% at second week.

The grain filling period in the present experiment ranged from 81 to 94 days, whereas, in the same varieties, it was 64 up to 80 days in the previous study by Fekede (2009) which was shorter than current studied varieties due to differences in sowing season and lack of moisture content in the area.

Morphological traits

The number of tillers under the oat-vetch mixture of 40% oat + 60% vetch (T_6) was significantly higher than the sole vetch (T_2) (17.67) (Table 3). The lower number of tillers obtained from the sole vetch plot is obviously due to the tillering capacity of legumes and also due to less competition for resources and light among vetch plants. The previous study (Gebremedhn *et al.*, 2015) showed that the highest number of tillers per plant was 14.2 followed by 13.30 tillers per plant at 50% flowering stage which were lower than the current observations. Interplant competition in grasses causes rapid and exhaustive height increment. Consequently, overcrowding results in the neighboring plants produce weak tillers (Alemu *et al.*, 2007). Therefore, the competitor plants are forced to grow upright to dominate other tillers produced on the same plant rather than lateral expansion by bearing more tillers. The variation of number of tillering was due to seed proportion that it is increased with increasing seed proportions of both oats and vetch varieties and the present report agrees with Assefa and lendin (2001).

The mean plant height obtained in the current study was 102.5 cm under irrigation condition. Plant height of oat/vetch mixtures reaches as high as 180 cm to 200 cm under rain-fed condition (Gezahegn *et al.*, 2014). The results obtained in the present study were by far less than the plant height reported for rain-fed condition. However, the period of the study was highly exposed for sunlight and atmospheric demand of water is actually high, which limits plant growth through evaporation and evapotranspiration. Generally, in a grass-legume mixture, plant height is a result of mutual benefit of cereal (grass) and legume components for each other (Turemen *et al.*, 1990). This is because companion cereals (grasses) provide structural support for legume growth, while improved provision of fixed N due to legumes promote growth of cereals or grass families. The present result disagrees with the finding of Basbag *et al.* (1999) who noted taller than its pure stands compared to vetch in mixed stands might be due to the effect of support and thus better exposure to sunlight, and plant height of vetch decreased with a decrease in its ratio in the mixture.

The results of the current study were in agreement with reports of Shoaib *et al.* (2013) who indicated increased harvests which are affected plant physiology and plant height. However, another author Alemu *et al.* (2007) reported values from 111.5–118 cm at the 80th day of harvesting compared to the results of the current study at 75th and 90th harvesting stage are 103.29 - 160.56 cm. This variation in plant height might be attributed to factors such as season and soil type. The variation in plant height may also be attributed to the competition effects of the treatments and or adaptability of oat to the area more than vetch.

Significant variation was observed in the number of leaves per plant by varietal mixture and harvesting stage (Table 3). Sole vetch (T_2) (20.56) produced the highest ($P < 0.01$) number of leaves per tiller compared to pure stand of oat (T_1) (9.78) (Fig. 1). The current result is higher than the study by Alemu *et al.* (2007), who reported the highest and lowest number of leaves per plant in oats as 5.15 and 4.58, respectively. The number of tillers play vital role in growth and development of plant and also number of leaves play a dynamic role in overall development and growth of the plant, since leaves act as the basic factory for food production. The increase or decrease in the number of leaves per tiller has a direct effect on the yield of forage crops (Shoaib *et al.*, 2013).

Table 3. Means of mix cropping treatment for phenological and morphological traits

Treatments	Days to emergence	50% flowering	Days to maturity	Plant height (cm)	Tillers no. per plant	Leaves no. per tiller
Sole oat (T_1)	13 ^{d}	84^{a}	94^{a}	113.6^{a}	18.00^{ab}	9.78^{c}
Sole vetch (T_2)	19^{a}	64.33^{f}	81^{d}	108.2^{ab}	17.67^{b}	20.56^{a}
85% oat + 15% vetch (T_3)	15^{c}	82^{b}	96.67^{a}	94.79^{b}	18.67^{ab}	13.04^{b}
70% oat + 30% vetch (T_4)	17^{b}	75^{c}	90.33^{b}	96.64^{b}	19.67 ^{ab}	12.56^{bc}
55% oat + 45% vetch (T_5)	18^{ab}	71^{d}	89^{b}	93.89^{b}	19.67^{ab}	15.56^{b}
40% oat + 60% vetch(T_6)	18^{a}	69^{e}	85^{c}	108.02^{ab}	21.00^{a}	15.78^{b}
Mean	17	74.22	88.83	102. 53	18.94	14.55
CV%	3.46	1.27	0.99	4.53	1.95	0.80
SEM	0.33	0.54	0.51	13.27	30.88	21.6
p-value	0.01	0.01	0.01	0.01	0.04	0<0.01
Year	NS	NS	NS	NS	NS	NS
Mixed cropping *year	NS	NS	NS	NS	NS	NS

