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Research Article

Forage Yield and Nutritive Values of Vetches Grown as a Sole and Intercropped with Desho Grass at Different Row Spacing in Western Oromia, Ethiopia

Yerosan Wekgari*, Fikre Dereba

Oromia Agricultural Research Institute, Haro Sabu Agricultural Research Center, Haro Sabu, Ethiopia

Abstract

Legume forage, like vetches, is an important feed source for animals as a supplement to low-quality feeds. This study was conducted to evaluate the forage yield and nutritional values of vetches intercropped at various spacings of desho grass. The study was designed in a factorial arrangement with a randomized complete block design with three inter-row spaces (0.50 m, 0.75 m, and 1 m) and intercropping two vetches (*Vicia sativa* ICARDA 61509 and *Vicia dasycarpa* lana) and desho grass with three replications. Agronomic parameters, forage and seed yield, chemical analysis, and in vitro digestibility of vetch forage samples were determined. Results showed that significant differences ($p<0.05$) were observed for all measured agronomic parameters of vetches, except leaf length, due to spacing and interaction effects. Dry matter yield of vetch (DMY) was only affected by row spacing, while crude protein yield (CPY) was affected by row spacing and their interactions. Higher DMY (3.87 - 4.04 t/ha) and CPY (0.74 - 0.79 t/ha) were obtained from solely grown vetches as compared to intercropped vetches (2.26 - 2.42 t/ha and 0.417 - 0.423 t/ha), respectively. Forage yield significantly decreased as row spacing increased. Seed yield decreased as the row space increased, and the yield obtained from *Vicia sativa* ICARDA 61509 was higher (0.6 and 1.23 t/ha) than *Vicia dasycarpa* lana (0.41 and 0.82 t/ha) when either intercropped with desho grass or sown alone, respectively. The interaction of intercropping with spacing unaffected vetch's chemical composition. However, crude protein (CP) and acid detergent lignin of vetches were influenced by intercropping, whereas CP, neutral detergent fiber, and acid detergent fiber were affected by spacing ($p<0.05$). Intercropped *Vicia dasycarpa* gave higher in vitro dry matter digestibility (IVDMD), *in vitro* organic matter digestibility, and metabolizable energy than *Vicia sativa*, and IVDMD increased as row spacing increased from 0.5 to 1 m.

Keywords

Nutritive Value, Desho Grass, Forage Yield, Intercropping, Row Spacing, Vetch

1. Introduction

Vetch is a species of herbaceous plant in the pea family (Fabaceae). Vetches are annual, have moderate stem strength, and grow as small bushes. Vetches are potentially adapted to most areas and grow where there is an annual rainfall of 300 - 750 mm and a range of soil types, from sandy loams to clays of moderate fertility. Also, it prefers neutral to alkaline soils and a temperature range of 10 - 35 ℃. It can be grown in mixtures with grasses, volunteer cereals, or sown cereals for

*Corresponding author: wyerosan2019@gmail.com (Yerosan Wekgari)

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grass/legume pasture or hay production.

Vetch is one of the important legumes used for fodder production, cover crops, and as green manure. Like other legumes, they add nitrogen to the soil by means of nitrogen-fixing bacteria [1] and thus are particularly valuable as a soil-enriching crop. Vetch fixes atmospheric nitrogen in the soil; this is beneficial for subsequent cereal crops in both yield and quality. Farmers perceive vetches as a reliable, versatile legume for pasture, green manure, hay/silage, and grain. Vetches are rich in protein and minerals and have a lower fiber content. With the highest level of nutritive value, they could be used as a supplement to roughages for dairy cows.

Species of vetch have different characteristics in terms of growth habit, days to maturity, morphological fractions, and climatic adaptation. The growth habits of vetch species can be broadly grouped as erect, creeping, or climbing. These differences in genetic characteristics are the basis for variation in nutritive values and also determine production, utilization, and various management practices. This shows that the different vetch species need to be assessed for nutritional quality differences under the different soil types and climatic conditions [2]. Vetches (*Vicia sativa* and *Vicia dasycarpa*) are an annual pasture/forage/grain legume, palatable at all growth stages, from early green shoots to dry matter, hay, or silage. It has high feed values for animals as green plants and dry matter, and is satisfactory for ruminants.

The use of proper agronomic practices is one of the important factors contributing to the increase in yield per unit area. Among those practices, the arrangement of plants in rows or plant density on the given farm is one of the essential agronomic practices, as it is a major management variable used in matching crop requirements to the environmental offer of resources. Plant density affects early ground cover, the competitive ability of crops with weeds, soil surface evaporation, light interception, lodging, and the development of an optimum number of fruiting sites in a crop canopy. With regard to row spacing and forage production, both narrow and wide row spacing have implications for different aspects of forage production [3], as the number of plants per unit area is the primary source of competition. Therefore, this study was aimed at evaluating the forage dry matter yield and nutritive value of vetches intercropped with different row spacings of desho grass and legumes monocultures.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was conducted at Haro Sabu Agricultural Research Center, Mata Research Sub-site in Kellem Wollega zone of Oromia region during the main cropping season in 2019. The area is located at 8°53’ 33” N latitude and 34°80’ 11” E longitude, with an altitude of 1900 meters above sea level. It has a sub-humid climate with average minimum and maximum annual temperatures of 16.21 and 27.77 ℃, respectively. The area receives an average annual rainfall of 1219.15 mm.

