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Chemical Composition and *In vitro* Dry Matter Digestibility of Elephant Grass as Affected by Plant Spacing and Vetch Intercropping

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Abstract: This study was conducted to evaluate the effects of vetch intercropping (elephant grass planted in pure stand, intercropped with *Vicia dasycarpa* and *Vicia villossa*) and plant spacing? S1 (75 x 75 cm), S2 (100 x 50 cm), S3 (125 x 25 cm) and S4 (50 x 50 cm) on the chemical composition and *in vitro* dry matter digestibility (IVDMD) of elephant grass during the main cropping seasons of 2016 and 2017 at Holetta and Debre Zeit Agricultural Research Centers. The treatments were laid out in a randomized complete block design with three replications. Most traits showed significant ($P<0.05$) differences between the treatments, locations and years, while plant spacing had no significant effect. The crude protein (CP) content and IVDMD were higher in vetch- intercropped treatments than sole or pure stand elephant grass over years and locations. When combined over years and locations, the overall mean CP and IVDMD contents of elephant grass were 11.96% and 61.00% (in DM basis), respectively and were higher in the case of vetch intercropping than sole elephant grass. However, elephant grass plant spacing did not significantly affect the nutritional quality of the forage. In conclusion, vetch intercropping at a seeding rate of 25 kg/ha after three weeks of elephant grass establishment/planting considerably improved the crude protein content and in vitro dry matter digestibility implying the significance of vetch intercropping to improve nutritional quality and feeding value of elephant grass for feeding of ruminants. Moreover, it allows quality feed production on the same piece of land and saves the land required for separate production of the companion forages. The lab-based result of the current study should be further verified using animal performance trials.

Key words: Elephant Grass · Vetch Species · Vetch Intercropping · Spacing · Chemical Composition · Digestibility

INTRODUCTION

Livestock plays a central role in the Ethiopian agriculture, although the productivity per animal is very low and the contribution to the overall economy is much lower than the expected potential. Among the factors constraining the development of livestock, feed shortage has remained to be the main bottleneck hindering the livestock productivity [1-3]. The main feed resources which account for more than 90% of the livestock feed in Ethiopia are natural pasture and crop residues, but they are low in quantity and quality for sustainable animal production [4]. The production of sufficient quantity of good quality forages for supplementation of native pastures, roughages and crop residues is the widely advocated strategy to overcome feed scarcity [5]. They are surely a cost-effective feed instead of commercial concentrates. Replacing concentrates with improved forages from 30 to 70% has been reported to reduce up to 30% of production cost in the dairy cattle diet [6]. In Ethiopia, among the introduced improved forage crops, elephant grass could play a main role in providing a substantial quantity of quality forage, both for the smallholder farmers and intensive livestock production systems under proper management practices [7, 8].

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The major limiting factors of forage grasses are low nutritive value in terms of crude protein content and digestibility. They are usually incorporated with legumes to produce high forage quantity with more quality nutrition for livestock feeding [9]. Moreover, intercropping of legumes with grasses reduce inputs through lowering of pesticide and fertilizer requirements and it provides to a greater uptake of nutrients and water, increased land use efficiency, improved soil conservation, suppression of weeds, increasing the capture and use of light, greater productivity and profitability than pure stand cropping systems [10, 11]. Similarly, inter and intra rows plant spacing influenced the CP, NDF, ADF, ADL, Ca, P and IVDMD contents of Bana grass (*P. purpureum x P. typhoides*) [12].

Applying available means or technologies of acquiring adequate supply of medium to high quality feeds is essential throughout the year. However, farmers do not have adequate information on optimum management practices of elephant grass [13]. Hence, in view of the information gap stated above, this study was proposed to evaluate the effects of vetch intercropping and plant spacing on the chemical composition and *in vitro* dry matter digestibility of elephant grass in the central highlands of Ethiopia.