$^{a, b, c, d, e}$ and ^{f} in a column with different superscripts differ (P < 0.05); CV% = coefficients of variation; SEM = standard errors of means; NS = none significant

Forage yield

Statistically the maximum total fresh yield was recorded in sole oat (T_1) (40.56 t/ha), 55% oat + 45% vetch (T_5) (41.49 t/ha) and 40% oat + 60% vetch (T_6) (42.09t/ha). The minimum total fresh yield was recorded in 85% oat + 15% vetch (T_3) (35.76 t/ha). Results agreed with those of El-kramany *et al.* (2012) and Ross *et al.* (2003); who reported that total fresh yield was decreased with increased oat seed proportion in mixtures.

The dry matter (DM) yield of Oat and Vetch mixtures were significantly (P<0.01) affected by treatments (Table 4). Higher mean DM yield (6.75 t/ha) was obtained in the mixture of 55% oat + 45% vetch (T_5) and 70% oat + 30% vetch (T_4) (5.77 t/ha) respectively; whereas, the lowest mean DM yield was recorded in sole vetch (T_2) (5.09 t/ha) and 85% oat + 15% vetch (T_3). Those varieties with higher dry matter accumulation and morphological performance in the growing period gave better DM yield. Hence, better plant vigor tended to produce higher herbage yield as compared to less sole stands. The results of the current study were supported by Gezahegn *et al.* (2014) who reported that DM yield range between 6.64 - 5.06 t/ha.

Table 4. Fresh yield, Dry matter yield (t/ha) and DM accumulation % of oats, vetch and sole counterparts

Treatments	Total fresh yield (t/ha)	DM yield (t/ha)
Sole oat (T_1)	40.56^{a}	5.56^{b}
Sole vetch (T_2)	38.83^{c}	5.09^{c}
85% oat + 15% vetch(T_3)	35.76^{d}	5.07^{c}
70% oat + 30% vetch(T_4)	38.99^{bc}	5.77b^{ab}
55% oat + 45% vetch(T_5)	41.49^{a}	*6.75*^{a}
40% oat + 60% vetch(T_6)	42.09^{a}	5.52^{b}
Mean	39.62	5.63
SEM	0.44	0.32
CV	4.18	6.2
p-value	<0.001	0<0.001
Year effect	NS	NS
Mixed cropping ×year	NS	NS

$^{a-d,}$ in a column with different superscripts differ (P < 0.05); NS, non-significant; SEM, standard error of mean; CV, coefficient of variation

Land equivalent ratio (LER)

The highest amount of LER was observed in treatment, 55% oat + 45% vetch (T_5) (1.23). Therefore, 23% extra area would be required for the same amount of yield using solitary cropping (Table 5. This indicates that intercropping oat with vetch enhanced its effectiveness of resource use to produce the same yield. The reason the amount of LER is more than one is perhaps because of fixing and absorbing nitrogen in intercropping oat and vetch mixed. Koocheki *et al.* (2009) found similar results in intercropping corn and beans, which is consistent with the results of the present experiment. Also, in intercropping of wheat and lentil, the maximum LER (1.52) was achieved in lentil and 40% wheat as mixed cropping system (Akter *et al.*, 2004).

The LER of mixtures were greater than 1 except seed proportion of 85% oat + 15% vetch (T3) (Table 5). The LER values less than one means that the yields obtained in mixed stand is less than that obtained from pure stands. The intercropping system resulted in higher cumulative total biomass yield than either of the sole crops, resulted in LER values greater than one. This report agrees with that of Ibrahim *et al.* (2018) who reported similar results in sorghum/lablab intercropping. Erol *et al.* (2009) observed the importance of intercropping maize with faba bean as it gave higher LER.