2.2. Land Preparation and Planting

The land was ploughed and harrowed with oxen, and then hoed to make the soil fine. Before the experimental plots were laid out, fine seedbed plots were prepared. Fertilizer was applied at a rate of 100 kg/ha of di-ammonium phosphate (DAP) during establishment for all experimental units [4]. Vetch seed was sown in rows on well-prepared soil. Weeding was done by hand, which eliminated the regrowth of undesirable plants and promoted fodder grass growth by increasing soil aeration. The plots were kept weed-free throughout the growth period [5].

2.3. Experimental Design and Treatments

The experimental design was a randomized complete block design (RCBD) consisting of three inter- and intra-spacings of desho grass: 0.50 m x 0.25 m, 0.75 m x 0.25 m, and 1 m x 0.25 m, with two vetches intercropped between the rows of desho grass and sole vetch species with 0.3 m row spacing. The experiment consists of three blocks; each block contains eight experimental units, which make twenty-four plots in a total area of 465 m^2, with 3 m x 4 m in each plot. The space between plots and blocks was 1 m and 1.5 m, respectively.

Table 1. *Treatment arrangements for row spacing and forage plants.*

Treatments	Row spacing (m)	Plants intercropped
T1	0.50	Desho grass (Kulumsa-DZF- 592) + *Vicia* sativa ICARDA 61509
T2	0.75	Desho grass (Kulumsa-DZF-592) + *Vicia sativa* ICARDA 61509
T3	1	Desho grass (Kulumsa-DZF-592) + *Vicia sativa* ICARDA 61509
T4	0.50	Desho grass (Kulumsa-DZF-592) + *Vicia dasycarpa* lana
T5	0.75	Desho grass (Kulumsa-DZF-592) + *Vicia dasycarpa* lana

Treatments	Row spacing (m)	Plants intercropped
T6	1	Desho grass (Kulumsa-DZF-592) + *Vicia dasycarpa* lana
T7	0.30	Sole *Vicia sativa* ICARDA 61509
T8	0.30	Sole *Vicia dasycarpa* lana

DZF=Debrezeit forage; ICARDA=International Center for Agricultural Research in the Dry Areas

Desho grass (Kulumsa-DZF-592) and vetch varieties (*Vicia sativa* ICARDA 61509 *and Vicia dasycarpa* lana) were the planting materials. Desho grass was planted by vegetative root splits, with the space between plants being 0.25 m, according to the recommendations [6]. The seeds of vetch species were sown by the drilling method in between the rows of desho grass and sole at a seeding rate of 30 kg/ha for *Vicia sativa* ICARDA 61509 and 25 kg/ha for *Vicia dasycarpa* lana, as cited by Gezahagn et al. [7]. The vetch species were sown after two weeks of planting the grass based on the recommendation [8]. The treatment arrangements are indicated in Table 1.

2.4. Data Collection

2.4.1. Agronomic Parameters

The agronomic parameters of vetches, like the number of leaves per plant, plant height, and leaf length, were counted and measured from the middle rows of each plot at the forage harvesting stage (10% of the flowering stage) based on continuous visual observation [9]. The plants were randomly selected in the middle rows of each plot to avoid edges or border effects.

2.4.2. Dry Matter Yield Determination

The dry matter yield of the leguminous forages (vetches) was harvested at 10% of the flowering stage based on continuous visual observation [9]. Accordingly, harvesting was done by hand using a sickle. The harvested fresh weight was immediately recorded in the field by using a top-holding field balance scale. A fresh subsample was taken from each plot, weighted, and then chopped into short lengths of 2–5 cm for dry matter determination. Then the weight of the fresh sample was oven dried at 65 ℃ for 72 hours, and the dry weight was recorded to estimate the dry matter production. The dry matter production is calculated as follows:

$$\text{DMY (t / ha)} = 10 * \text{TFW} * (\text{DWSs}/(\text{HA} * \text{FWSs})) \text{ [10]}$$

Where; TFW: Total Fresh Weight from plot in kg, DWSs: Dry Weight of the Subsample in grams, HA: Harvested Area (meter square), FWSs: Fresh Weight of the Subsample in grams, 10 = is a constant for conversion of yields in kg m^2 to tone/ha.

Besides, crude protein yield was determined by multiplication of dry matter yield with crude protein content of the feed samples.

2.4.3. Seed Yield of Vetches Species

The inner rows of each plot were intercropped with grass at different row spacings, and the soles of the two vetch species were maintained for seed yield determination. The plants were harvested at ground level at the optimum seed harvesting time, and the total seed yield was determined from the inner rows after threshing and winnowing. Seed samples were taken and oven dried at 100 ℃ for 48 hours to adjust the moisture content to 10%, a recommended percentage level for legumes [11]. Seed yield (t/ha) was then calculated at 10% moisture content.

$$\text{Seed yield (t/ha)} = \frac{\text{quantity of seeds harvested (t)}}{\text{Plot area } (m^2)} \times 10$$

2.4.4. Chemical Composition and in Vitro Digestibility Analysis

The composite sample of each vetch species intercropping at various row spacings and sole vetch species was taken and dried in a forced draft oven at 65 ℃ for 72 hours and ground using a Wiley mill to pass through a 1mm sieve screen for chemical analysis. The AOAC [12] procedure was used for the determination of DM, ash, and nitrogen. The organic matter was determined by subtracting the ash component from 100. From the total N, 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 [13].