MATERIALS AND METHODS

Descriptions of the Experimental Locations: The experiment was conducted at Holetta and Debre Zeit Agricultural Research Centers of the Ethiopian Institute of Agricultural Research (EIAR). Holetta Agricultural Research Center (HARC) is situated at an altitude of 2400 masl between 9° 03`N latitude and 38° 30`E longitude in Welmera district of the Oromia Special Zone surrounding Finfinnee and presented in Figure 1. The rainfall of the area has a bimodal pattern where around 75% falls during the main rainy season (June to September) and the rest 25% during the short rainy season (February to May). The average maximum and minimum temperatures of Holetta were 24.1°C and 6.4°C, respectively. Frost occurs during November to January when the minimum temperature occasionally drops below zero [14]. Debre Zeit Agricultural Research Centre (DZARC) is located at an altitude of 1850 masl between 8°44` N latitude and 38°58` E longitude in Adaa district in the East Shewa Zone of Oromia Regional States and presented in Figure 1. It also experiences a bimodal rainfall pattern with a long rainy season (June to October) and a short rainy season (March to May). The average maximum and minimum temperatures of the area were 27.1°C and 11.9°C, respectively.

Field Preparation: Both experimental fields were plowed and harrowed using a tractor mounted with moldboard plow and disc harrow to make seedbed with desirable soil tilth before plots were laid out and elephant grass root splits were planted, followed by under sowing of vetches three weeks after the establishment of elephant grass.

Experimental Design and Treatments: Thirty-six (36) plots each at Holetta and Debre Zeit with a plot size of 13.5 m^2 were used. The spacing between the plots and replications were 0.5 m and 1 m, respectively. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The treatments were set in a 3x4 factorial arrangement as follows:

- Factor 1 - Vetch intercropping
- Pure stand elephant grass (*Pennisetum purpureum*)
- Elephant grass intercropped with vetch legume (*Vicia dasycarpa*)
- Elephant grass intercropped with vetch legume (*Vicia villosa*)
- Factor 2 - Elephant grass plant spacing (Table 2)

Planting and Establishment: Elephant grass (*Pennisetum purpureum*) was established using root splits obtained from Holetta Agricultural Research Center. It was planted in well-prepared plots in rows: S1 (24 root split), S2 (30 root splits), S3 (45 root splits) and S4 (60 root splits)). The root splits were planted at a depth of 15 - 20 cm at Holetta and Debre Zeit, on a plot size of 13.5 m^2. Seeds of the two vetch species (*V. dasycarpa* and *V. villossa*) were sown according to the treatment set-ups, at the rate of 25 kg/ha by broadcasting three weeks after the establishment of elephant grass plots during the establishment year. The vetches were also over sown to the elephant grass plots in the second year following clearing of the elephant grass re-growth owards the end of June. The sown vetch seeds were mixed with the upper soil layer by hoeing to facilitate the germination process. DAP fertilizer (Diammonium Phosphate: 18% N and 46% P_2O_5) was uniformly applied at the rate of 100 kg ha^{-1} for all treatment plots at the time of elephant grass planting to enhance better root development. Hand weeding and hoeing were performed during planting and establishment and after every elephant grass harvest to facilitate the regrowth.

Table 1: Physico-chemical properties of the soil sampled at 0-30 cm depth from the experimental plots in the study areas

			Texture								
Location	pH	P-Available (ppm)	Clay (%)	Sand (%)	Silt (%)	Textural class	N- Total (%)	OC (%)	OM (%)	CEC (meq/100 g soil)	Soil type
Holetta	5.19	6.45	66.66	19.16	14.26	Clay	0.19	1.57	2.7	23.33	Nitosol
Debre Zeit	6.24	25.45	61.67	22.5	15.83	Clay	0.14	1.17	2.01	42.42	Vertisol

P = phosphorus; N = nitrogen; OC = organic carbon; OM= organic matter; CEC = cation exchange capacity; ppm = parts per million; meq = milli equivalent; g=gram

Table 2: Description of the different plant spacing's used in the experiment

Treatments	Inter-row Spacing, cm	Intra-row Spacing, cm
S1	75	75
S2	100	50
S3	125	25
S4	50	50