Relative yield total (RYT)

The most important mixture of biological advantage is the relative yield total (RYT) that was used to quantify the yield advantages in a replacement series. In this study the relative yield total in all intercropping of the oat – vetch mixture and sole stand was more than one except 85% oat + 15% vetch (T_3) (0.97) and 40% oat + 60% vetch (T_6) (0.86) (Table 5). The highest value of RYT was observed (1.27) in treatment 55% oat + 45% vetch (T_5). The minimum RYT of oat + vetch mixture was recorded in treatment 85% oat + 15% vetch (T_3) (0.78). A RYT greater than one indicates partial resource complementarities between competing species. It means the competing species use partially different growing resources or utilize the same resources, but more efficiently due to differences in plant architecture, physiology or growing cycle (Bulson *et al.*, 1997). Ghaderi *et al.* (2008) showed that the best RYT for alfalfa and wheatgrass intercropping was 1.15 and the maximum R (yield in intercropping/yield in single cropping) for alfalfa and wheatgrass was 1.02 and 0.36, respectively.

Table 5. Land equivalent ratio and Relative yield total of oats and vetch mixtures

Treatments	Land equivalent ratio	Relative yield total
Sole oat (T_1)	1.03[b]	1.02[b]
Sole vetch (T_2)	1.04[b]	1.06[b]
85% oat + 15% vetch (T_3)	0.98[b]	0.78[c]
70% oat + 30% vetch (T_4)	1.05[b]	1.03[b]
55% oat + 45% vetch (T_5)	1.23[a]	1.27[a]
40% oat + 60% vetch (T_6)	1.04[b]	0.86[b]
Mean	1.06	1.00
SEM	0.54	0.64
CV	10.2	9.7
p-value	<0.01	<0.01

[a – b] In a column with different superscripts differ at (P <0.05); NS, non-significant; SEM, standard error mean; CV, coefficient of variation

Fig. 1. Experimental plots, Damot gale

Nutritional quality

Analysis of variance and level of significance for pure stand of oats and vetch and their mixtures at different seed proportions of chemical composition was given in (Table 6. The results showed that Ash, NDF, ADL, CP and IVDMD differed significantly among treatments while DM, ADF and EE did not show significant differences among treatments.

Ash content was significantly affected ($P<0.05$) by mixture due to seed rate proportions. In the oat- vetch mixture of 40% oat + 60% vetch (T_6) (10.99%) and 55% oat + 45% vetch (T_5) (10.75%) possessed the highest ash contents ($P< 0.05$) as compared to the rest oat/vetch mixture and their sole stand. The lowest ash content (8.8%) was obtained from sole vetch (T_2). The current study is in line with variations in concentration of minerals (10.11%) might be affected by factors like varieties (Gezahegn *et al.*, 2014), growth stage, morphological fractions, climatic conditions, soil characteristics, and seasonal conditions (McDonald *et al.*, 2002) and fertilization regime (Jukenvicius and Sabiene, 2007).

The mean CP content was significantly different ($P < 0.01$). The higher CP content was obtained at the sole vetch (T_2) (23.09%) and lower ($P < 0.01$) value at sole oat (T_1) (12.81%) (Table 6). Likewise, CP content was significantly higher in mixtures of 55% oat + 45% vetch (T_5) and 40% oat + 60% vetch (T_6) compared to sole oat (T_1). Similarly, Dura *et al.* (2012) reported higher CP contents in purely sown legumes than in cereals. The high CP value obtained in mixed forages of the current study is supported by Alemu *et al.* (2007), who reported up to 25–50% legume produced more quality forage and yield per unit area than purely sown forages. Befekadu and Yunus (2015) also suggested that the maximum CP concentration was recorded in the highest proportion of legume plants. Gezahegn (2016) and Starks *et al.* (2006) reported 18% CP in oats–vetch mixture and 26% CP in pure stands of vetch.

The mean NDF obtained in the current study was 45.9%, which is an indicator for quality forage although it varied greatly among the treatments. The highest NDF was recorded in sole oat (T_1) (53.88). Geleti (2000), indicated that NDF contents above the value of 60% results in decreased voluntary feed intake reduced feed conversion efficiency and longer rumination time. According to Van Soest (1965), the critical level of NDF which limits intake was reported to be 55%. However, the NDF content of the entire oat – vetch mixture and sole stand were observed to be comparatively lower than above mentioned value, this could be indicative of its better digestibility and intake. The acid detergent lignin (ADL) content ranged from 1.15 to 1.72%. There was significant difference ($p<0.05$) in ADL content at sole vetch (T_2) (1.72%) compared to other treatments, which disagree with Amanuel *et al.* (2018) who reported the ADL content range from (1.98-2.55%) in different oat varieties. Digestibility decreases with advancing age and this could be linked to the interaction of factors such as increased fiber concentration in plant tissue, and increased lignifications during plant development (Wilson *et al.*, 1991).