All samples used in chemical analysis were taken for *in vitro* dry matter digestibility (IVDMD). The two-stage rumen inoculates pepsin method of Tilley and Terry [14], was used to determine IVDMD. Rumen liquor was collected from three rumen fistulated steers and then transported to the laboratory using a thermos flask that had been pre-warmed to 39 ℃. Rumen liquor was taken in the morning before animals were offered feed. A duplicate sample of about 0.5 g each was incubated with 30 ml of rumen liquor in a 100-ml test tube in a water bath at 39 ℃ for a period of 48 hours for microbial digestion. This was followed by another 48 hours of enzyme digestion with an acid pepsin solution. Blank samples containing only buffered rumen fluid were also incubated in

duplicates for adjustment. The drying of sample residues was done at 60 ℃ for 72 hours.

IVDMD was calculated as [15]:

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

In vitro OM digestibility was calculated as:

$$\frac{\text{OM in the feed} - (\text{OM in residue} - \text{blank})}{\text{OM in the feed}} \times 100$$

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

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

$$ME\ (MJ\ kg^{-1}\ DM) = 0.15 * IVOMD\ [16]$$

2.5. Statistical Analysis

Data were subjected to ANOVA procedure by using the General Linear Model of SAS software [17]. Significantly different treatment means were separated and compared using Least Significant Difference (LSD) test at 5 % significant level or 95 % of confidence interval. The statistical model for analysis of data was:

$$Y_{ijk} = \mu + V_i + R_j + (V*R)_{ij} + \varepsilon_{ijk}$$

where;

Y_{ijk}=Response (dependent) variable of ijk^{th}, μ= Overall mean, V_i= i^{th} effect of intercropped vetches, R_i=j^{th} effect of row spacing, $V*R_{ij}$=ij^{th} effect of vetches intercropped and row spacing interaction, ε_{ijk}=Random error

3. Results and Discussion

3.1. Agronomic Performance of Vetches

There was an interaction effect ($p<0.05$) on some agronomic parameters like the number of leaves per plant and the plant height of vetch varieties planted in desho grass in different spaces. Intercropping desho grass with vetches significantly affected all the measured morphological parameters of vetches, while spacing had a significant effect on the number of leaves per plant and the plant height of the legumes (Table 2).

The plant height of vetches at forage harvest was significantly affected by intercropping, spacing and their interactions ($p<0.05$). The height of vetches in the mixtures or intercrops was higher as compared to sole planted vetches, which could be caused by the intercropping of grasses with legumes, which provides structural support for vetches and improves light interception [18]. As well, spacing was affected plant height of vetches and the highest (131.08 cm) was recorded at a narrow spacing (0.50 m), whereas the lowest (112.87 cm) height was recorded at a wider spacing (1 m). This indicated that plant heights decreased as row spacing increased which agrees with the findings of Bagci, [19].

Table 2. *Morphological characteristics of vetches (Mean ±SE) intercropped in desho grass at different row spacing.*

Factors	Parameters		
	NLPP (count)	PH (cm)	LL (cm)
Vetches intercropped			
DVS	230.93 ±7.44^{b}	81.36 ±3.07^{b}	2.42 ±0.07^{b}
DVD	375.52 ±10.23^{a}	163.62 ±3.27^{a}	2.81 ±0.08^{a}
SVS	199.33 ±22.57	70.20 ±10.15	2.37 ±0.04
SVD	372.67 ±23.72	153.77 ±4.96	2.62 ±0.07
Mean	298.92	119.86	2.58
P-value	< 0.0001	< 0.0001	0.0084
Row Spacing (m)			
0.50	323.00 ±35.35^{a}	131.08 ±18.36^{a}	2.62 ±0.15
0.75	302.33 ±35.65^{ab}	123.52 ±18.01^{a}	2.59 ±0.12
1	284.33 ±29.14^{b}	112.87 ±19.18^{b}	2.63 ±0.10
P-value	0.029	0.0012	0.945
Interaction Effect			

Factors	Parameters		
	NLPP (count)	PH (cm)	LL (cm)
DVS* 0.50 m	245.33 ±13.13[c]	90.27 ±3.15[c]	2.35 ±0.12
DVS * 0.75 m	224.77 ±16.72[c]	82.40 ±1.15[c]	2.47 ±0.14
DVS * 1 m	222.67 ±7.51[c]	70.40 ±0.61[d]	2.45 ±0.12
DVD * 0.50 m	400.67 ±6.76[a]	171.9 ±3.25[a]	2.90 ±0.13
DVD * 0.75 m	379.88 ±7.88[ab]	163.63 ±3.5[a]	2.70 ±0.20
DVD * 1 m	346 ±19.49[b]	155.33 ±6.07[ab]	2.81 ±0.06
Mean	303.22	122.49	2.61
P-value	0.0001	0.0001	0.550
CV (%)	6.89	4.87	9.47

[a-b] Means with different letters in a column significantly different ($p<0.05$). DVS= Desho grass intercropped with Vicia sativa ICARDA 61509; DVD= Desho grass intercropped with Vicia dasycarpa lana; SD= Sole desho grass; SVS=sole Vicia sativa ICARDA 61509; SVD= sole Vicia dasycarpa lana; NLPP= number of leaves per plant; PH= plant height; LL= leaf length; m = meter; cm = centimeter; CV = coefficient of variation.