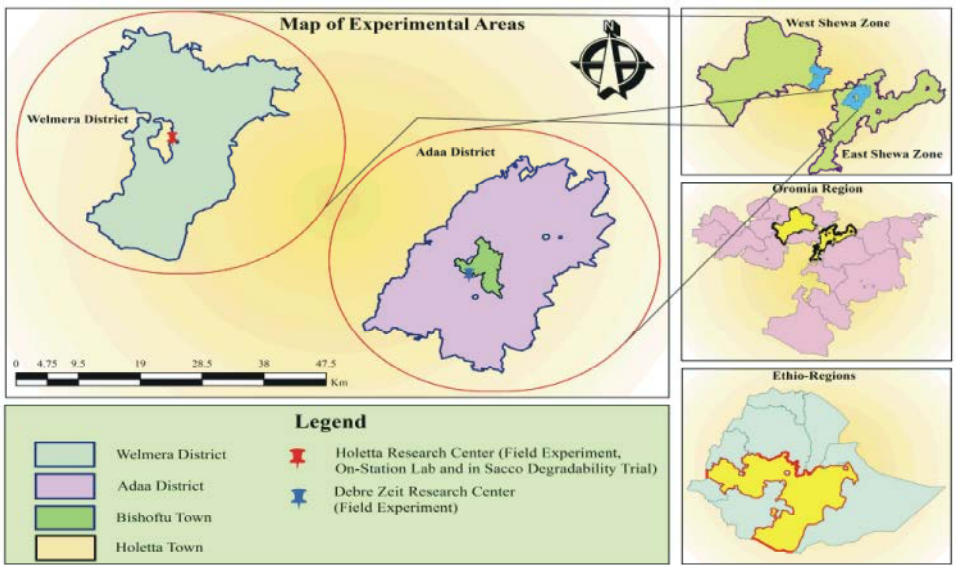

Fig. 1: Map of the experimental locations (Holetta and Debre Zeit agricultural research centers) in the central highlands of Ethiopia

Data Collection: Elephant grass and the intercropped vetches were harvested when the vetches reached about 50% of flowering stage. The forages were harvested at about 5 to 10 cm height from the ground level manually using sickles. The harvested fresh forage subsamples of 900 g were taken from each plot and forage species separately.

Dry Matter Percentage: For dry matter determination, the forage subsamples were dried using a forced air draft oven at 65°C for 72 hours (to constant weight). The subsamples of elephant grass were chopped and shredded to facilitate the drying process. Dry matter percentage was estimated by dividing the dried weight of forage subsample by the fresh weight of subsample and multiplying by hundred.

Grass – legume proportions: For laboratory analysis, grass – legume proportions were prepared based on the proportions of elephant grass and the vetches out of the total dry matter yield estimated for each plot.

Chemical Analysis of Feed Samples: Samples of forage were harvested and chopped to a size of 3-5 cm and dried in air draft oven at 65°C for 72 hours and maintained for chemical analysis being packed in paper bags at room temperature. The subsamples were then ground to pass through 1 mm screen using Wiley mill for chemical analysis. Dry matter and ash contents were determined by oven drying at 105°C overnight and combusting in a muffle furnace at 500°C for 6 hours, respectively [15]. The nitrogen (N) content was determined by Kjeldahl method and CP was calculated as N x 6.25 [16]. The methods of Van Soest and Robertson [17] were used for the determination of neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) contents.

***In vitro* Dry Matter Digestibility Determination:** *In vitro* dry matter digestibility (IVDMD) of the forage samples was determined following the two-stage rumen inoculum pepsin method of Tilley and Terry [18]. Duplicate samples of about 0.5 g each were incubated with 30 ml rumen liquor in 100 ml test tube in water bath at 39°C for a period of 48 hours for microbial digestion. These were followed by another 48 hours for enzyme digestion with acid pepsin solution. Blank samples containing buffered rumen fluid only were also incubated in duplicate for adjustment. Drying of sample residues was done at 105°C for 24 hours. The IVDMD was calculated as dry sample weight- (residue- blank) / dry sample weight x 100.

Data Analysis: Data were subjected to analysis of variance using the general linear model (GLM) procedures of Statistical Analysis System, version 9.1 [19]. Least significance difference (LSD) at 5% significance level was used for comparison of means. The following general model was used for analysis:

$Y_{ijklm} = \mu + B_i + I_j + S_k + L_l + H_m + (I*S)_{jk} + e_{ijklm;}$ where Y_{ijklm} = the measured response, μ = the overall mean; B_i= the effect of the ith block; I_j = the effect of the jth cropping method/intercropping (j= 3); S_k= the effect of the kth spacing (k=4); L_l = the effect of the lth location (l= 2); H_m = the effect of mth year of harvesting (m= 2); $(I*S)_{jk}$= the interaction effect of vetch intercropping and plant spacing; e_{ijklm} = the random error.