The *in vitro* dry matter digestibility values (IVDMD) had greater than 65% that indicated good nutritive value, and values below this level result in reduced intake due to lowered digestibility (Meissner *et al.*, 2000). The intercropping that produces maximum at 55% oat + 45% vetch (T_5) (73.14) IVTDMD was higher by 5.26% from minimum IVDMD % of sole oat (T_1) (67.88%) cropping.

Table 6. The effect of varieties and seed proportions on qualities of oats and vetch mixtures

Treatments	Chemical composition %							
	DM	ASH	ADF	ADL	NDF	CP	EE	IVDMD
sole oat (T_1)	89.53	10.08^c	9.91	1.15^b	53.88^a	12.81^c	0.71	67.88^b
sole vetch (T_2)	88.16	8.80^e	8.44	1.72^a	46.27^b	23.14^a	0.45	70.17^b
85% oat + 15% vetch (T_3)	89.31	10.27^b	9.06	1.37^b	46.61^b	16.57^{bc}	0.80	69.79^b
70% oat + 30% vetch (T_4)	88.59	9.39^d	9.95	1.38^b	46.37^b	15.45^{bc}	0.81	69.84^b
55% oat + 45% vetch (T_5)	88.45	10.75^a	8.01	1.31^b	45.77^b	19.09^b	0.48	73.14^a
40% oat + 60% vetch (T_6)	88.67	10.99^a	8.91	1.34^b	46.50^b	19.64^b	0.78	69.15^b
Mean	88.78	10.05	9.05	1.38	45.90	17.69	0.67	69.99
SEM	0.36	0.44	0.39	0.095	1.50	1.19	0.64	1.81
CV	0.71	7.6	7.37	11.9	5.6	11.64	0.34	4.31
p-value	NS	<0.05	NS	<0.05	<0.01	<0.001	NS	<0.01

$^{a, b, c, d}$ and ^{e} in a column with different superscripts differ ($P < 0.05$); DM= dry matter; CP= crude protein; NDF= neutral detergent fiber; ADF = acid detergent fiber; SEM= standard error of mean; CV%= Coefficients of variation; EE = ether extract; ADL = Acid detergent lignin; IVDMD = *In-vitro dry matter* digestibility.

Conclusion

Oat-vetch intercropping evaluated in the present study have potential to produce forage with good nutritive value and can be considered as alternative options for smallholders. Oat and vetch intercropping had optimal CP, organic matter digestibility, DM yield, LER and relative yield total which make them good forage supplements in the smallholder system where crop residues constitute basic feed resources under irrigation condition. Exceptionally, intercropping a mixture of 55% oat and 45% vetch had preferably recommended given its organic matter digestibility, greater biomass production, DM yield, LER and relative yield total, and acceptable forage nutritive value.

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References

Adeel, K., Maqbool, H. A, Muhammad, K. U. R., Qamar, Z. and Raza, U. 2014. Comparative Study on Quantitative and Qualitative Characters of Different Oat (Avena sativa L.) Genotypes under Agro-Climatic Conditions of Sargodha, Pakistan. *American Journal of Plant Sciences*, 3097-3103.

Akililu, M. and Alemayehu M. 2007. Measurements in pasture and forage cropping systems. Technical manual 18, EIAR, Addis Ababa, Ethiopia. Pg 41.

Akter, N., Alim, A., Islam, M.M., Naher, Z., Rahman, M., & Iqbal Hossein, A.S.M. 2004. Evaluation of mixed and intercropping of lentil and wheat. *Journal of Agronomy*, 3: 48-51

Alemu, B., Melaku S. and Prasad N.K. 2007. Effects of varying seed proportions and harvesting stages on biological compatibility and forage yield of oats (*Avena sativa L.*) and vetch mixtures. *Livestock Research for Rural Development* 19(1). http://www.lrrd.org/lrrd19/1/alem19012.htm.

Amanuel W, Kassa S, Deribe, G. 2018. Biomass Yield and Nutritional Quality of Different Oat Varieties (Avena sativa) Grown under Irrigation Condition in Sodo Zuriya District, Wolaita Zone, Ethiopia. *Agri Res & Tech*: 20(4): 556138. DOI: 10.19080/ARTOAJ.2019.20.556138.

