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# YIELD, YIELD DYNAMICS AND NUTRITIONAL QUALITY OF GRASS-LEGUME MIXED PASTURE

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## ABSTRACT

The shortage of quality feed is a major constraint affecting livestock production in eastern parts of Ethiopia. However, the development of grass-legume mixed pasture is an alternative strategy to improve feed resources availability both in quantity and quality since forage quality and seasonal distribution of dry matter (DM) production of grass-legume mixed sward is higher compared to those grasses or forage legumes grown in pure-stands. Therefore, we studied the DM yield, competition function and chemical composition of grass-legume mixtures in a randomized complete block design with 3 replications during 2008 and 2009 cropping seasons. *Chloris gayana, Panicum coloratum, Melilotus alba* and *Medicago sativa* were planted as pure-stand and in mixtures using 50:50, 67:33, 33:67, 75:25 and 25:75 seed rate proportions of grasses and legumes, respectively. *C. gayana* mixed with *M. alba* at seed rate of 50:50 and 33:67 had a higher DM yield [27 and 26 t ha$^{-1}$, respectively] than other mixtures and pure-stands. The relative total yields of all grass/legume mixtures were greater than unity, indicating that the DM yields of the mixtures were higher than those of the pure-stands. Pure-stand legumes and their mixtures with grasses had a higher crude protein contentsthan pure-stand grasses, whereas pure-stand grasses had a higher fiber fraction contents compared to pure-stand legumes and their mixture with grasses. To alleviate the feed shortage, *C. gayana* mixed with *M. alba* at seed rates of 50:50 and 33:67 can be introduced under smallholder livestock production conditions in eastern parts of Ethiopia.

**Key words:** crude protein; feed shortage; fiber fraction; mixed farming; nutritive value.

## INTRODUCTION

Livestock production is an integral part of the agricultural activities in Ethiopia. The livestock sector provides 12-16% of the total gross domestic product (GDP) and 30-35% of the agricultural GDP in the country (Ayele *et al.,* 2002; EEA, 2002). Moreover, livestock contributes about 60-70% of the livelihoods of the Ethiopian population (Tessema *et al.,* 2010a). However, the productivity of the livestock subsector in Ethiopia is low due to feed shortage (Tessema *et al.,* 2010b). Both undernutrition and malnutrition are major constraints for livestock production in most parts of Ethiopia (Tessema *et al*., 2010a, b). The main feed resources in the country are natural pasture and crop residues, which are not adequate to satisfy the nutritional requirements (Manaye *et al*., 2009).

However, the development of grass-legume mixed pasture is an alternative strategy to improve feed resourcesavailability both in quantity and quality (Diriba and Diriba, 2013). Forage quality and seasonal distribution of dry matter (DM) production of grass-legume mixed sward has been found superior than those of grasses or legumes grown alone (Tessema and Baars, 2006). Moreover, the emphasis under smallholder crop-livestock systems should focus on low-input and sustainable strategies of feed development. Accordingly, grass-legume mixture based forage development provides better land use efficiency than the respective monoculture without an additional investment (Cinar *et al*., 2011). Therefore, a grass-legume mixed pasture could play an important role in improving both the quantity and quality of forage without additional organic and/or inorganic fertilizer applications compared to pure-stands (Diriba and Diriba, 2013). Thus, a grass-legume mixed pasture provides advantages over monocultures. Moreover, it reduces bloat from forage legumes and incidence of crop diseases and insect pests, as well as controls soil erosion (Casler, 1988).

The adaptability and DM production of promising perennial grasses and herbaceous legumes were evaluated in pure-stands in the eastern parts of Ethiopia (Berhan, 2006). However, the DM yield production and nutritional quality of grass-legume mixed pasture largely dependson the compatibility of the grass and legume species and their relative proportion in the mixed swards (Diriba and Diriba, 2013). This is because a low seed rate in the mixture may result in poor stand and low DM yield; whereas a high seed rate in the mixed pasture may not be economical for smallholder livestock producers due to high cost of forage seeds (Tessema and Baars, 2006). According to previous studies (Lemma *et al.,* 1991; Diriba, 2002) a progressive increase in the contribution of the legume component to the total DM yield has been reported compared to the grass component as the seed rate of the legume increases in the mixture. Moreover, combining both the DM yield and nutritional quality of feeds under smallholder livestock production systems could be possible by growing perennial grass-legume mixed pastures with compatible grass and legume species (Baba *et al.,* 2011; Ahmad *et al.,* 2016) using appropriate seed rate proportion of each component (Larbi *et al.,* 1995; Tessema and Baars, 2006). Although, grass-legume mixed pasture is known to be superior in sustaining seasonal DM yield production and increase nutritional quality of the sward, information is either minimal or lacking in the eastern parts of Ethiopia. Therefore, the objective of this studywas to determine the effects of different seed rate proportions on DM yield production, competition function and nutritional quality of pure-stand grassesand herbaceous legumes and their mixtures at Haramaya University in the eastern part of Ethiopia.