RESULTS AND DISCUSSION

Crude Protein Content of Elephant Grass: The crude protein (CP) content of elephant grass as affected by vetch intercropping and plant spacing during the establishment year and in the regrowth during the second year is presented in Tables 3. Comparable and significantly (P<0.05) higher CP contents were recorded in vetch (*V. dasycarpa* and *V. villosa*) intercropping than pure stand elephant grass at Holetta, Debre Zeit, in year 1 and in the combined analysis over years and locations. The effects of plant spacing and interaction between vetch intercropping and plant spacing were not significant (P>0.05) on the CP contents. The highest CP content was attained in *V. villosa* intercropping followed by *V. dasycarpa* intercropping and the lowest was recorded in pure stand elephant grass. Forage yield and quality were highly affected by species composition in intercropping [20]. Grass-legume mixtures (intercropping) have multiple advantages of getting high quality forage, economic benefits of efficient use of resources like land, labour and ecological advantages as these legumes are an efficient of source nitrogen [21, 22]. The CP contents of the present study were considerably higher in vetch (*V. dasycarpa* and *V. villosa)* intercropping than pure stand elephant grass. These results were concurred with the earlier findings of Eskandari *et al.* [23]; Ojo *et al*. [24] and Gulwa *et al.* [25] indicated those legumes have the potential to increase the CP contents of the herbage mixtures compared with grass monocropping. These could be attributed to the legumes in fixing of atmospheric nitrogen in to nitrate. The final concentration of the CP content in the present study was above the minimum level (7.0%) required for optimal rumen function in vetch intercropping combined over years and locations. Except, over years at Debre Zeit and over locations in year 2 in pure stand elephant grass; the present study was agreed with the results of other findings of pure stand elephant grass [26, 27] and guinea grass [28].

In vetch intercropping, the CP contents were not substantially affected by elephant grass spacing in the present study. These findings were concurred with the previous report of Tessema [26], who showed that non-significant effect of spacing (150 cm x 25 cm, 100 cm x 25 cm, 50 cm x 25 cm, 150 cm x 50 cm, 100 cm x 50 cm, 50 cm x 50 cm, 150 cm x 75 cm 100 cm x 75 and 50 cm x 75 cm) on the CP contents of elephant grass. Wijitphan *et al*. [29] reported that elephant grass spacing (50 cm x 100 cm, 50 cm x 80 cm, 50 cm x 60 cm and 50 cm x 40 cm) did not have substantial effect on the CP contents of elephant grass. On the contrary, Berihun [12] reported that the combination of row and plant spacing did not greatly affect the CP contents of Bana grass in the semiarid areas of northwestern Ethiopia. These CP variations with the present study could be attributed to the differences of management practices and environmental conditions.

Ash Content: The ash content of elephant grass during the establishment year and in the regrowth during the second year as affected by vetch intercropping and plant spacing is indicated in Table 4. In this study the ash contents were comparable and significantly (P<0.05) lower in vetch (*V. dasycarpa* and *V. villosa*) intercropping than pure stand elephant grass at Holetta, Debre Zeit,

Table 3: Mean crude protein (CP) content (% in DM basis) of elephant grass during the establishment year (Year 1) and in the regrowth during the second year (Year 2) as affected by vetch intercropping and plant spacing (combined over years and locations)

