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Effects of Spacing of Elephant Grass and Vetch Intercropping on Agronomic Performance and Herbage Yield of Elephant Grass

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*ይህ ምርምር የተካሄደው በተለያዩ የመስመር እና እፅዋት መካከል የዝሆኔ ሳርን እያራራቁ በመትከል እና መኖ ጓያ ዝርያዎችን ቀላቅሎ በመዝራት በዝሆኔ ሳር ቁመት ፣የቅጠል እና ግንድ ማመዛዘን፣ ቲለር ቁጥር፣ የጸደቀው ቁጥር ፣ ብሎም የደረቀ ምርት (DMY) መጠናቸው ተገምግመዋል፡፡ የመስክ ምርምሩ በመኖ ሰብሎች ላይ የተካሄደው በሆለታ እና በደብረዘይት ግብርና ምርምር ማዕከል እንደ አዉሮፓዉያን አቆጣጠር በ2016 እና በ2017 በዎናው የመኸር ወቅት በማዕከላዊ የኢትዮጲያ ደጋማው አካባቢ ነው፡፡ የጥናቱ አዘገጃጀት የሚያካትተው ዝሆኔ ሳር ለብቻው፤ ከቪሽያ ዳሲካርፓ እና ከቪሽያ ቪሎሳ ጋር ተቀላቅለው በአራት የተለያዩ የመስመር እና የዝሆኔ ሳር መካከል እያራራቁ በመትከል S1(75*75), S2(100*50) , S3(125*25) እና S4(50*50 ሳ.ሜ) ተከናውኗል:: የጥናቱ አዘገጃጀት ህብር በሶስት ዝዜ የረድፍ ድግግሞሽ በ13.5ካሬ ሜትር ማሳ ላይ በrandomized complete block design መሰረት ተካሂዷል፡፡ አብዛኛው የተለኩ ባህሪያት የጎላ ልዩነት በጥናቱ አዘገጃጀት፣ አመታት እና የጥናት ቦታዎች መካከል አሳይተዋል፡፡ መኖ ጓያ ከዝሆኔ ሳር ጋር ሲቀላቀሉ በ70.0 እና በ8.5% አብላጫ የምርት ጥቅም ከዝሆኔ ሳር ብቻውን ከተተከለው በሆለታ እና በደብረ ዘይት በቅደም ተከተላቸው መሰረት አስገኝተዋል፡፡ እንዲሁም በቦታዎች እና አመታት ሲጣመሩ ደግሞ አማካይ አመታዊ ደረቅ ምርት 9.47, 12.16 እና 12.01ቶን በሄ/ር ዝሆኔ ሳር ለብቻው፤ ከቪሽያ ዳሲካርፓ፤ ቪሽያ ቪሎሳ ጋር ተቀላቅለው በቅደም ተከተላቸው በስረት አስመዝግበዋል፡፡ የሁለቱ ቦታዎች ሲጣመሩ የዝሆኔ ሳር በመስመር እና በእፅዎት መካከል በማራራቅ ሲተከሉ በS4, S3, S2 እና S1 በቅደም ተከተላቸው በ12.96, 11.02, 10.55 እና 10.32ቶን በሄ/ር ደረቅ ምርት አስገኝተዋል፡፡ S4 በ17.6, 22.8 እና 25.6% ደረቅ የምርት አብላጫ ጠቀሜታ ከS3, S2 እና S1 ጋር ሲነጻጸር በቅደም ተከተላቸው የሰጠ ስለሆነ የመጀመሪያ ተመራጭ አድርጎታል፡፡ ይህ ጥናት ሲጠቃለል በዝሆኔ ሳር መስመር እና መካከል በ50 ሴንቲ ሜትር ተራርቀው ሲተከሉ እና የመኖ ጓያ ዝርያዎችን ዘር (25ኪ.ግ በሄ/ር) የዝሆኔ ሳር ከተተከለ ከሶስት ሳምንታት በሓላ ሲዘራ አመታዊ ደረቅ የዝሆኔ ሳር ምርታማነትን በከፍተኛ መጠን ያሻሻለ መሆኑን ከጥናቱ ለመረዳት ተችሏል፡፡ ስለዚህ ዝሆኔ ሳር ብቻውን የሚተከሉ ገበሬዎች መኖ ጓያ እየቀላቀሉ በመዝራት ከብቶቻቸውን ቢመግቡ የተሻለ ነው፡፡*

Abstract

*An experiment was conducted to investigate the effects of different spacing of elephant grass (***Pennisetum purpureum***) and vetch (***Vicia dasycarpa*** and ***Vicia villossa)*** intercropping on plant height, leaf to stem ratio, tillering, stand count, and subsequent dry matter yield (DMY) of elephant grass. The forages for field experiment were evaluated during the main cropping season of 2016 and 2017 at Holetta and Debre Zeit Agricultural Research Centers in the central highlands of Ethiopia. The treatments consisting of three vetch intercropping (pure stand elephant grass, elephant grass intercropped with* **V. dasycarpa** *and* **V. villosa***) and four spacing of elephant grass S1(75*75), S2(100*50), S3(125*25) and S4(50*50 cm). The treatment combinations were planted on 13.5m^2 plots using randomized complete block design with three replications. Most measured traits revealed significant (P<0.05) differences between the treatments, years and locations. Vetch intercropping resulted 70.0 and 8.5% yield advantage over pure stand elephant grass at Holetta and Debre Zeit, respectively. When combined over locations and years, average annual DMY was 9.47, 12.16, and 12.01 t/ ha for elephant grass planted in pure stand, intercropped with* **V. dasycarpa** *and* **V. villosa** *respectively. In the combined analysis, herbage DM produced 12.96, 11.02, 10.55, and 10.32 t/ha* *when planted at spacing of S4, S3, S2, and S1, respectively. S4 had 17.6, 22.8 and 25.6% higher DMY advantage when compared with S3, S2 and S1, respectively. In conclusion, vetch intercropping (at a seed rate of 25 kg/ha) three weeks after elephant grass establishment at inter and intra row spacing of 50 cm substantially improve annual DM yields of elephant grass. Hence, it could be advisable to be adopted by farmers who grow elephant grass in pure stands as livestock feed.*

Introduction

Ruminant livestock production is constrained by chronic shortage of feed in most developing countries (Devendra and Leng, 2011). In Ethiopia, the main feed resources for livestock are natural pasture and crop residues, which are characterized by low quality to support sustainable animal production. The current trends also indicate that the existing grazing lands are heavily overstocked and shrinking from time to time due to expansion of cropping to nourish the rapidly increasing human population in the developing countries (Kechero, 2008). To improve the ever-increasing demand for animal products in developing countries like Ethiopia, options that enhance the supply of high quality livestock feed is a priority in feed resource development (Getnet, 2007).