The highest plant height (171.90 cm) was obtained from *Vicia dasycarpa* lana intercropped in grass at 0.5 m row spacing, whereas the lowest was obtained from *Vicia sativa* intercropped in the grass at 1 m row spacing. The mean plant height of the intercropped vetch at various row spacing was 122.49 cm, which was higher than the mean height of five vetch species grown at Holeta (113.8 cm). This height difference could be attributed to genetic variability, soil fertility, and environmental conditions [20]. Among vetches, *Vicia sativa* ICARDA 61509 showed a lower height (81.36 cm) than *Vicia dasycarpa* lana (163.62 cm), because of varietal differences, particularly that *Vicia sativa* has an erect growth habit and is short, whereas *Vicia dasycarpa* has a creeping/climbing growth habit [7].

The number of leaves per plant and leaf length of vetches was significantly affected by intercropping. *Vicia dasycarpa* lana intercropped with grass had a significantly higher number of leaves per plant and leaf length than *Vicia sativa (*ICARDA 61509), and this could be attributed to species or variety disparity. However, except for the number of leaves per plant, spacing did not affect the leaf length of the vines. Leaf number increased as row spacing was decreased. The highest leaf number (400.67) was obtained from *Vicia dasycarpa* lana intercropped with desho grass at narrow row spacing (0.50 m), followed by *Vicia dasycarpa* lana intercropped in desho grass at 0.75 m spacing, whereas the lowest (222.67) was obtained from *Vicia sativa* ICARDA 61509 intercropped in desho grass at 1 m. However, the overall mean of leaf number and length of vetches intercropped with grass were higher as compared to sole *Vicia sativa* ICARDA 61509, but lower than *Vicia dasycarpa* lana.

3.2. Forage Yield

Dry matter and crude protein yield of legume were unaffected by intercropping ($p>0.05$) but affected significantly ($p<0.05$) by row spacing. Except CP yield of legume, interaction of intercropping with spacing did not show significant differences ($p>0.05$) (Table 3).

3.2.1. Dry Matter Yield of Vetches

Legumes (vetches) didn't show a significant difference ($p>0.05$) in dry matter yield when intercropped with desho grass and the interaction of intercropping vetches with row spacing of desho grass. However, the solely cropped vetches gave higher DMY than the intercropped vetches in desho grass due to the discrepancy in row spacing and the higher plant densities occupied by the sole vetches. The DMY of vetches in the present result is less the mean DMY (5.33 t/ha) of different vetch species tested at Holeta and Ginchi, Ethiopia [7], while it was higher as compared to the vetch DMY ranged between 1-1.7 t/ha in vetches-maize intercropping in West Arsi and East Showa zones of Oromia, Ethiopia [21]. These differences were probably due to the agronomic activities, various soil and climate conditions and variety differences.

The DMY of vetch was significantly affected ($p<0.05$) by row spacing. The highest dry matter yield of vetches (2.63 t/ha) was obtained at narrow spacing, which was significantly higher by 14.06% and 19.39% as compared to intermediate and wider spacing, respectively. This greater yield of vetches in narrow spacing could be attributed to higher plant densities (number of leaves per plant) and plant height than in intermediate and wider spacing, and the intercropping of forage grasses with legumes provides structural support for vetch and improves light interception [18]. The significant difference in DMY of legumes

(vetches) among row spacing in the current result was in agreement with the report by Kusvuran [22] in Hungarian vetch and annual Ryegrass intercropping systems, in which the highest yield was obtained at 30 cm row spacing and the yield decreased with increasing row spacing. The current result concurs also with the finding of Alemu [8], who noted that the highest vetch dry matter yield (3.34 t/ha) was obtained when vetch was intercropped with sorghum in 75 cm rather than in 150 cm row space. Generally, the DMY of legumes declined as the spacing between rows increased. Narrow spacing and decreased within-row plant spacing are effective means of increasing dry matter production [23, 24].