	Location		Year		
Treatment	Holetta	Debre Zeit	Year 1	Year 2	Mean
Vetch Intercropping (I)					
Pure stand Elephant G	8.72^{b}	7.01^{b}	9.59^{b}	6.15^{c}	7.87^{b}
Elephant G + *V. dasycarpa*	15.64^{a}	12.17^{a}	19.87^{a}	7.94^{b}	13.91^{a}
Elephant G + *V. villosa*	15.36^{a}	12.83^{a}	19.31^{a}	8.38^{a}	14.09^{a}
P-value	0.0001	0.0001	0.0001	0.0001	0.001
Plant Spacing (S), cm					
S1 (75 x 75)	13.46	11.24	16.94	7.77	12.35
S2 (100 x 50)	12.96	10.91	16.29	7.57	11.93
S3 (125 x 125)	13.65	10.41	15.96	7.44	12.03
S4 (50 x 50)	12.90	10.13	15.84	7.18	11.51
Mean	13.24	10.67	16.26	7.49	11.96
SEM	0.212	0.174	0.174	0.095	0.139
CV (%)	24.40	18.86	13.42	8.71	23.19
I*S	NS	NS	NS	NS	NS
P-value	0.8696	0.3569	0.4410	0.0632	0.6417

$^{a-c}$ Means followed by different superscripts within a column are significantly different (P<0.05); Elephant G = elephant grass; SEM= standard error of the mean; CV= coefficient of variation; NS= non-significant

Table 4: Mean ash content (% in DM basis) of elephant grass during the establishment year (Year 1) and in the regrowth during the second year (Year 2) as affected by vetch intercropping and plant spacing (combined over years and locations)

	Location		Year		
Treatment	Holetta	Debre Zeit	Year 1	Year 2	Mean
Vetch Intercropping (I)					
Pure stand Elephant G	19.26^{a}	16.19^{a}	17.36^{a}	18.08^{a}	17.72^{a}
Elephant G + *V. dasycarpa*	14.79^{b}	15.35^{b}	13.46^{b}	16.68^{b}	15.07^{b}
Elephant G + *V. villosa*	15.06^{b}	14.90^{b}	12.04^{b}	17.37^{ab}	14.98^{b}
P-value	0.0001	0.0013	0.0001	0.0013	0.0001
Plant Spacing (S), cm					
S1 (75 x 75)	16.28	15.23	13.72	17.63	15.76
S2 (100 x 50)	16.08	15.18	13.78	17.31	15.63
S3 (125 x 125)	16.89	15.86	15.03	17.50	16.38
S4 (50 x 50)	16.23	15.64	14.63	17.08	15.94
Mean	16.37	15.48	14.29	17.38	15.92
SEM	0.180	0.128	0.172	0.132	0.117
CV (%)	14.22	7.58	14.85	7.20	12.38
I*S	NS	NS	NS	NS	NS
P-value	0.7391	0.2436	0.1865	0.5748	0.4006

$^{a-b}$ Means followed by different superscripts within a column are significantly different (P<0.05); Elephant G = elephant grass; SEM= standard error of the mean; CV= coefficient of variation; NS= non-significant

in year 1 and in the combined analysis over years and locations. Moreover, in year 2, significantly (P<0.05) the highest ash content was recorded in pure stand elephant grass followed by *V. villosa* intercropping, while the lowest was recorded in *V. dasycarpa* intercropping. The effects of plant spacing and interaction between vetch intercropping and plant spacing were not significant (P>0.05) on the ash contents of vetch intercropping and pure stand elephant grass. The ash contents of vetch (*V. dasycarpa* and *V. villosa*) intercropped with elephant grass were significantly lower than pure stand elephant grass. The present results were agreed with the findings of Mohammed *et al*. [30] in elephant grass intercropped with or without lablab in Ethiopia and Njoka-Njiru *et al*. [31] in elephant grass intercropped with herbaceous legumes in the semi-arid regions of Kenya. On the other hand, the present finding was disagreed with the reports of Alalade *et al.* [32] and Foster *et al*. [33] showed higher ash contents in grass-legume mixtures than in pure stand grass. Such variations could be attributed to the differences of variety/ species of forage, management and environmental conditions. The ash contents of the present study were not significantly affected by elephant grass spacing. This finding was coincided with finding of Tessema [26], who reported that non-significant effect of spacing (150 cm x 25 cm, 100 cm x 25 cm, 50 cm x 25 cm, 150 cm x 50 cm, 100 cm x 50 cm, 50 cm x 50 cm, 150 cm x 75 cm, 100 cm x 75 cm and 50 cm x 75 cm) on the ash content of the same species grass.