Forages are certainly known as a cost effective feed rather than commercial concentrates. The substitution of forages to concentrates from 30 to 70% in dairy cattle diet could reduce up to 30% cost of production (Sanh *et al.*, 2002). Amongst the improved forage crops introduced in Ethiopia, elephant grass could play an important role in providing a considerable amount of quality forage, both for the smallholder farmers as well as intensive livestock production systems (Seyoum *et al*., 1998). It is propagated vegetatively using stem cuttings and root splits (Tessema, 2008) which usually vary across agro-ecologies (Getnet and Gezahagn, 2012). Yields of the grass vary depending on genotypes (Cuomo *et al*., 1996), edaphic and climatic factors, and management practice (Chaparro *et al.*, 1996). The main limiting factor of grasses is low protein supply. Forage grasses are commonly intercropped with legumes to produce high quantity of forage with more balanced nutrition for livestock feeding (Mwangi *et al*., 2002; Koc *et al*., 2013). Legumes increase soil nitrogen through their nitrogen fixation ranging from 32 to 115 kg/ha in symbiosis with rhizobium bacteria (Iannetta *et al*., 2016). This can in turn decrease subsequent fertilizer use for crops grown thereafter, a reduction between 23 and 31 kg N, ha (Preissel *et al*., 2015). Therefore, legume intercropping with grasses allow lower inputs through reduced fertilizer and pesticide requirements, and it contributes to a greater uptake of water and nutrients, increased soil conservation, increased efficiency of land use, enhancing the capture and use of light, controlling weeds, high productivity and profitability (Coll *et al*., 2012; Akman *et al*., 2013) compared to mono cropping systems.

Two vital components of technology for grasses are proper plant spacing and adequate nitrogen fertilization, which play a key role in the development of fast growing and profusely tillering grasses like elephant grass (Bilal *et al*., 2000). Plant spacing influence on total dry matter yield of elephant grass (Wijitphan *et al*., 2009). Despite the potential role of elephant grass as a source of forage, adequate studies have not been made on agronomic management practices such as different spacing of elephant grass and vetch intercropping which would help to improve its agronomic performance and herbage productivity. Therefore, the objective of this study was to evaluate the effects of inter and intra row spacing of elephant grass and vetch intercropping on agronomic performance and subsequent dry matter yield of elephant grass in the central highlands of Ethiopia.

Materials and Methods

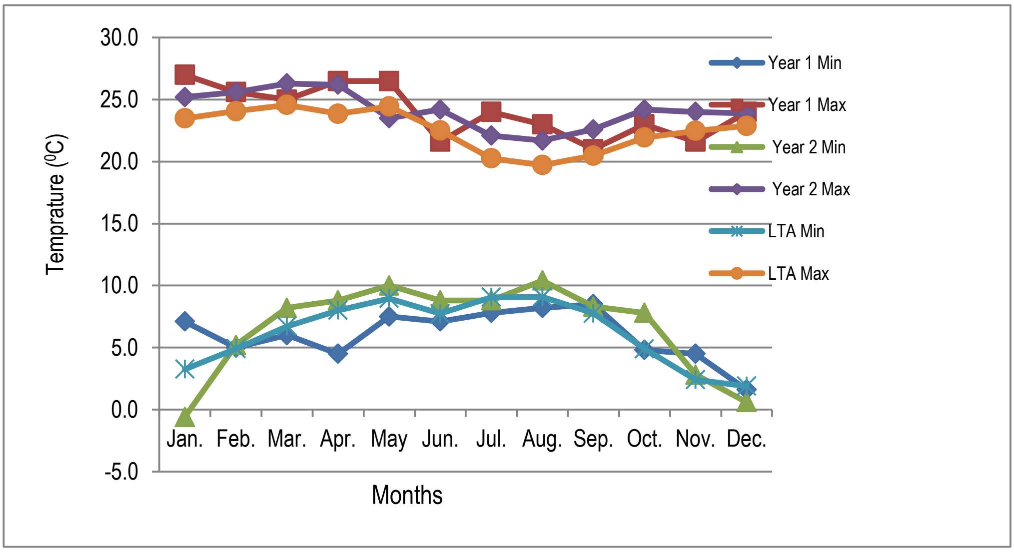
Experimental locations

The experiment was conducted at Holetta and Debre Zeit Agricultural Research Centers of the Ethiopian Institute of Agricultural Research (EIAR). Holetta Research Center is situated at an altitude of 2400 meter above sea level (m.a.s.l.) between 9° 00`N latitude and 38° 30`E longitude. The area has a bimodal rainfall where about 75% falls during the main rainy season (June to September) and the rest 25% during the short rainy season (February to May). Average maximum and minimum temperature of the area is 23.6^{o}C and 6.3^{o}C, respectively. The minimum temperature sometimes drops below zero when frost occurs during November to January (HARC, 2003). Debre Zeit Agricultural Research Centre is located at an altitude of 1850 m.a.s.l. between 9^{0} N latitude and 39^{0}E longitude. It also experiences a bimodal rainfall pattern with a long rainy season (June to October) and a short rainy season (March to May). Average maximum and minimum temperature of the area is 26.8^{o}C and 11.6^{o}C, respectively. The Long term (1971-2017) and the experimental period weather data of Holetta and Debre Zeit are shown in Figures 1 and 2. Prior to planting, representative soil samples were taken from the experimental fields using soil-sampling augur at a depth of 0 to 30 cm layer. The composite samples were analyzed for its physico- chemical analysis and presented in Table 1.

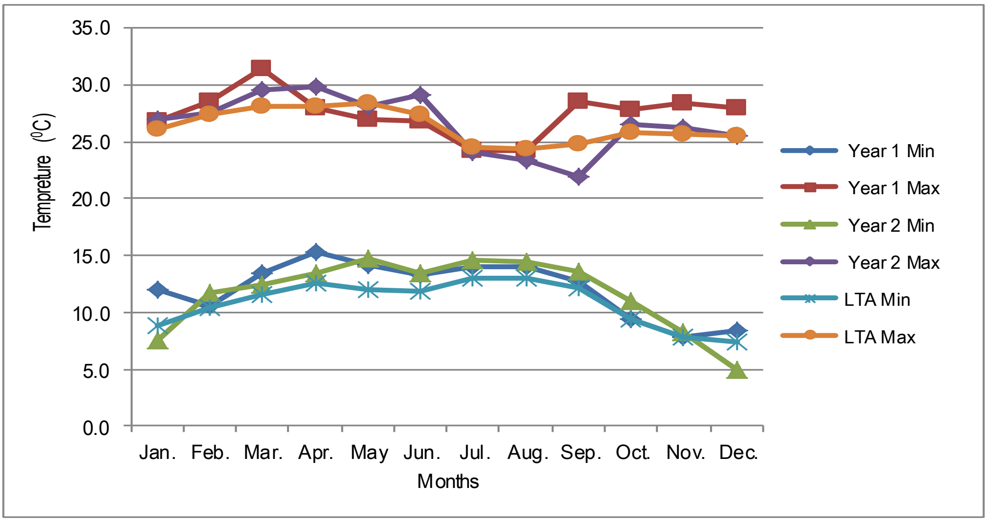
Table 1. Physico-chemical properties of the soil experimental locations (depth 0-30 cm)

Location	pH	P-Available (ppm)	Texture			Textural class	Nutrient				Soil type
			Clay (%)	Sand (%)	Silt (%)		N-Total (%)	OC (%)	OM (%)	CEC (meq/100 g soil)	
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