Association of official analytical chemist (AOAC). 1995. Official methods of analysis. Association of Official Analytical Chemists (AOAC), 15th ed. Washington, DC, 69-88.

Assefa, G. and Ledin I. 2001. Effect of variety, soil type and fertilizer on the establishment, growth, forage yield, quality and voluntary intake by cattle of oats and vetches cultivated in pure stands and mixtures. *Animal Feed Science and Technology* 92: 95-111.

Basbag, M., Gul, I. And Saruhan, V. 1999. The effect of different mixture rate on yield and yield components in some annual legumes and cereal in Diyarbakir Conditions. 3rd Field crops, Congress, 15-18 November, Adana, Turkey, pp. 69-74.

Befekadu C, and Yunus A. 2015. Evaluation of biomass yield and growth performance of alfalfa and oat cultivars in the High Land of Arsi, Ethiopia. *Livestock Research for Rural Development* 27(6).

Biruk, J. 2015. Value chain analysis of bee honey and credit market participation of bee keepers: the case of Damot Gale district, Southern Ethiopia. MSc. Thesis. Haramaya University, Ethiopia. 95p.

Bulson, H.A.J., Snaydon, R.W., and Stopes, C.E. 1997. Effects of plant density on intercropped wheat and field beans in an organic farming system. *Journal Agricultural Science*, Cambridge.128: 59-71.

Crews, T.E., and M.B. Peoples. 2004. Legume versus fertilizer sources of nitrogen: Ecological trade-offs and human needs. *Agric. Ecosyst*. 102:279–297.

Dura K, Aleksandar M, Branko M, Sanja V, and Nenad D. 2012. Common vetch– wheat intercropping: haylage yield and quality depending on sowing rates. *Afr. J. Biotechnol*. 2012;11(30):7637–42.

El-kramany, M. F., T. A. Elawa and A. B. Bakry. 2012. Effect of mixture rates on forage mixture of Egyptian clover (Trifolium alexandrinum L.) with triticale (X Triticosecale Wittmack) under newly reclaimed sandy soil. *Aus. J. Basic Applied Sci.*, 6:40-44.

Erol, A., Kaplan M. and Kizilsimsek, M. 2009. Oats (*Avena sativa*) common vetch (*Vicia sativa*) mixtures grown on a low-input basis for a sustainable agriculture. *Tropical Grasslands* 43: 191-196.

Fekede, F. 2009. Variation in maturity among oats varieties and its implications for integration into the highland farming systems. *Ethiopian Institute of Agricultural Research* (EIAR), Holetta Research Center, Animal Feeds and Nutrition Research Program, Addis Ababa, Ethiopia.

Funte, S., Negesse, T. and Legesse, G. 2009. Feed Resources and Their Management Systems in Ethiopian Highlands: The Case of Umbulo Whaco Watershed in Southern Ethiopia. *Tropical and subtropical agroecosystems*. 12(1): 47-56.

Gebremedhn, B., Alemu, A. and Haylay, G. 2015. Evaluation of different oat varieties for fodder yield and yield related traits in Debre Berhan Area, Central Highlands of Ethiopia. *Livestock Research for Rural Development*, 27: 2.

Geleti, D. 2000. Productivity and nutritional qualities of *panicumcoloratum* under varying stages of harvest, different levels of nitrogen fertilizer and in combination with *stylosanthes guianensis*during establishment year. M.Sc. Thesis submitted to Haramaya University, Ethiopia.

Getnet, A, Tekleyohanes, B, Lemma, G, Mesfin, D and Diriba, G. 2003. Major herbaceous forage legumes: Some achievements in species and varietal evaluation in Ethiopia. *In* Kemal A, Seid A, Surendra B, Gemechu K, Rajendra M and Khaled M. (eds.). Food and forage legumes of Ethiopia: Progress and prospects. Proceedings of the workshop on food and forage legumes 22 26 September 2003. Addis Ababa, Ethiopia.

Gezahegn, K., Getnet A., Alemayehu M. and Fekede F. 2014. Forage nutritive values of vetch species and their accessions grown under nitosol and vertisol conditions in the central highlands of Ethiopia. *Livestock Research for Rural Development* 26 (1).

Gezahegn K. 2016. Evaluation of vetch species for yield, yield components and herbage quality in the central highlands of Ethiopia. *Acad. Res. J. Agric. Sci. Res.* 2016; 4:264–78. https://doi.org/10.14662 /ARJAS R2016.034.