Neutral detergent fiber, acid detergent fiber and acid detergent lignin contents The neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) contents of elephant grass during the establishment year and in the regrowth during the second year as affected by vetch intercropping and plant spacing are presented in Tables 5 to 7, respectively. The NDF contents were comparable and significantly (P<0.05) lower in vetch (*V. dasycarpa* and *V. villosa*) intercropping than pure stand elephant grass at Holetta, Debre Zeit, in year 1, 2 and in the combined analysis over years and locations (Table 5). The effect of vetch intercropping did not significantly (P>0.05) affect the ADF contents over years and locations (Table 6). Comparable and significantly (P<0.05) higher ADL contents were recorded in vetch (*V. dasycarpa* and *V. villosa*) intercropping than pure stand elephant grass at both locations and years in the combined analysis (Table 7). The effects of plant spacing and interaction between vetch intercropping and plant spacing were not significant (P>0.05) on the NDF, ADF and ADL contents, except elephant grass spacing on the NDF contents in year1; higher NDF at narrower planting spacing than wider spacing. The NDF contents of roughage diets ranged from 45-65 and below 45%, which are generally considered as medium and high-quality feeds, respectively [34]. The NDF contents of elephant grass intercropped with vetch (*V. dasycarpa* and *V. villosa)* were closer to medium-quality feed (45- 65%) category, except in pure stand elephant grass and in year 2 over locations which had higher NDF contents. The NDF contents of vetch (*V. dasycarpa* and *V. villosa*) intercropping was lower than pure stand elephant grass in the present study. These results were agreed with the findings of Bayable *et al.* [35] and Mohammed *et al*. [30] in elephant grass intercropped with lablab or desmodium and lablab, respectively. According to Mohammed *et al*. [30], elephant grass intercropped with lablab had no significant effect on the ADF contents, which were concurred with what were reported in the present study. On the contrary, Bayable *et al.* [35] reported that there were significant effects of elephant grass intercropped with lablab or Desmodium on the ADF contents. The ADL contents of vetch (*V. dasycarpa* and *V. villosa)* intercropping were considerably higher than pure stand elephant grass in the present study. These results were agreed with the finding of Bayable *et al.* [35] who showed that elephant grass intercropped with lablab or Desmodium had significantly higher ADL contents than pure stand elephant grass. The ADL contents were higher in the legumes compared to elephant grass and this also caused an escalation of the ADL contents in legumes intercropped with elephant grass harvesting at 90 and 120 days. The results of the present study could be expected due to greater ADL contents in the tropical legumes than grasses [36]. On the contrary, elephant grass intercropped with or without lablab had no significant effect on the ADL contents [30].

Except NDF content in year 1, the NDF, ADF and ADL contents of elephant grass were not significantly affected by the different elephant grass spacing. With the exception of NDF in year 1, the present results were concurred with the report of Tessema [26] who showed non-significant effect of elephant grass spacing on the NDF, ADF and ADL contents. On the contrary, Berihun [12] reported that plant spacing configurations (100 cm x 50 cm, 100 cm x 75 cm, 75 cm x 50 cm and 75 cm x 75 cm) significantly affect the NDF, ADF and ADL contents of Bana grass in semiarid areas of north western Ethiopia. Similarly, Wijitphan *et al*. [29] revealed that elephant grass spacing (50 cm x 100 cm, 50 cm x 80 cm, 50 cm x 60 cm and 50 cm x 40 cm) had significant effect on the NDF, while non- significant on the ADF and ADL contents.

In vitro Digestibility**:** The *in vitro* dry matter digestibility (IVDMD) of elephant grass during the establishment year and in the regrowth during the second year as affected by vetch, intercropping and plant spacing are presented in Table 8. Comparable and significantly (P<0.05) higher IVDMD were recorded in vetches (*V. dasycarpa* and *V. villosa*) intercropped with elephant grass than pure stand elephant grass combined over locations and years. The effects of plant spacing and interaction between vetch intercropping and plant spacing were not significant (P>0.05) on the IVDMD. The IVDMD of elephant grass when intercropped with vetches (*V. dasycarpa* and *V. villosa*) were higher than pure stand elephant grass. Legumes intercropping increased the CP and decreased the NDF contents of the companion crops like elephant grass as the legumes are a good source of fixed nitrogen [37, 38]. Lower NDF content has