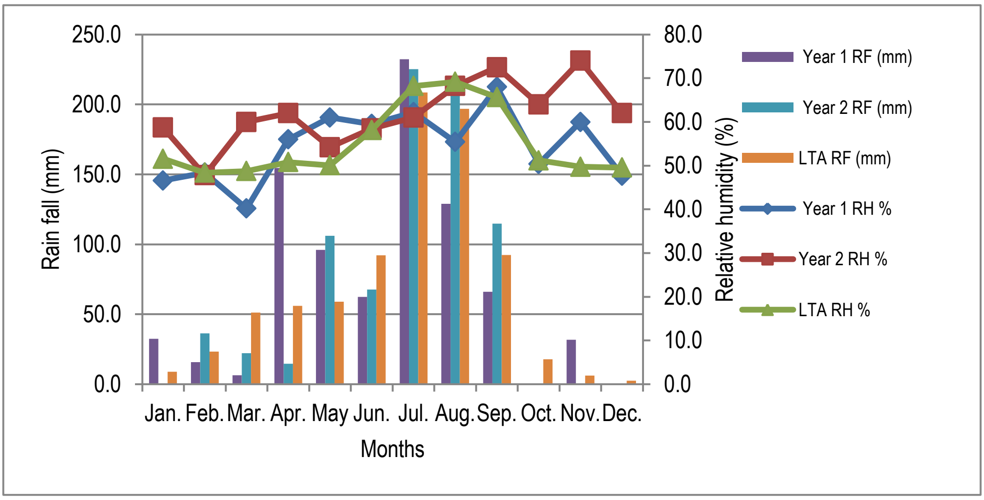


1a) Holetta

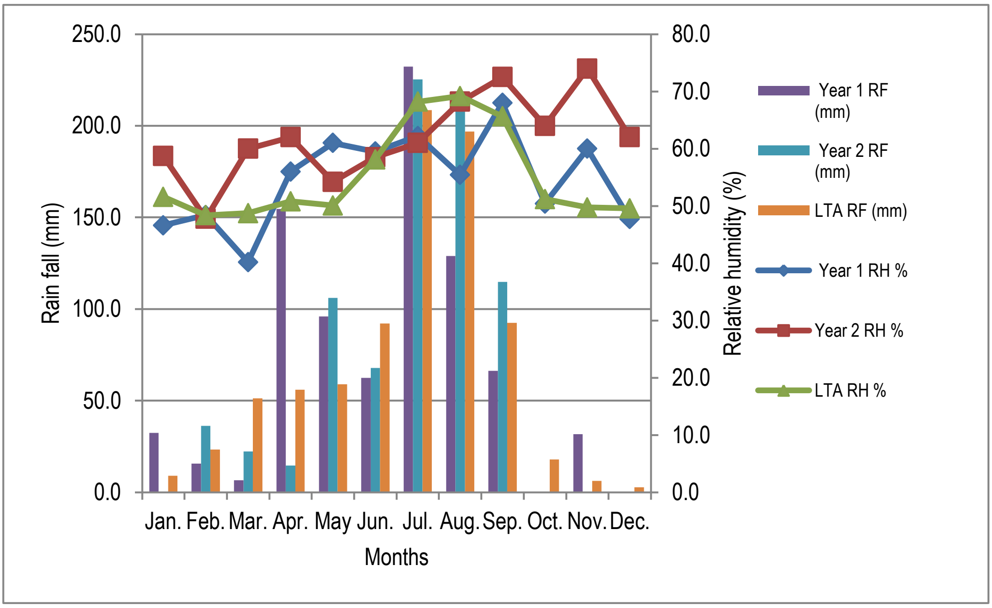


1b) Debre Zeit

Figure 1. Long-term average (LTA) (1971-2017) and during the experimental period (year 1 (2016) and year 2 (2017)) maximum and minimum air temperature (°C) at Holetta (1a) and Debre Zeit (1b)



2a) Holetta



2b) Debre Zeit

Figure 2. Long-term average (LTA) (1971-2017) and experimental period (year 1 (2016) and year 2 (2017)) total annual rainfall (mm) and mean relative humidity (%) at Holetta (2a) and Debre Zeit (2b).

Experimental design and treatments

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:

a) Three intercropping/cropping methods

1) Elephant grass (Accession No. 14984) pure stand
2) Elephant grass intercropped with vetch - *Vicia dasycarpa*
3) Elephant grass intercropped with vetch - *Vicia villosa*

b) Four planting spaces of elephant grass as described in table 2

Table 2. Description of spacing

Spacing	Inter row s pacing (cm)	Intra row spacing (cm)
S1	75	75
S2	100	50
S3	125	25
S4	50	50

Field preparation and forage establishment

The experimental field at both the locations was plowed and harrowed using a tractor mounted moldboard plow and disc harrow. Elephant grass (Accession no 14984) root splits obtained from Holetta research center were planted on 1 July 2016 and 14 July 2016 at Holetta and Debre Zeit, respectively on a plot size of 13.5 m^2 (2.25 m x 6 m). Seeds of the two vetch species (*V. dasycarpa* and *V. villossa*) were also obtained from Holetta and sown according to the treatment set up, at the rate of 25 kg/ha by broadcasting uniformly over three weeks established elephant grass plots. The vetch seeds sown were mixed with the upper soil layer using hand hoeing to facilitate germination. At both locations, fertilizer at the rate of 100 kg/ha DAP (18 kg N and 46 kg P_2O_5) was uniformly applied for all treatment plots at the time of elephant grass planting to enhance better root development. Hand weeding and hoeing were done during establishment and after every harvest of elephant grass to facilitate regrowth.

Data collection and sampling

Harvesting of elephant grass and vetch intercropping was made when the vetch reaches at a stage of 50% flowering. During harvesting of elephant grass, each plant constituted a bunch of tillers. Plant height (cm) of elephant grass and vetch species was determined by recording an average height of five randomly selected plants per plot and measured from the ground to its highest tip of the plant using a height measuring marked timber prior to harvesting. The forages were harvested about 5 to 10 cm from the ground using sickles. The fresh weight of the harvested herbage in each plot was measured using spring balance. Fresh subsamples of 900 g were taken from each plot and from each plant species, separately. Forage samples were chopped and shredded to facilitate drying. Drying was done using a forced air draft oven at 65^0C for 72 hours. Dry matter percentage was estimated by dividing the dried forage sample by the fresh sample and multiply it by hundred. The dry biomass yield (DM, t/ha) was calculated using the following formula as

$$\text{DM yield (t/ha)} = TFW \times (DWss / HA \times FWss) \times 10$$

Where; TFW = total fresh weight kg/plot, DWss = dry weight of subsample in grams, FWss = fresh weight of subsample in grams, HA = Harvest plot area in square meters and 10 is a constant for conversion of yields in kg/m^2 to t/ha.

The leaf to stem ratio (LSR) of elephant grass was determined by harvesting five randomly selected plants and partitioning into leaf and stem fractions for each plot. The fresh leaves and stems were weighed separately and dried in forced air draft oven to constant weights and proportions on dry matter basis were determined. Stand count (the bunch against to the initially planted root splits) of elephant grass (a bunch considered as one plant) per plot was taken during every harvest to determine its stand count as a percentage of the total number of plants initially planted root splits per plot (S1= 24 root splits per plot (13.5m^2), S2= 30 root splits, S3= 45 root splits and S4= 60 root splits were used).

Statistical analysis

The collected field performance data (plant height, leaf to stem ratio, number of tillers, stand count and biomass yield) were analyzed using analysis of variance (ANOVA) procedures of SAS (SAS, 2002) version 9.1. Least significance difference (LSD) at 5% significance level was used for comparison of means. The following general model was used for data analysis:

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

Results and Discussion

Agronomic performance

Overall, there were no significant interactions between the effects of the main treatment variables (vetch intercropping and plant spacing) so main effects only are presented except for leaf to stem ratio in the combined analysis over years at Holetta, over locations in year 1 and over years and locations ($P<0.05$) (Table 4).