Ghaderi, G.R., Gazanchian, A., and Yousefi, M. 2008. The forage production comparison of alfalfa and wheatgrass as affected by seeding rate on mixed and pure cropping. *Iranian Journal of Range and Desert Research.* 15(2):256-268.

Hellewell, K.B., Stuthman, D. D., Markhart, A. H. and Erwin, J. E. 1979. Determination of physiological maturity in oats. *Crop Sciences*, 71: 931-935.

Ibrahim A, Babaye H, Ya'u M, Babagana K, Abubakar SM, *et al.* 2018. Nigerian Citrullus Lanatus Fruit and Seed Juice Reduces Cardiovascular Diseases Modifiable Risk Biomarkers in Normal Experimental Rats. *J. Hypertens Manag.* 4:036. doi.org/10.23937/2474-3690/1510036:

Koocheki, A., NassiriMahallati, M., Mondani, F., Feizi, H., and Amirmoradi, S. 2009. Evaluation of radiation interception and use by maize and bean intercropping canopy. *Journal of Agroecology*. 1:13- 23.

Jukenvicius, S. and Sabiene N. 2007. The content of mineral elements in some grasses and legumes. *Ekologija*53: 44-52.

McDonald, P., Edwards R.A.J., Green halgh, F.D. And Morgon, C. A. 2002. Animal nutrition 6th ed. Longman, UK, p. 585.

Meissner, H.H., Zacharias, P.J.K., Reagain. P.J. 2000. Forage quality (Feed value). *In*: Tainton, N.M. (eds.). Pasture Management in South Africa. University of Natal press, Pietermaritzburg, 66-88.

Melkamu, B, Kindu M, Aberra A and Peter T. 2016. Guidelines on the utilization of cultivated oat-vetch and tree lucerne fodder in the Africa Rising sites of the Ethiopian highlands. International Livestock Research. www.africa-rising.netInstitute.

Negash, D, Animut G, Urgie M, and Mengistu S. 2017. Chemical Composition and Nutritive Value of Oats (*Avena sativa*) Grown in Mixture with Vetch (Vicia villosa) with or Without Phosphorus Fertilization in East shoa Zone, Ethiopia. *J. Nutr. Food Sci*., 7:609. doi: 10.4172/2155-9600.1000609.

Ross, S. M., J. R. King, J. T. O'Donovan and R. C. Izaurralde. 2003. Seeding rate effects on oatberseem clover intercrops. Can. J. Pl. Sci., 83:769-778.

SAS. 2008. SAS Users' guide, 9.2 version. Statistical Analysis System Institute Inc., Cary, NC, USA.

Shoaib, M, Ayub M, Zamir M, and Akhtar MJ. 2013. Dry matter yield of oat–Egyptian clover mixture under varying proportions and different growth stages of oat. *Int J Agric Biol.* 15(4):673–9.

Starks, P.J, Zhao D., Philips W.A, and Coleman S.W. 2006. Herbage mass, nutritive value and canopy spectral reflectance of Bermuda grass. *Grass Forage Sci.*, 61: 101-111.

Tilly, J. M. and Terry, R.A. 1963. A two-stage technique for the in vitro digestion of forage crops. *J. Brit. grassl. Soc.*18, 104-111.

Turemen, T., Saglamtimur, T., Tansi, V. and Baytekin, H. 1990. Performance of annual ryegrass and common vetch in association under different ratios. *C. Uni. J. of Fac. Agric.*,5(1): 69-78.

Van Soest P.J. 1965. Symposium on factors influencing the voluntary intake in relation to chemical composition and digestibility. *J. Anim. Sci*., 24: 834.

Van Soest, P.J. and Robertson J.B. 1985. Analysis of Forages and Fibrous Foods. A Laboratory Manual for Animal Science 613.Cornel University, Ithaca. New York, USA, 202p.

Wilson, J. R., Deinum B. and Engels F. M. 1991. Temperature influences on anatomy and digestibility leaf and stem of tropical and temperate forage species. *Netherland Journal of Agricultural Sci.*, 39:1-31.

Worku, M., Lemma, H., Shawle, K., Adie, A., Duncan, A. J., Jones, C. S., Mekonnen, K., Notenbaert, An, & Bezabih, M. 2021. Potential of *Urochloa* grass hybrids as fodder in the Ethiopian highlands. *Agronomy Journal*; 1−12. https://doi.org/10.1002/agj2.20789