Table 3. *Forage dry matter and crude protein yield vetches (Mean ±SE) as affected by intercropping, spacing and their interactions.*

Factors	Forage yield (t/ha)	
	DMY	CPY
Vetches Intercropped		
DVS	2.42 ±0.10	0.423 ±0.02
DVD	2.26 ±0.11	0.417 ±0.02
SVS	4.04	0.74
SVD	3.87	0.79
P-value	0.1827	0.7818
Row Spacing (m)		
0.50	2.63 ±0.08^{a}	0.45 ±0.02^{a}
0.75	2.26 ±0.13^{b}	0.42 ±0.02^{ab}
1	2.12 ±0.09^{b}	0.39 ±0.01^{b}
P-value	0.0101	0.0181
Interaction Effect		
DVS *0.50 m	2.60 ±0.17	0.43 ±0.03^{ab}
DVS * 0.75 m	2.52 ±0.18	0.47 ±0.03^{a}
DVS * 1 m	2.13 ±0.08	0.38 ±0.02^{b}
DVD * 0.50 m	2.66 ±0.08	0.47 ±0.03^{a}
DVD * 0.75 m	2.03 ±0.03	0.38 ±0.01^{b}
DVD * 1 m	2.10 ±0.17	0.41 ±0.01^{ab}
Overall mean	2.34	0.42
P-value	0.1381	0.0441
CV (%)	9.99	9.84

$^{a-b}$ Means with different letters in a column are statistically different ($p<0.05$). DMY= dry matter yield; CPY= crude protein yield; DVS= desho grass intercropped with vicia sativa ICARDA 61509; DVD= desho grass intercropped with vicia dasycarpa lana; SVS=sole Vicia sativa ICARDA 61509; SVD= sole Vicia dasycarpa lana; m = meter; CV = coefficient of variation.

3.2.2. Crude Protein Yield of Vetches

The interaction of intercropping with spacing and spacing alone affected ($p<0.05$) the CPY of vetch, whereas no significant difference was observed by intercropping with desho grass. However, higher CPY was obtained from pure vetches than the vetches intercropped in grass because of the higher DMY and CP content recorded from sole vetches. The higher CPY of vetches was recorded in the narrow spacing due to the high dry matter yield of vetches in the narrow space, whereas the lower CPY was recorded in the wider spacing. The highest CPY of vetch (0.47 t/ha) was obtained from *Vicia dasycarpa* lana intercropped in desho grass at 0.50 m row spacing and *Vicia sativa* ICARDA 61509 intercropped in desho grass at 0.75 m spacing, followed by *Vicia sativa* ICARDA 61509 intercropped in desho grass at narrow spacing (0.50 m), whereas the lowest CPY was recorded from *Vicia dasycarpa* lana at intermediate row spacing and *Vicia sativa* ICARDA 61509 at wider spacing. This was due to the higher dry matter yield of legumes obtained in narrow spaces because of the higher plant densities available. Diriba [25] suggested that a higher CPY indicates a higher importance of the forages.

3.3. Seed Yield of Vetches

The present results showed that intercropping, row spacing, and the interaction of intercropping with spacing significantly ($p<0.05$) affected the seed yield of vetches. Seed yield in the intercropping of the study area ranged from 0.31 to 0.78 t/ha, with a mean of 0.51 t/ha (Table 4). Lower seed yield was recorded due to the existence of high rainfall at the blooming or flowering time of vetches, which caused flower shattering and low pod setting and highly affected the seed yield performance of vetches. The highest seed yield was recorded from *Vicia sativa* ICARDA 61509 at narrow row spacing (0.50 m), followed by *Vicia sativa* ICARDA 61509 at intermediate (0.75 m) row spacing, whereas the lowest seed yield was recorded from *Vicia dasycarpa* lana at wider (1 m) row spacing. This result indicated that the seed yield decreased as the row space increased, and the yield obtained from *Vicia sativa (*ICARDA 61509) was higher than that obtained from *Vicia dasycarpa* lana when they were intercropped with desho grass. The difference could be due to the inherent variation, environmental conditions, and planting pattern.

On the other hand, the solely cropped vetches gave a higher seed yield than the intercropped vetch varieties due to the variation of row spaces and the higher plant densities occupied by the solely cropped vetches. The mean seed yield of vetches in the present study was found to be within a range of seed yield recorded at Holeta (0.4 and 0.8 t/ha) tested from five vetch species, but it was lower than 2 to 2.9 t/ha evaluated from similar species at Ginchi by Gezahagn et al. [7]. This variation was due to several factors, such as agro-ecology, environmental conditions like rainfall, climate, soil fertility, and management practices. The present result was also supported by Sabanci et al. [26], who reported that a higher seed

yield of common vetch (*Vicia sativa*) was observed in narrow row spacing than in wider row spacing.

Table 4. *Seed yield (t/ha) of vetches (Mean ±SE) as affected by intercropping, spacing and their interactions.*

Factors	Row spacing (m)			Mean
Vetches intercropped	**0.50**	**0.75**	**1**	
Desho grass + Vicia sativa	0.78 ±0.04[a]	0.61 ±0.02[b]	0.42 ±0.02[d]	0.60 ±0.05[a]
Desho grass + Vicia dasycarpa	0.53 ±0.02[c]	0.40 ±0.02[d]	0.31 ±0.01[e]	0.41 ±0.03[b]
Mean	0.65 ±0.06[a]	0.51 ±0.05[b]	0.36 ±0.03[c]	
Sole *Vicia sativa*	0.30 m			1.23
Sole *Vicia dasycarpa*	0.30 m			0.82
P-value	VI	<0.0001		
	RS	<0.0001		
	Interaction	0.0205		
CV (%)	6.98			

[a-e] Means with different letters in a column or a row significantly different ($p<0.05$). VI= vetches intercropped; RS= row spacing; CV=coefficient of variation; m=meter.