Plant height at harvest

Elephant grass did not attain the recommended harvesting height (100.0 cm to 150.0 cm) during the establishment year (year 1 harvesting) at Holetta. This was in line with the previous reports of Fekede *et al.* (2005) and Kariuki *et al.* (2016) in elephant grass in Ethiopia and Kenya, respectively. This was expected due to its slow rate of growth during the establishment year in the cool highlands like Holetta. On the other hand, height of vetch species was higher than that of elephant grass during establishment year at Holetta. This could be due to their dominance and better competition for resources. However, in the second year (year 2 harvesting) elephant grass attained the recommended harvesting height (100.0 cm to 150.0 cm) within three months during the active growing period in the area. The mean plant height observed in the present study was in agreement with previous finding of Fekede *et al.* (2005) in the central highlands of Ethiopia. In contrast, elephant grass attained the range of recommended harvesting height during both year 1 and 2 at Debre Zeit. Unlike at Holetta, shorter plant height of vetch species was recorded in vetch intercropping at Debre Zeit during both years indicating that elephant grass better expressed its genetic potential relatively under warmer than cooler environmental conditions.

Spacing of elephant grass had no significant (P>0.05) effect on height of elephant grass except the combined analysis of vetch species height (Table 3). The present result was consistent with the finding of Genet *et al.* (2017) who reported that Desho grass spacing (10 x 50, 30 x 50, 50 x 50 cm) had no significant effect on plant height at harvest. In the present study, the mean height of elephant grass was 98.5 cm over locations and years. This figure was closely lower than the value (109.6 cm) reported by Fekede *et al*. (2005) at Holetta. The low moisture stress encountered, minimum temperature (frost) and higher maximum temperature in the establishment year of the study period might have resulted in non-significant effect of spacing on elephant grass and vetch species height except for combined analysis of vetch species over locations (Figure 1 and 2). Height of vetch intercropping at harvest was in order of increasing with a decreasing in spacing of elephant grass (S1>S2>S3>S4) in the combined analysis. It could be attributed to more competition of vetch intercropping at a lower spacing (high density) of elephant grass for light. This finding was consistent with the value reported by Taleie *et al.* (2012) who observed that taller stevia plants were achieved by the closer (lower) spacing (50×20 cm). Such an increase in plant height with increased plant density (lower spacing) might be explained by increased activity of stem growth hormone for plant sun light competition. In contrary to the present study, Mujeeb-ur-Rahman *et al.* (2007) reported that the wider spacing resulted in the tallest plant height and was due to lesser competition for nutrients, moisture, and CO_2 among the roots of the plants.

Table 3. Mean plant height (cm) of elephant grass and vetch species as affected by vetch intercropping and plant spacing (combined over years at each location)

Treatment	Holetta		Debre Zeit		Mean	
	Elephant	Vetch	Elephant	Vetch	Elephant	Vetch
Vetch Intercropping						
Pure stand Elephant G	91.1	-	103.6	-	97.3	-
Elephant G + *V. dasycarpa*	97.9	147.8	100.9	130.5	99.4	139.2
Elephant G + *V. villosa*	94.4	149.4	103.1	133.6	98.8	141.5
P-value	0.0814	0.6665	0.4436	0.5270	0.5579	0.4492
Plant Spacing (cm)						
S1 (75 x 75)	94.8	145.3	100.9	126.8	97.8	136.0^{bc}
S2 (100 x 50)	94.4	145.9	102.1	124.5	98.3	135.2^{c}
S3 (125 x 25)	93.7	147.3	106.4	141.5	100.1	144.4^{ab}
S4 (50 x 50)	94.7	156.0	100.1	135.4	97.8	145.7^{a}
Mean	94.41	148.60	102.56	132.06	98.49	140.33
SEM	0.38	0.53	0.33	0.59	0.28	0.40
CV (%)	10.97	9.08	7.57	12.50	9.69	10.85
P-value	0.9896	0.1930	0.1176	0.0577	0.7178	0.0327

a-c Means followed by different superscripts within a column are significantly different (P<0.05); Elephant G = elephant grass.

Leaf to stem ratio of elephant grass

The combined analysis showed that leaf to stem ratio (LSR) of vetch intercropping was significantly (P<0.05) different (Table 4). Higher LSR of elephant grass was recorded in vetch intercropping (*Vicia villosa* and *Vicia dasycarpa*) and the lower was recorded for pure stand elephant grass with a mean of 2.53 at Holetta. Similarly, higher LSR was recorded in vetch intercropping (*Vicia dasycarpa* and *Vicia villosa*) than pure stand elephant grass with a mean value of 1.88 at Debre Zeit. The current results were within the range values (1.13 to 4.84) reported for different elephant grass accessions in the central highlands of Ethiopia (Gezahagn *et al*., 2016) and cultivars ranged from (0.74 to 3.18) in Malaysia (Zailan *et al*., 2018). Whereas, at both locations the current mean results were higher than the figure (1.38) reported by Kawub *et al*. (2014) in elephant grass in Uganda. Higher LSR was recorded for vetch intercropping (*Vicia dasycarpa* and *Vicia villosa)* than pure stand elephant grass when combined over locations at each year. Other documented research results showed that the LSR of elephant grass can range from 1.7 to 3.1 in Thailand (Tudsri *et al*., 2002) and from 1.65 to 6.1 in Kenya (Mwendia *et al*., 2006). Results of this study were also agreed with the earlier reported ranges.

Spacing of elephant grass was significantly (P<0.05) affect the LSR of elephant grass at Debre Zeit in the combined over years (Table 4). The highest LSR was recorded at a wider spacing of S1 (75 cm * 75 cm) and the lowest was obtained at S3 (125 cm * 25 cm) when combined over years at Debre Zeit with an overall mean of 1.88. The present result was comparable with the findings of Tessema *et al.* (2003) who reported LSR of 1.91 for elephant grass planted at a spacing of 100 cm * 50 cm, but higher than the figure (1.49) reported by Taye (2004) at a spacing of 50 cm * 50 cm. There was a significant (P<0.05) effect of vetch intercropping and plant spacing interaction on LSR of elephant grass at Holetta, in year 1 and the combined analysis over years and locations with an overall mean of 2.53, 2.64 and 2.21, respectively. These results were higher than the figures reported by Tessema *et al.* (2003) and Taye (2004).Generally, the trend of LSR value was decreased for all vetch intercropping almost in order of decreasing plant spacing; at all plant spacing S1 (75 cm * 75 cm) gave the highest LSR and S3 (125 cm * 25 cm) gave the least.

Table 4. Mean leaf to stem ratio of elephant grass as affected by vetch intercropping and plant spacing (combined over years and locations)

Treatment	Holetta	Debre Zeit	Year 1	Year 2	Mean
Vetch Intercropping					
Pure stand Elephant G	2.33^{b}	1.65^{b}	2.34^{b}	1.64^{b}	1.99^{b}
Elephant G + *V. dasycarpa*	2.55^{ab}	1.95^{a}	2.68^{a}	1.86^{a}	2.25^{a}
Elephant G + *V.villosa*	2.71^{a}	2.04^{a}	2.89^{a}	1.82^{a}	2.38^{a}
P-value	0.0345	0.0005	0.0025	0.0022	0.0001
Plant Spacing (cm)					
S1 (75 x 75)	2.63	2.11^{a}	2.92	1.82	2.37^{a}
S2 (100 x 50)	2.56	1.80^{b}	2.59	1.77	2.18^{ab}
S3 (125 x 25)	2.41	1.75^{b}	2.44	1.71	2.08^{b}
S4 (50 x 50)	2.53	1.86^{b}	2.59	1.77	2.20^{ab}
Mean	2.53	1.88	2.64	1.77	2.21
SEM	0.08	0.07	0.08	0.06	0.05
CV (%)	19.66	17.85	19.53	12.38	18.41
P-value	0.6240	0.0103	0.0528	0.5082	0.0280
I*S	0.0396	0.0536	0.0164	0.3781	0.0035