# MATERIALS AND METHODS

**Description of the study area:** A grass-legume experiment was conducted during 2008 and 2009 cropping seasons at Haramaya University Research Centre (9° 26' N Latitude and 42° 03' E Longitude; 1980 m above sea level), 511 km from Addis Ababa on alluvial-vertisols (Berhan, 2006). The 0-40 cm layer of the soil before sowing and fertiliser application had a pH of 6.34, total N of 0.16, available phosphorus of 0.66 ppm, organic matter of 2.28% and organic carbon of 1.33% (Tessema, 2008). The twenty years mean annual rainfall of the area is 625 mm and the average annual air temperatures were 20.2°C. The rainy season during the study were extended from May-October with a peak during July-September. The monthly rainfall and the minimum and maximum air temperatures during the study period are presented in Figure 1a and 1b.

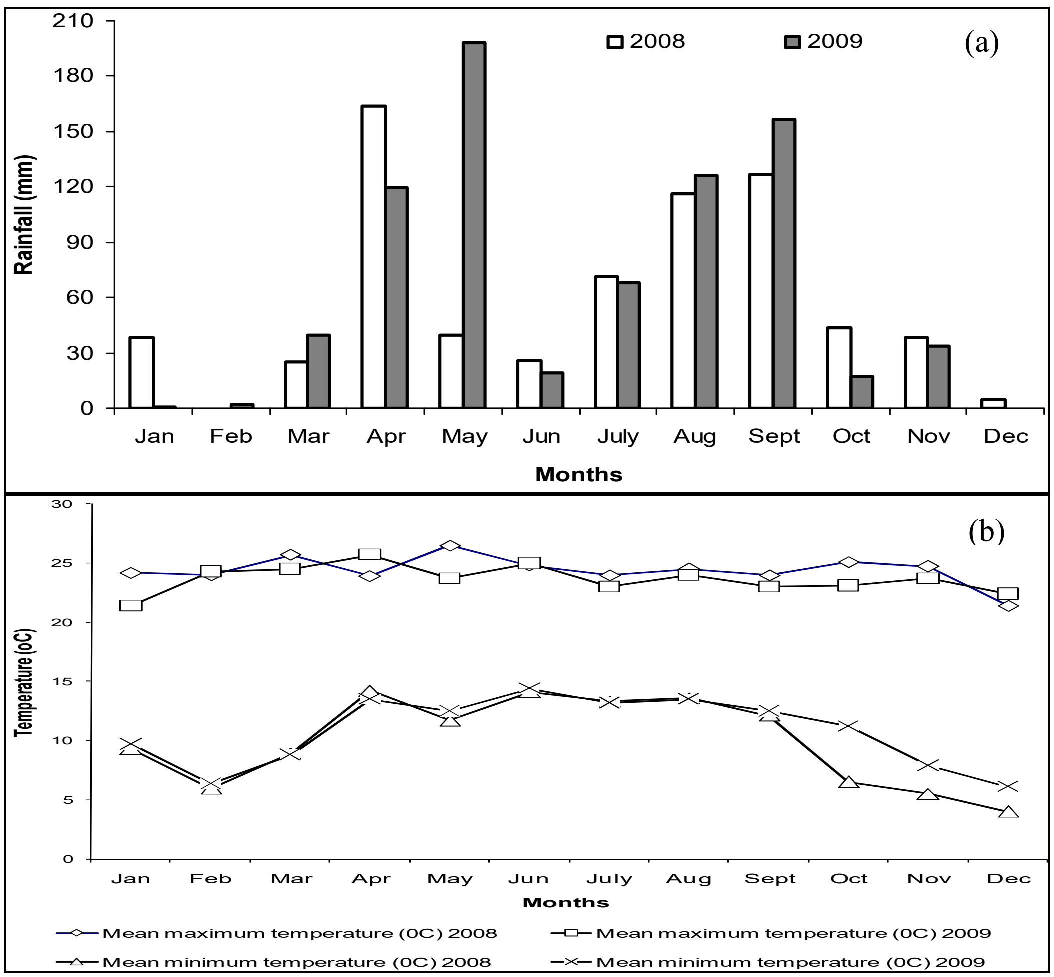


**Fig. 1. Monthly rainfall (1a) and maximum and minimum temperatures (1b) during the study periods at Haramaya University in the eastern part of Ethiopia**