3.4. Chemical Composition of Vetches

The chemical composition of vetch varieties intercropped in desho grass and the pure stand is given in Table 5. Intercropping, row spacing, and the interaction of intercropping with spacing did not affect ($p > 0.05$) the dry matter content of vetches.

The present result showed that the ash content of vetch species significantly ($p<0.05$) varied among vetches when intercropped with desho grass. But no significant difference was observed between spaces and the interaction of intercropping and spaces (Table 5). Among vetches intercropped in desho grass, the highest ash content (10.3%) was recorded from *Vicia dasycarpa* lana, whereas the lowest (9.01%) was recorded from *Vicia sativa (*ICARDA 61509). Intermediate to late maturing vetch species (*Vicia dasycarpa*) 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 [7].

The interaction effect had no significant effect on the CP content of vetches, while the CP content of vetches was significantly affected by intercropping and row spacing (Table 5). The CP content of *Vicia dasycarpa* lana intercropped with desho grass was greater than that of *Vicia sativa* ICARDA 61509, and also, sole-sown vetches had higher crude protein than those with respective vetches intercropped in the grass. This difference was attributed to species or varietal differences among the legumes. This result was in agreement with Rahetlah et al. [27], who reported that a pure stand of vetch had a higher CP concentration than vetch mixed with oat. The present result was in line with Gezahagn et al. [7], who reported that *Vicia dasycarpa* species had a comparatively higher CP content than *Vicia sativa* species.

Among the row spaces, vetches sown at intermediate and wider spacing had a higher CP content than narrow spaces (0.50 m), which might be due to more soil resource competition by the grass. Getnet and Ledin [28] reported that vetch has a higher CP content compared to many other tropical herbaceous legumes. Most of the herbaceous legumes have a CP content of >15%, a level that is usually required to support lactation and growth, which suggests the adequacy of herbaceous legumes to supplement basal diets 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 animal growth.

Table 5. *Chemical composition of vetches (Mean ±SE) as affected by intercropping, row spacing and their interactions.*

Factors	Parameters					
	DM (%)	Ash (%)	CP (%)	NDF (%)	ADF (%)	ADL (%)
Vetches intercropped						
DVS	92.14 ±0.15	9.01 ±0.25^{b}	17.36 ±0.32^{b}	47.28 ±0.38	33.19 ±0.35	8.04 ±0.25^{b}
DVD	92.47 ±0.13	10.3 ±0.23^{a}	18.58 ±0.36^{a}	46.64 ±0.49	33.87 ±0.41	8.90 ±0.19^{a}
P-value	0.126	0.004	0.014	0.157	0.107	0.013
Row spacing (m)						
0.50	92.07 ±0.16	9.56 ±0.43	17.04 ±0.41^{b}	48.16 ±0.41^{a}	34.41 ±0.24^{a}	8.95 ±0.18
0.75	92.42 ±0.12	9.37 ±0.42	18.34 ±0.23^{a}	46.87 ±0.34^{a}	33.43 ±0.30^{ab}	8.42 ±0.25
1	92.42 ±0.23	10.06 ±0.33	18.53 ±0.55^{a}	45.85 ±0.42^{b}	32.74 ±0.58^{b}	8.04 ±0.42
P-value	0.304	0.299	0.029	0.004	0.016	0.071
Interaction Effect						
DVS * 0.50 m	91.91 ±0.28	8.94 ±0.47	16.49 ±0.27	48.13 ±0.88	34.13 ±0.24	8.80 ±0.35
DVS * 0.75 m	92.32 ±0.14	8.52 ±0.11	17.96 ±0.21	47.21 ±0.51	33.28 ±0.61	7.96 ±0.28
DVS * 1 m	92.18 ±0.34	9.56 ±0.46	17.64 ±0.72	46.51 ±0.24	32.16 ±0.31	7.37 ±0.24
DVD * 0.50 m	92.23 ±0.15	10.18 ±0.58	17.60 ±0.68	48.19 ±0.25	34.69 ±0.38	9.10 ±0.14
DVD * 0.75 m	92.52 ±0.21	10.23 ±0.39	18.73 ±0.26	46.52 ±0.43	33.59 ±0.26	8.88 ±0.13
DVD * 1 m	92.66 ±0.31	10.57 ±0.29	19.43 ±0.44	45.2 ±0.63	33.32 ±1.11	8.71 ±0.62
Overall mean	92.30	9.67	17.97	46.96	33.53	8.47
Sole *Vicia sativa*	92.13	9.09	18.40	40.61	30.56	7.10
Sole *Vicia dasycarpa*	91.93	9.76	19.87	43.45	32.39	8.26
P-value	0.847	0.717	0.605	0.445	0.658	0.358
CV (%)	0.46	7.75	4.87	1.91	2.42	7.08

$^{a\text{-}c}$ Means with different letters in a column significantly different ($p<0.05$). DVS = Desho grass intercropped with Vicia sativa ICARDA 61509; DVD = Desho grass intercropped with Vicia dasycarpa lana; DM = dry matter; CP= crude protein; NDF= neutral detergent fiber; ADF= acid detergent fiber; ADL= acid detergent lignin; m = meter; CV =coefficient of variation.