*[a, b] Means followed by different superscripts within a column are significantly different (P<0.05); Elephant G = elephant grass; Year 1= 2016 harvesting; Year 2= 2017 harvesting; I= vetch intercropping; S= plant spacing; I*S= interaction of vetch intercropping and plant spacing*

Tillering performance of elephant grass

The number of tillers per plant (elephant grass) varied significantly (P< 0.05) in vetch intercropping when combined over locations for year 1 (Table 5). Comparable and higher number of tillers was recorded in *Vicia dasycarpa* and *Vicia villosa* intercropping than pure stand elephant grass. In contrast, non-significant (P> 0.05) results were reported by Fekede *et al*. (2005) in vetch intercropping. More number of elephant grass tillers was produced at Debre Zeit than Holetta in both pure stands and vetch intercropped plots. The low stand count of elephant grass at Debre Zeit as indicated in Table 6 might be accelerated componentry growth to produce more number of tillers. The mean number of tillers produced per elephant grass (Debre Zeit vs Holetta) was 44.3 vs 32.1, 47.5 vs 32.9 and 48.0 vs 32.0 for pure stand elephant grass, *Vicia dasycarpa* and *Vicia villosa* intercropping, respectively. At Debre Zeit and Holetta, the present results were higher and within the range value (26.4 to 38.2) reported by Gezahagn *et al*. (2016), respectively and higher than the value (21.3) reported by Zhang *et al*. (2010) in pure stand elephant grass. Similarly, mean tiller numbers per plant (year 2 vs year 1) was 58.3 vs 18.0, 60.6 vs 19.8 and 61.9 vs 18.6 for pure stand elephant grass, *Vicia dasycarpa* and *Vicia villosa* intercropping, respectively. Year 1 is the establishment year where plant tends to establish its root system from where tillers emerge in the subsequent growing season (Year 2) and it could be due to the perennial nature of elephant grass, which produces more number of tillers per plant and high vegetative growth, as reported by Tessema (2005). Year 1 result in this study was lower than the figure reported for elephant grass in Ethiopia (Fekede *et al*., 2005) and for Brachiaria grass in Kenya (Nguku *et al*., 2016). In year 2, about 4.0% and 6.1% number of tillers per plant (elephant grass) was produced in *Vicia dasycarpa* and *Vicia villosa* intercropping, respectively than the pure stand elephant grass. This might be due to vetch dominance during the establishment year of the grass and resulted in the death of some plants during the dry season that could be compensated by producing more number of tillers in the subsequent year (year 2). This result was in agreement with the finding of Fekede *et al*. (2005) in Ethiopia.

The number of tillers per elephant grass varied significantly (P< 0.05) at different spacing of elephant grass when combined over years at each location, combined over locations at year 2 and combined over locations and years. The highest number of tillers per elephant grass was recorded at a spacing of S1 (75 cm * 75 cm) followed by S2 (100 cm * 50 cm), S3 (125 cm * 25 cm) and the lowest were recorded at a spacing of S4 (50 cm * 50 cm) in order of decreasing at Holetta. More or less similar trends were also observed at Debre Zeit, combined over locations at year 2 and combined over locations and years. Year 2 mean number of tillers per elephant grass in the current result was higher than the value (54.3) reported by Kesang *et al.* (2015) in elephant grass hybrid and comparable with the figure (60.0) documented by Nyambati *et al.* (2010) in elephant grass. The present result was comparable with the findings of Yasin *et al*. (2003) and Zhang *et al.* (2010) who reported higher number of tillers at a higher spacing of elephant grass. It could be high competitions for nutrients, water and sunshine at a narrow (closer) spacing of elephant grass. Similarly, the highest density in the cultivation line, there is greater competition for light, spacing, moisture and nutrients of plants, reducing the stimulation of tillering during the growing period as reported by many researchers (Tessema, 2008; Wijitphan *et al*., 2009; May *et al*., 2016).

Table 5. Mean number of tillers per plant in elephant grass as affected by vetch intercropping and plant spacing (combined over years and locations)

Treatment	Holetta	Debre Zeit	Year 1	Year 2	Mean
Vetch Intercropping					
Pure stand Elephant G	32.1	44.3	18.0[b]	58.3	38.2
Elephant G + *V. dasycarpa*	32.9	47.5	19.8[a]	60.6	40.2
Elephant G+ *V. villosa*	32.4	48.0	18.6[ab]	61.9	40.2
P-value	0.7981	0.3832	0.0350	0.5285	0.3363
Plant Spacing (cm)					
S1 (75 x 75)	36.7[a]	49.2[a]	19.5	66.3[a]	42.9[a]
S2 (100 x 50)	32.5[b]	45.4[ab]	18.6	59.3[ab]	38.9[b]
S3 (125 x 25)	30.6[b]	51.5[a]	18.8	63.3[a]	41.1[ab]
S4 (50 x 50)	30.2[b]	40.4[b]	18.3	52.2[b]	35.3[c]
Mean	32.5	46.6	18.8	60.3	39.5
SEM	0.25	0.38	0.18	0.39	0.23
CV (%)	13.55	21.78	12.81	18.13	19.81
P-value	0.0001	0.0099	0.5225	0.0023	0.0006

[a-c] Means followed by different superscripts within a column are significantly different (P<0.05); Elephant G = elephant grass; Year 1= 2016 harvesting; Year 2= 2017 harvesting

Stand count of elephant grass

Stand counts of elephant grass has shown significant (P<0.05) difference due to treatment effects over years and locations (Table 6). Mean stand count (%) of pure stand elephant grass and vetch intercropping during the two years period was lower than the figure (73.4%) reported by Fekede *et al*. (2005) through the three years experimental period in Ethiopia, but higher than those values (55.6%) reported by Ramadhan *et al*. (2015) in Kenya. The stand count of elephant grass was reduced in the second year following vetch intercropping during the establishment year that may have dominated the grass and resulted in the drying out of some plants during the dry season. This was supported by a similar study in the central highlands of Ethiopia (Fekede *et al*., 2005). The effect of vetch (*Vicia dasycarpa* and *Vicia villosa)* intercropping reduced the stand count of elephant grass by 7.4 and 27.8 %, respectively as compared to the pure stand elephant over locations and years.

The stand count of elephant grass was significantly (P< 0.05) affected by spacing of elephant grass combined over years at Holetta and combined over locations and years. Comparable and higher figures were recorded at a wider spacing of S2 (100 cm * 50 cm) and S1 (75 cm * 75 cm) than S3 (125 cm * 25 cm) and S4 (50 cm * 50 cm). This could be attributed to the higher competition of plants for resources when planted at high plant density. The combined analysis has shown a stand count of 59.4 %. Tessema (2005) reported higher mean stand count of 89.9 % for different accessions of elephant grass. The low moisture stress encountered, minimum temperature (frost) and higher maximum temperature in the establishment year of the study period might have resulted in the low stand count of elephant grass (Figure 1 and 2).