Table 5: Mean neutral detergent fiber (NDF) content (% in DM basis) of elephant grass during the establishment year (Year 1) and in the regrowth during the second year (Year 2) as affected by vetch intercropping and plant spacing (combined over years and locations)

	Location		Year		
Treatment	Holetta	Debre Zeit	Year 1	Year 2	Mean
Vetch Intercropping (I)					
Pure stand Elephant G	67.69[a]	69.83[a]	61.73[a]	75.78[a]	68.76[a]
Elephant G + *V. dasycarpa*	60.74[b]	65.56[b]	52.70[b]	73.60[b]	63.14[b]
Elephant G + *V. villosa*	60.70[b]	64.43[b]	50.64[b]	74.49[b]	62.56[b]
P-value	0.0001	0.0001	0.0001	0.0011	0.0001
Plant Spacing (S), cm					
S1 (75 x 75)	61.29	65.77	52.65[b]	74.42	63.53
S2 (100 x 50)	62.93	66.04	54.33[ab]	74.65	64.49
S3 (125 x 25)	64.19	67.21	56.57[a]	74.82	65.70
S4 (50 x 50)	63.76	67.39	56.55[a]	74.60	65.58
Mean	63.04	66.60	55.02	74.62	64.82
SEM	0.256	0.212	0.234	0.164	0.176
CV (%)	7.51	4.84	7.15	2.60	6.90
I*S	NS	NS	NS	NS	NS
P-value	0.2791	0.3374	0.0093	0.9400	0.1392

[a-b] Means followed by different superscripts within a column are significantly different ($P<0.05$); Elephant G = elephant grass; SEM= standard error of the mean; CV= coefficient of variation; NS= non-significant

Table 6: Mean acid detergent fiber (ADF) content (% in DM basis) of elephant grass during the establishment year (Year 1) and in the regrowth during the second year (Year 2) as affected by vetch intercropping and plant spacing (combined over years and locations)

	Loction		Year		
Treatment	Holetta	Debre Zeit	Year 1	Year 2	Mean
Vetch Intercropping (I)					
Pure stand Elephant G	45.16	45.35	38.75	51.76	45.25
Elephant G + *V. dasycarpa*	45.93	45.15	39.51	51.56	45.54
Elephant G + *V. villosa*	46.70	45.47	39.99	52.18	46.08
P-value	0.0862	0.8152	0.1576	0.5124	0.1625
Plant Spacing (S), cm					
S1 (75 x 75)	45.39	45.07	38.85	51.61	45.23
S2 (100 x 50)	46.50	45.09	39.54	52.05	45.79
S3 (125 x 25)	46.05	44.91	39.81	51.19	45.50
S4 (50 x 50)	45.77	46.17	39.47	52.48	45.97
Mean	45.93	45.32	39.41	51.83	45.62
SEM	0.181	0.156	0.176	0.161	0.122
CV (%)	5.14	3.85	5.63	3.62	4.73
I*S	NS	NS	NS	NS	NS
P-value	0.5540	0.1352	0.6163	0.2027	0.4808

Means followed by different superscripts within a column are significantly different ($P<0.05$); Elephant G = elephant grass; SEM= standard error of the mean; CV= coefficient of variation; NS= non-significant

Table 7: Mean acid detergent lignin (ADL) content (% in DM basis) of elephant grass during the establishment year (Year 1) and in the regrowth during the second year (Year 2) as affected by vetch intercropping and plant spacing (combined over years and locations)

	Loction		Year		
Treatment	Holetta	Debre Zeit	Year 1	Year 2	Mean
Vetch Intercropping (I)					
Pure stand Elephant G	5.49[b]	5.50[b]	5.46[b]	5.53[b]	5.50[b]
Elephant G + *V. dasycarpa*	9.22[a]	9.43[a]	9.56[a]	9.08[a]	9.32[a]
Elephant G + *V. villosa*	9.60[a]	9.38[a]	9.65[a]	9.32[a]	9.49[a]
P-value	0.0001	0.0001	0.0001	0.0001	0.0001
Plant Spacing (S), cm					
S1 (75 x 75)	7.90	8.00	8.31	7.59	7.95
S2 (100 x 50)	7.94	8.18	8.03	8.09	8.06
S3 (125 x 25)	8.05	8.10	8.07	8.08	8.08
S4 (50 x 50)	8.52	8.13	8.49	8.16	8.32
Mean	8.10	8.10	8.22	7.98	8.10
SEM	0.117	0.116	0.119	0.115	0.082
CV (%)	12.13	11.91	12.36	11.85	12.00
I*S	NS	NS	NS	NS	NS
P-value	0.2202	0.9559	0.4941	0.2659	0.4216