The interaction effect and intercropping had no significant effect on the NDF content of legumes (vetches), while the NDF content of vetches was significantly affected by spacing (Table 5). The NDF content of vetches in narrow and intermediate spaces was higher than in wider spaces. This is because inter-row plant competition in wider spaces was less than in narrow and intermediate spaces. The mean NDF values of intercropped vetches were higher than the pure vetches tested in the present study, and this is probably due to legumes sharing resources from the grass as compared to pure stand vetch. Among the pure stand legumes, sole *Vicia dasycarpa* lana had a higher NDF content than sole *Vicia sativa* ICARDA 61509. This result was contrary to the report by Gezahagn et al. [7], who noted that *Vicia sativa* species had higher NDF content than *Vicia dasycarpa* and *Vicia antropurpurea* species, and they also reported that early-maturing and erect-growing types of vetch species had comparatively higher NDF content than intermediate- to late-maturing and creeping types of vetch species. The NDF contents are above the critical value of 60%, which can decrease voluntary feed intake, feed conversion efficiency, and rumination time [30]. However, the NDF content of all the tested vetch species was found below this threshold level, which indicates higher digestibility.

The interaction effect and intercropping had no significant effect on the ADF content of legumes (vetches), while the ADF content of vetches was significantly affected by spacing (Table 5). The result revealed that the vetches in narrow space recorded the highest ADF content (34.41%) than intermediate space insignificantly and wider space significantly. The current result showed solely sown vetch had the lowest ADF

content compared to the overall mean of vetches intercropped in the grass at different row spaces. Legumes with less than 31% ADF values are rated as having superior quality, whereas those with values greater than 55% are considered to have inferior quality [31]. Therefore, the ADF content of vetches in the current study was categorized in the medium range of quality.

The ADL content of *Vicia sativa* ICARDA 61509 and *Vicia dasycarpa* lana intercropped in desho grass was significantly affected by intercropping but not significantly affected by ($p > 0.05$) row spaces and the interaction of both factors. *Vicia dasycarpa* lana intercropped in desho grass had significantly higher ADL values than *Vicia sativa (*ICARDA 61509), and this is due to variation among species of the legumes. The ADL of vetches intercropped in desho grass ranged from 6.71% to 9.1% with an overall mean of 8.47%, which was slightly higher than solely sown vetches.

3.5. In Vitro Dry Matter and Organic Matter Digestibility Vetches

The *in vitro* dry matter digestibility of vetches was significantly affected by intercropping and spacing; however, no significant difference ($p>0.05$) in the interaction of intercropping with spacing was declared (Table 6). Among vetches intercropped in the grass, *Vicia dasycarpa* lana was the highest, while the lowest was obtained from *Vicia sativa* ICARDA 61509. This might be due to the competition of nutrients among the legumes with grass and the inherent characteristics differences. The result was consistent with Gezahagn et al. [7], who reported that the early maturing vetch species had lower IVDMD compared to intermediate to late maturing vetch species, which could be due to the presence of higher fibers and cell wall constituents and low crude protein in the early maturing vetch than the intermediate to late maturing vetch species. The overall mean value of IVDMD of vetches intercropped in *desho* grass was lower than that of solely sown vetches (Table 6).

Among the row spaces, the highest IVDMD values were recorded at wider row spacing (1 m), which was not statistically different from intermediate row spacing (0.75 m), whereas the lowest was recorded at narrow row spacing (0.50 m). This could be due to the competition of environmental resources, which may result in the presence of higher fiber and cell wall constituents and lower CP contents in narrow spaces than wider spaces. IVDMD of any forage crop varied with harvesting stage, fiber and cell wall constituents [32]; proportions of morphological fractions [33]; soil, plant species, and climate [28]. IVDMD values greater than 65% indicate a good feeding value, and values below this threshold level result in reduced intake due to lowered digestibility [34]. The IVDMD values observed in this study were below the threshold levels, which may implicate lower voluntary intake and digestibility except for sole *Vicia dasycarpa* lana.

Table 1. *In vitro digestibility and Metabolizable energy of vetches (Mean ±SE) as affected by intercropping, row spacing and their interactions.*