Table 6. Mean stand count (%) of elephant grass as affected by vetch intercropping and plant spacing (combined over years and locations)

Treatment	Holetta	Debre Zeit	Year 1	Year 2	Mean
Vetch Intercropping					
Pure stand Elephant G	75.7[a]	55.5[a]	68.4[a]	62.8[a]	65.6[a]
Elephant G + *V. dasycarpa*	71.6[a]	50.6[a]	63.0[a]	59.2[a]	61.1[b]
Elephant G + *V. villosa*	61.4[b]	41.3[b]	54.0[b]	48.8[b]	51.4[c]
P-value	0.0001	0.0002	0.0001	0.0006	0.0001
Plant Spacing (cm)					
S1 (75 x 75)	70.5[ab]	52.0	64.4	58.1	61.2[ab]
S2 (100 x 50)	74.8[a]	50.6	65.4	60.0	62.7[a]
S3 (125 x 25)	68.3[b]	45.5	60.1	53.7	56.9[b]
S4 (50 x 50)	64.7[b]	48.6	57.3	55.8	56.6[b]
Mean	69.6	49.2	61.8	56.9	59.4
SEM	0.35	0.40	0.38	0.41	0.28
CV (%)	12.70	23.29	16.45	21.21	18.69
P-value	0.0095	0.3644	0.0730	0.4364	0.0472

[a-c] Means followed by different superscripts with in a column are significantly different (P<0.05); S1= 24 root splits of elephant grass per plot (13.5m²) planted initially; S2= 30 root splits per plot; S3= 45 root splits per plot; S4=60 root splits per plot; Elephant G = elephant grass; Year 1= 2016 harvesting; Year 2= 2017 harvesting

Herbage yield of elephant grass and vetch species

Dry matter yield (DMY) of vetch intercropping varied significantly (P<0.05) at Holetta combined over years and locations (Tables 7 and 8). The result showed that vetch intercropping gave higher DM yield than the pure stand elephant grass in both the locations over years. *Vicia villosa* intercropping gave higher DM yield at Holetta in year 1. On the other hand, *Vicia dasycarpa* intercropping gave better DM yield at Debre Zeit in year 2. Vetch intercropping gave higher overall mean DM yield at Debre Zeit than Holetta. Year of harvesting was also affected the DM yield of vetch intercropping and the overall mean DM yields were 8.03 and 14.39 t/ha for year 1 and 2, respectively. Generally, at Holetta intercropping *Vicia dasycarpa* and *Vicia villosa* gave 67.1 and 72.9 % more DM yield advantages than the pure stand elephant grass, respectively. Similarly, at Debre Zeit, intercropping *Vicia dasycarpa* and *Vicia villosa* gave 11.0 and 6.0 % more DMY than the pure stand elephant grass, respectively. This could be due to nitrogen accretion from the vetch to the grass through nitrogen fixation (Tessema and Baars, 2006). This shows vetch intercropping could be more advantageous in the cooler areas like Holetta where elephant grass requires more time for establishment and fodder production. In vetch intercropping treatment the dry matter yield (DMY) of vetch species was significantly (P<0.05) varied over years and locations (Table 8). The DMY of *Vicia villosa* was significant and higher than *Vicia dasycarpa.*

Combined analysis over locations and years also indicated that vetch intercropping gave higher DM yield than the pure stand elephant grass. The DM yield of pure stand elephant grass (9.47 t/ ha) was in line with the value (9.2 t/ha) reported earlier by ILRI, (2010). It was also shown that intercropping *Vicia dasycarpa* and *Vicia villosa* had more DM yield advantages of 28.4 and 26.8 % over the pure stand elephant grass, respectively. A considerable variation in terms of DM yield was observed among vetch intercropping and the pure stand elephant grass, which was in agreement with other findings (Fekede *et al*., 2005; Samuel *et al*., 2015). Combined analysis of vetch intercropping and pure stand elephant grass in the current study was also closer and within the range values (10 to 15 DM t/ ha/year) reported for pure stand elephant grass under rain fed conditions at Holetta (Seyoum *et al*., 1998).

Dry matter yield of pure stand elephant grass and vetch intercropping varied significantly (P<0.05) at different spacing of elephant grass (Table 7). Total dry matter yield of pure stand elephant grass and vetch intercropping was increased with plant density at Debre Zeit and year 1. The combined analysis has also showed a similar trend in dry matter yield. Furthermore, S4 (50 cm * 50 cm) at narrower (lower) spacing of elephant grass resulted in 17.6, 22.8 and 25.6 % more DM yield advantage over S3 (125 * 25), S2 (100 cm * 50 cm) and S1 (75 cm* 75 cm), respectively. These could be attributed to greater number of plants per unit area (higher density of plants). Similarly, Wijitphan *et al.* (2009) indicated that there were significant effects of spacing of pure stand elephant grass (50 cm * 80 cm) on total DM yields. Dry matter yield differences observed among the tested spacing of elephant grass were in agreement with the findings of Muhammad *et al.* (2003) and Geren *et al.* (2015) who reported higher herbage yield at the lower spacing of pure stand elephant grass (45 cm * 45 cm) in Pakistan and giant king grass (70 cm * 50 cm) in Turkey, respectively. In contrast, Genet *et al.* (2017) reported that plant spacing (10 * 50, 30 * 50 and 50 * 50 cm) had no significant effect (P>0.05) on DM yield of Desho grass in northwestern highlands of Ethiopia. The overall mean DM yield recorded in this study was within the range values reported by Gezahagn *et al.* (2016; 2017) in which DM yields of different elephant grass accessions was ranged from 7.05 to 13.06 t/ha at 100 cm * 50 cm spacing of elephant grass in Ethiopia. The combined analysis of overall mean DM yield (11.22 t/ha) in the current study was also comparable with the findings of Gezahagn *et al.* (2016) who reported 11.04 t/ha at 100 cm * 50 cm spacing of elephant grass. Generally, pure stand elephant grass and vetch intercropping combined over years gave higher DM yield at Debre Zeit than Holetta. This could be associated with the warm weather condition which supports fast growth and higher DM production of elephant grass.

Table 7. Mean annual herbage dry matter yield (t/ha) of elephant grass + vetch species as affected by vetch intercropping and plant spacing (combined over years and locations)

Treatment	Location		Year		Mean
	Holetta	Debre Zeit	Year 1	Year 2	
Vetch Intercropping					
Pure stand Elephant G	5.90[b]	13.03	6.14[b]	12.78[b]	9.47[b]
Elephant G + *V. dasycarpa**	9.86[a] (35.0)	14.46 (29.8)	8.58[a] (56.2)	15.74[a] (2.3)	12.16[a] (21.3)
Elephant G + *V. villosa**	10.20[a] (42.3)	13.81 (17.5)	9.37[a] (66.9)	14.64[ab] (3.2)	12.01[a] (28.1)
P-value	0.0001	0.4111	0.0001	0.0374	0.0001
Plant Spacing (cm)					
S1 (75 x 75)	8.46 (45.4)	12.17[b] (19.6)	7.00[c] (83.1)	13.63 (3.0)	10.32[b] (30.1)
S2 (100 x 50)	7.98 (45.0)	13.12[b] (16.2)	7.29[c] (72.0)	13.81 (3.4)	10.55[b] (27.1)
S3 (125 x 25)	8.35 (44.8)	13.68[ab] (12.9)	8.41[b] (60.4)	13.62 (3.0)	11.02[b] (25.0)
S4 (50 x 50)	9.84 (45.9)	16.09[a] (12.7)	9.43[a] (64.1)	16.50 (2.2)	12.96[a] (24.7)
Mean	8.66	13.77	8.03	14.39	11.22
SEM	0.17	0.23	0.14	0.23	0.14
CV (%)	25.2	26.79	18.38	26.97	26.06
P-value	0.0668	0.0163	0.0001	0.0827	0.0008

[a-c] *Means followed by different superscripts within a column are significantly different (P<0.05); *Figures in parenthesis are percentage of vetch species DMY from the total DMY (Elephant grass + Vetch species); Elephant G = elephant grass ; Year 1= 2016 harvesting; Year 2= 2017 harvesting; SEM-standard error of the mean; CV- coefficient of variation.*