[a-b] Means followed by different superscripts within a column are significantly different ($P<0.05$); Elephant G = elephant grass; SEM= standard error of the mean; CV= coefficient of variation; NS= non-significant

Table 8: Mean *in vitro* dry mater digestibility (% in DM basis) of elephant grass during the establishment year (Year 1) and in the regrowth during the second year (Year 2) as affected by vetch intercropping and plant spacing (combined over years and locations)

	Location		Year		
Treatment	Holetta	Debre Zeit	Year 1	Year 2	Mean
Vetch Intercropping (I)					
Pure stand Elephant G	59.95[b]	56.09[b]	63.06[b]	52.99[b]	58.02[b]
Elephant G + *V. dasycarpa*	62.69[a]	62.14[a]	69.69[a]	54.97[a]	62.41[a]
Elephant G + *V. villosa*	63.15[a]	62.00[a]	70.13[a]	54.90[a]	62.58[a]
P-value	0.0001	0.0001	0.0001	0.0159	0.0001
Plant Spacing (S), cm					
S1 (75 x 75)	62.15	59.94	67.81	54.18	61.05
S2 (100 x 50)	62.41	60.79	68.43	54.49	61.60
S3 (125 x 25)	61.37	59.16	66.47	54.06	60.27
S4 (50 x 50)	61.79	60.42	67.80	54.41	61.10
Mean	61.93	60.08	67.62	54.28	61.00
SEM	0.186	0.207	0.185	0.190	0.146
CV (%)	4.00	5.16	3.63	4.81	5.06
I*S	NS	NS	NS	NS	NS
P-value	0.6152	0.4366	0.1171	0.9579	0.3325

[a-b] Means followed by different superscripts within a column are significantly different (P<0.05); Elephant G = elephant grass; SEM= standard error of the mean; CV= coefficient of variation; NS= non-significant

been associated with increasing digestibility and feed intake [39]. The IVDMD of elephant grass in the present study was higher than the digestibility of most tropical grasses (54%) [40]. The digestibility of elephant grass intercropped with vetches (*V. dasycarpa* and *V. villosa*) was considerably higher than pure stand elephant grass and this result was agreed with the findings of Njoka-Njiru *et al*. [31] and Mohammed *et al*. [30] reported in herbaceous legumes intercropped with elephant grass had greater digestibility than pure stand elephant grass. The variations could be attributed to the increased nitrogen content obtained from biological fixation of nitrogen (N_2) by legumes. Minson [40] was also supported that intercropping of perennial tropical grasses with legumes enhance pasture quality through increased CP and reduced NDF contents, which were coincided with the results of the present study.

The IVDMD of elephant grass was not significantly affected by elephant grass spacing. This result was agreed with the finding of Wijitphan *et al*. [29] who reported that the dry matter digestibility of elephant grass was not significantly affected by plant spacing configurations (50 cm x 40 cm, 50 cm x 60 cm, 50 cm x 80 cm and 50 cm x 100 cm). On the contrary, Berihun [12] reported that bana grass spacing had significant effect on the IVDMD.

CONCLUSION AND RECOMMENDATIONS

Vetch intercropping with elephant grass established using different plant spacing had resulted in higher crude protein (CP) content and *in vitro* dry matter digestibility (IVDMD) during both the establishment year and in the regrowth during the second year, while the neutral detergent fiber (NDF) content of elephant grass was decreased when intercropped with vetches. The result generally revealed that intercropping vetches with elephant grass has improved the overall nutritional quality of the forage with significant implications to ruminant feeding. Moreover, grass-legume mixed cropping is an efficient land use system as it enables quality feed production on the same plot of land. The results of the present study should be further verified using animal response trials.

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