Factors	Parameters		
	IVDMD (%)	**IVOMD (%)**	**ME ($MJkg^{-1}$)**
Vetches intercropped			
DVS	61.19 ± 0.73^{b}	50.85 ± 1.23^{b}	7.63 ± 0.25^{b}
DVD	63.62 ± 0.51^{a}	55.14 ± 1.01^{a}	8.27 ± 0.15^{a}
P-value	0.002	0.006	0.044
Row spacing (m)			
0.50	60.79 ± 0.99^{b}	52.14 ± 0.87	7.82 ± 0.20
0.75	63.31 ± 0.52^{a}	54.24 ± 0.92	8.13 ± 0.19
1	63.12 ± 0.86^{a}	52.62 ± 2.59	7.89 ± 0.42
P-value	0.009	0.378	0.639
Interaction Effect			
DVS * 0.50 m	59.03 ± 1.05	50.93 ± 1.15^{bc}	7.64 ± 0.38
DVS * 0.75 m	63.16 ± 0.78	54.36 ± 1.70^{ab}	8.15 ± 0.34
DVS * 1 m	61.39 ± 0.61	47.26 ± 1.21^{c}	7.09 ± 0.45
DVD * 0.50 m	62.55 ± 0.83	53.34 ± 1.02^{b}	8.00 ± 0.14
DVD * 0.75 m	63.46 ± 0.84	54.13 ± 1.17^{ab}	8.12 ± 0.26

Factors	Parameters		
	IVDMD (%)	IVOMD (%)	ME (MJkg^{-1})
DVD * 1 m	64.85 ±0.60	57.97 ±1.90[a]	8.69 ±0.20
Overall mean	62.41	52.99	7.95
Sole *Vicia sativa*	63.77	54.73	8.21
Sole *Vicia dasycarpa*	65.38	56.38	8.46
P-value	0.078	0.012	0.089
CV (%)	1.98	4.93	7.44

[a-c] Means with different letters in a column significantly different ($p<0.05$). DVS = Desho grass intercropped with Vicia sativa ICARDA 61509; DVD = Desho grass intercropped withVicia dasycarpa lana; IVDMD = in vitro dry matter digestibility; IVOMD= in vitro organic matter digestibility; ME = Metabolizable energy; m = meter; MJ = mega joule; kg = kilogram; CV =coefficient variation.

The *in vitro* organic matter digestibility (IVOMD) of vetches was significantly different ($p<0.05$) at intercropping and the interaction of intercropping with spacing; however, no significant difference ($p>0.05$) due to row spacing was noticed (Table 6). Among vetch varieties intercropped in the grass, *Vicia dasycarpa* lana produced a higher IVOMD than *Vicia sativa* ICARDA 61509.

The interaction of intercropping with spacing significantly ($p<0.05$) affected the IVOMD of vetches. The highest IVOMD of vetch (57.97%) was recorded from *Vicia dasycarpa* lana intercropped in desho grass at wider row spacing (1 m), followed by *Vicia sativa* ICARDA 61509 at 0.75 m space (54.36%), and *Vicia dasycarpa* lana intercropped in desho grass at 0.75 m spacing (54.13%), respectively, whereas the lowest (47.26%) was recorded from *Vicia sativa* ICARDA 61509 intercropped in desho grass at wider (1 m) row spacing. On the other hand, the values of IVOMD for sole vetches were higher than the overall mean of interaction treatments for vetches within the grass. Therefore, in the present study, the mean IVOMD values of vetches were higher than the critical threshold level of 50% required for feeds to be considered to have acceptable digestibility [35].

3.6. Metabolizable Energy of Vetches

Intercropping vetches with desho grass significantly ($p<0.05$) affected the metabolizable energy (ME) of vetches used in the current experiment. However, row spacing and the interaction of intercropping with spacing did not significantly affect ($p>0.05$) the ME content of the vetches (Table 6). Among the intercropping effects, higher ME (8.27 MJ kg-1) was obtained from *Vicia dasycarpa* lana intercropped in desho grass as compared to *Vicia sativa* ICARDA 61509. In general, metabolic energy for all intercropping, spacing, and interaction of intercropping with spacing was higher than the critical threshold level of 7.5 MJkg^{-1} for roughages and forages, as noted by Owen and Jayasuriya [35].

4. Conclusions

In the present study, intercropping of vetches with *desho* grass at different row spacings for forage and seed yield and the chemical composition of legumes were decreased as compared to solely sown vetches; however, the agronomic performances of intercropped vetches were higher than those of pure sown vetches. Among vetches, *Vicia dasycarpa* lana showed higher height, leaf numbers and length than *Vicia sativa* ICARDA 61509 when intercropped with desho grass as well as a pure stand. *Vicia sativa* ICARDA 61509 produced higher dry matter and crude protein yields than *Vicia dasycarpa* lana in intercropping systems and vice versa in solitary stands. Similarly, *Vicia sativa* ICARDA 61509 produced a higher seed yield when sown in sole and intercropped with *desho* grass at different row spacings as compared to *Vicia dasycarpa* lana. Among vetches intercropped with desho grass and sown alone, higher ash, CP, and ADL contents were recorded from *Vicia dasycarpa* lana than *Vicia sativa* ICARDA 61509. The CP content of vetches increased, and the fiber contents (NDF and ADF) decreased as row spacing increased. IVDMD, IVOMD, and ME of *Vicia dasycarpa* lana were significantly higher than those of *Vicia sativa* ICARDA 61509 in intercropped *desho* grass as well as in sole stands. In general, *vetches* grown in association with desho grass gave lower forage yield and nutritive value as compared to solely planted vetches, and intermediate row spacing followed by narrow spacing was a better choice of spacing for intercropping of grass-legumes.

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Author Contributions

Yerosan Wekgari: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing

Fikre Dereba: Investigation, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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