Table 8. Mean annual herbage dry matter yield (t/ha) of vetch species (legumes) as affected by vetch intercropping and plant spacing (combined over years and locations)

Treatment	Location		Year		Mean
	Holetta	Debre Zeit	Year 1	Year 2	
Vetch Intercropping					
Pure stand Elephant G.	-	-	-	-	-
Elephant G + *V. dasycarpa*	3.45[b]	1.74[b]	4.83[b]	0.36[b]	2.59[b]
Elephant G + *V. villosa*	4.31[a]	2.42[a]	6.27[a]	0.47[a]	3.37[a]
P-value	0.0024	0.0011	0.0001	0.0008	0.0001
Plant Spacing (cm)					
S1 (75 x 75)	3.84	2.39	5.82	0.41	3.11
S2 (100 x 50)	3.59	2.13	5.25	0.47	2.86
S3 (125 x 25)	3.74	1.76	5.08	0.41	2.75
S4 (50 x 50)	4.35	2.05	6.04	0.36	3.20
Mean	3.88	2.08	5.55	0.41	2.98
SEM	0.14	0.12	0.14	0.05	0.12
CV (%)	23.86	32.48	16.76	25.55	22.58
P-value	0.2199	0.1658	0.0523	0.1032	0.0778

[a, b] *Means followed by different superscripts with in a column are significantly different (P<0.05); Elephant G = elephant grass; Year 1= 2016 harvesting; Year 2= 2017 harvesting*

Conclusions

The experiment showed that vetch intercropping with elephant grass at different inter and intra row spacing in the year of establishment responded differently for most measured agronomic traits and herbage yield of elephant grass over the testing locations and years. Higher herbage yield of elephant grass was recorded at Debre Zeit than at Holetta, indicating that elephant grass better expressed its genetic potential relatively under warmer than cooler environmental conditions. Vetch intercropping with elephant grass resulted 70.0 and 8.5% herbage dry matter yield advantage than the pure stand elephant grass at Holetta and Debre Zeit, respectively when planted using S4 (50 cm * 50 cm) spacing of elephant grass. This indicates that vetch intercropping during the establishment year of the grass could be an ideal means to produce significant amount of forage per unit area of land due to the added effect of the legumes (vetch species) in the central highlands where perennial grasses including elephant grass are slow to establish and produce very low amount of forage. In general, *Vicia dasycarpa and Vicia villosa* intercropping (at a seed rate of 25 kg/ha) three weeks after elephant grass establishment at a spacing of 50 cm * 50 cm (between rows and plants) has resulted in higher annual herbage productivity in the tested locations, and hence advisable to be adopted by farmers who grow elephant grass in pure stands as livestock feed.

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References

Akman H, A Tamkoc, and A Topal. 2013. Effects on yield, yellow berry and black point disease of fertilization applications in Hungarian vetch and durum wheat intercropping system. Digital Proceeding of the ICOEST'2013, Cappadocia, June, 18-21, Nevsehir, Turkey.839-847.

Bilal MQ, M Saeed, and M Sarwar. 2000. Effect of varying levels of nitrogen and farm yard manure application on tillering and height of Mott grass. *International Journal of Agriculture and Biology* 2: 21-23.

Chaparro CJ, LE Sollenberger, and LE Jones Jr. 1996. Defoliation effects on 'Mott' elephant grass productivity and leaf percentage. *Agronomy Journal* 87: 981-985.

Coll LA, R Cerrudo, J Rizzalli, P Monzon, and FH Andrade. 2012. Capture and use of water and radiation in summer intercrops in the southeast Pampas of Argentina. *Field Crops Research* 134: 105-113.

Cuomo GJ, DC Blouin and JE Beatty. 1996. Forage potential of dwarf Napier grass and a pearl millet x Napier grass hybrid. *Agronomy Journal* 88: 434-438.

Devendra C and RA Leng. 2011. Feed resources for animals in Asia: issues, strategies for use, intensification and integration for increased productivity. *Asian-Australasian Journal of Animal Science* 24: 303–321.

Fekede Feyissa, Getnet Assefa, Lulseged G/Hiwot, Muluneh Minta, and Tadesse T/Tsadik. 2005. Evaluation of Napier grass-vetch mixture to improve total herbage yield in the central highlands. In: Proceedings of the 13th annual conference of the Ethiopian Society of Animal Production (ESAP), August 25 – 27, 2004. Addis Ababa, Ethiopia.

Genet Tilahun, Bimrew Asmare and Yeshambel Mekuriaw. 2017. Effects of harvesting age and spacing on plant characteristics, chemical composition and yield of desho grass (*Pennisetum pedicellatum Trin*.) in the highlands of Ethiopia. *Tropical Grasslands-Forrajes Tropicales* 5(2):77–84.

Geren H and YT Kavut. 2015. Effect of different plant densities on the yield and some silage quality characteristics of giant king grass (*Pennisetum hybridum*) under mediterranean climatic conditions. *Turkish Journal of Field Crops* 20 (1): 85-91.

Getnet Assefa and Gezahagn Kebede. 2012. Seed Research and Development of Perennial Forage Crops in the Central Highlands. In: Getnet Assefa, Mesfin Dejene, Jean Hanson, Getachew Anemut, Solomon Mengistu & Alemayehu Mengistu (eds.). Forage Seed Research and Development in Ethiopia. Proceedings of workshop held on 12-14 May, 2011 at EIAR, Addis Ababa, Ethiopia. ISBN: 978-99944-53-84-9.

Getnet Assefa. 2007. Evaluation of Tagasaste (*Chamaecytisus palmensis*) as forage for ruminants. Humboldt University of Berlin, PhD dissertation, Report 75-100, Germany.

Gezahagn Kebede, Fekede Feyissa, Getnet Assefa, Mengistu Alemayehu, Alemayehu Mengistu, Aemiro Kehaliew, Kassahun Melese, Solomon Mengistu, Estifanos Tadesse, Shewangizaw Wolde and MergiaAbera. 2017. Agronomic performance, dry matter yield stability and herbage quality of Napier grass (*Pennisetum purpureum(L.)* Schumach) accessions in different agro-ecological zones of Ethiopia. *Journal of Agricultural and Crop Research* 5(4): 49-65.

Gezahagn Kebede, Fekede Feyissa, Getnet Assefa, Mengistu Alemayehu, Alemayehu Mengistu, Aemiro Kehaliew, Kassahun Melese, Solomon Mengistu, Estifanos Tadesse, Shewangizaw Wolde and Mergia Abera. 2016. Evaluation of Napier Grass (*Pennisetum purpureum(L.)* Schumach) Accessions for Agronomic Traits under Different Environmental Conditions of Ethiopia. *International Journal of Advanced Research* 4 (4): 1029-1035.

HARC (Holetta Agricultural Research Center). 2003. Annual progress report. Addis Ababa, Ethiopia.

Iannetta PP, M Young, J Bachinger, G Bergkvist, J Doltra, and RJ Lopez-Bellido. 2016. A comparative nitrogen balance and productivity analysis of legume and non-legume supported cropping systems: the potential role of biological nitrogen fixation. Front. Plant Science 7:1700. doi: 10.3389/fpls. 2016. 01700

ILRI (International Livestock Research Institute). 2010. Napier or elephant grass ILRI 14984 (*Pennisetum purpureum*) for livestock feed on small-scale farms. Information leaflet on livestock feeds and feeding technologies for small-scale farmers. Fodder Adoption Project fodder adoption.wordpress.com.

Kariuki IW, SW Mwendia, FN Muyekho, SI Ajanga, and DO Omayio. 2016. Biomass production and forage quality of head-smut disease Resistant napier grass accession. *African Crop Science Journal* 24:157 – 165.

Kawube G, T Alicai, M Otim, A Mukwaya, J Kabirizi, and H Talwana. 2014. Resistance of napier grass clones to napier grass stunt disease. *African Crop Science Journal* 22 (3): 229 – 235.

Kechero Y. 2008. Effect of Seed Proportions of Rhodes grass (*Chloris gayana*) and White sweet clover (*Melilotus alba*) at sowing on agronomic characteristics and nutritional quality. Livestock Research for Rural Development 20 (2) Retrieved May 19, 2019.

Kesang W, R Krishna, N Harilal, T Thuk, D Chhoyten, and M Durba. 2015. Forage growth, yield and quality responses of Napier hybrid grass cultivars to three cutting intervals in the Himalayan foothills .*Tropical Grasslands – Forrajes Tropicales* 3: 142−150.

Koc A, S Erkovan, HI Erkovan, U Oz Birben, MM, and R Tunc. 2013. Competitive effects of plant species under different sowing ratios in some annual cereal and legume mixtures. *Journal of Animal and Veterinary Advances* 12(4):509-520.

May A, VF Souza, GA Gravina, and PG Fernandes. 2016. Plant population and row spacing on biomass sorghum yield performance. *Crop Production* 46 (3):434-439.

Muhammad Yasin, M Asghar Malik, and M Shafi Nazir. 2003. Plant Spacing cum Nitrogen Management Effects on Forage Yield of Motto Elephant grass. *Pakistan Journal of Agronomy* 2(1): 13-19.

Mujeeb-ur-Rahman, M Iqbal, MS. Jilani, and K Waseen. 2007. Effect of different plant spacing on the production of cauliflower (*Brassica oleracae* var.Botrytis*)* under agro climatic conditions of DI Khan. *Pakistan Journal of Biological Sciences* 10: 4531-4534.

Mwangi DM and W Thorpe. 2002. The effect of establishing Desmodium intortum and Macrotyloma axillarefrom vines or seeds on dry matter yield of a Napier grass/legumes mixture. *In:* Mukisira, EA, Kiriro, FH., Wamuongo, JW Wamae, LW, Mureithi FM. and Wasike, W. (eds.) Collaborative and participatory research for sustainability improved livelihoods. Proceedings of the 7thKARI biennial scientific conference, 13 - 17 November 2000, KARI HQs, Nairobi. Kenya. pp. 13-17.

Mwendia SW, M Wanyoike, JGM Nguguna, RG Wahome, and DM Mwangi. 2006. Evaluation of Napier grass cultivars for resistance to Napier head smut. Proceedings of the 10th KARI Biennial Scientific Conference, KARI, Nairobi, Kenya, pp 85-97.

Nguku SA, DN Njarui, NKR Musimba, D Amwata, and EM Kaindi. 2016. Primary Production Variables of Brachiaria Grass Cultivars in Kenya Dry lands, Tropical and Subtropical. *Agro ecosystems* 19 (1): 29-39.

Nyambati EM, FN Muyekho, E Onginjo, and CM Lusweti. 2010. Production, characterization and nutritional quality of napier grass [*Pennisetum purpureum* (Schum.)] cultivars in Western Kenya. *African Journal of Plant Science* 4: 496–502.

Preissel S, M Reckling, N Schläfke, and P Zander. 2015. Magnitude and farm economic value of grain legume pre-crop benefits in Europe: a review. *Field Crops Research* 175: 64–79.

Ramadhan A, MN Njunie, and KK Lewa. 2015. Effect of Planting Material and Variety on Productivity and Survival of Napier Grass (*Pennisetum purpureum* schumach) in the Coastal Lowlands of Kenya. *East African Agricultural and Forestry Journal* 81(1): 40-45.

Samuel Menbere, Mesfin Dejene and Solomon Abreha. 2015. Dry Matter Yield and Agronomic Performance of Herbaceous Legumes Intercropped with Napier Grass (*Pennisetum purpureum*) in the Semi-Arid Areas of Eastern Amhara Region. *International Journal of Recent Research in Life Sciences* (IJRRLS) 2(1):7-14.

Sanh MV, H Wiktorsson, and LV Ly. 2002. Effects of natural grass forage to concentrate ratios and feeding principles on milk production and performance of crossbred lactating cows. *Asian- Australian Journal of Animal Sciences* 15 (5): 650-657.

SAS (Statistical Analysis System). 2002. SAS Institute Inc., Version 9.1, Cary, NC, USA.

Seyoum Bediye, Zinashi Sileshi, Tadesse TekileTsadik and Liyusew Ayalew. 1998. Evaluation of Napier (*Pennisetum purpureum*) and Pennisetum hybrids (*Pennisetum purpureumx pennisetum typhoides*) in the central highlands of Ethiopia. Proceedings of the 5th National Conference of the Ethiopian Society of Animal Production (ESAP), May 14-17, 1997. Addis Ababa, Ethiopia, pp. 194-202.

Taleie N, Y Hamidoghli, B Rabiei, and S. Hamidoghli. 2012. Effects of plant density and transplanting date on herbage, stevioside, phenol and flavonoid yield of Stevia rebaudiana Bertoni. International Journal of Agriculture and Crop Sciences 4 (6): 298-302.

Tessema Zewdu, RMT. Baars, Alemu Yami and N Dawit. 2003. Effect of plant height at cutting and fertilizer on growth of Napier grass (*Pennisetum purpureum* (L.) Schumach.) *Tropical science* 43: 57-61.

Tessema Zewidu and RMT Baars. 2006. Chemical composition, dry matter production and yield dynamics of tropical grasses mixed with perennial forage legumes. *Tropical Grasslands* 40:150 –156.

Tessema Zewidu. 2005. Variation in growth, yield, chemical composition and in vitro dry matter digestibility of Napier grass accessions (*Pennisetum purpureum*). *Tropical Science* 45: 93-99.

Tessema Zewidu. 2008. Effect of plant density on morphological characteristics, yield and chemical composition of Napier grass (*Pennisetum purpureum*(L.) Schumach). *East African Journal of Sciences* 2:55-61.

Tudsri S, ST Jorgensen, P Riddach, and A Pookpakdi. 2002. Effect of cutting height and dry season date on yield and quality of five Napier grass cultivars in Thailand. *Tropical Grasslands* 36: 248-252.

Wijitphan S, P Lorwilai, and C Arkaseang. 2009. Effects of plant spacing on yields and nutritive values of Napier grass (*Pennisetum purpureum* Schum.) under intensive management of nitrogen fertilizer and irrigation. *Pakistan Journal of Nutrition* 8(8):1240-1243.

Yasin M, M Asghar Malik and M Shafi Nazir. 2003. Effect of different spatial arrangement on forage yield, yield components and quality of Mott Elephant grass. *Pakistan Journal of Agronomy* 2: 52-58.

Zailan MZ, H Yaakub, and S Jusoh. 2018. Yield and nutritive quality of Napier (*Pennisetum purpureum*) cultivars as fresh and ensiled fodder. *The Journal of Animal & Plant Sciences* 28(1):63-72.

Zhang, X, H Gu, C Ding, X Zhong, J Zhang, and N Xu. 2010. Path coefficient and cluster analyses of yield and morphological traits in *Pennisetum purpureum*. *Tropical Grasslands* 44:95–102.