**Experimental design and treatments:** The experiment was conducted in a randomized complete block design with 3 replications and the treatments were 2 grass species (*Chloris gayana* and *Panicum coloratum) and* 2 forage legumes *(Melilotus alba* and *Medicago sativa)* grown in pure-stands and in mixtures using a seed rate proportions of 50:50, 67:33, 33:67, 75:25 and 25:75 of the grass and legume component, respectively. Spacing between replications and plots were 2 and 1 m, respectively. Inclusion of pure-stand grasses and legumes were maintained as a control to compare the DM yield and chemical compositions with the mixturesat various seeds rates.The forage species were planted on 26 July 2008 and data on DM yield was collected for two years until 29 October 2009. Seeds of grasses and legumes were weighed, then thoroughly mixed and row planted at a spacing of 20 cm interval on 2 x 4.5 m plots. A seed rate of 10 kg $ha^{-1}$ was used for all the pure-stand grasses, forage legumes and including their mixtures. Seeding rate for each mixture was calculated according to the seed rate proportion of both grasses and legumes**.**Diammonium phosphate (DAP) fertiliser was applied at planting at rate of 100 kg $ha^{-1}$ in all treatments, and 50 kg $ha^{-1}$ nitrogen fertiliser in the form of urea was applied after establishment for pasture plots receiving only grass species according to pervious recommendations (IAR, 1988). Maize crop was planted on the experimental site in the previous year before this study. Then, the experimental site was properly cultivated with draft oxen and fine seed bed was prepared manually before seeding the grass-legume mixtures.

**Data collection and analytical procedures:** Pure-stand grass and legume species were harvested at about 5cm above the ground at 50 and 100% flowering, respectively while the grass-legume mixtures were harvested when at least one of the component of the mixture had reached 50% flowering based on continuous visual observations of each component in the mixture (Tessema and Baars, 2006). Immediately after harvesting the pasture in each plot, a representative sample of 500g of fresh forage sample was taken for DM yield determination by drying in an oven at 70ºC for 48 h and weighing until constant weight (ILCA, 1990). The DM yield was calculated using the following formula as DMY kg $ha^{-1}$ = (Tot FW x (DWss/FWss) x 10 (Tarawali *et al*., 1995), where Tot FW is the total fresh weight, DWss is dry weight of the subsample and FWss is fresh weight subsample, and the final DM yield is reported in tone per hectare (t $ha^{1}$).

The relative DM yields (RY) of the components in the mixtures were calculated using the equations of De Wit (1960):

$$RY_{GL} = DMY_{GL}/DMY_{GG} \quad (1)$$

$$RY_{LG} = DMY_{LG}/DMY_{LL} \quad (2)$$

where $DMY_{GG}$ is the DM yield of any perennial grass 'G' as a monoculture; $DMY_{LL}$ is the DM yield of any perennial legume 'L' as a monoculture; $DMY_{GL}$ is the dry matter yield of any perennial grass component 'G' grown in mixture with any perennial legume 'L' and $DMY_{LG}$ is the DM yield of any perennial legume component 'L' grown in mixture with any perennial grass 'G'.

Relative total yield (RYT) was calculated according to the formula of De Wit (1960): $RYT_{GL}$ = $(DMY_{GL}/DMY_{GG}) + (DMY_{LG}/DMY_{LL})$ (3)

The relative crowding coefficient (RCC) of the perennial grass-legume mixtures was calculated to determine the competitive ability of the grass and legume in the mixture to measure whether that component has produced less or more DM yield than expected in a 50:50 perennial grass-legume mixture, according to De Wit (1960):

$$RCC_{GL} = DMY_{GL}/ (DMY_{GG} – DMY_{GL}) \quad (4)$$

$$RCC_{LG} = DMY_{LG}/ (DMY_{LL} – DMY_{LG}) \quad (5)$$

For mixtures different from 50:50, RCC was calculated as:

$$RCC_{GL} = DMY_{GL} \times Zba/ (DMY_{GG} – DMY_{GL} \times Zab) \quad (6)$$

$$RCC_{LG} = DMY_{LG} \times Zab/ (DMY_{LL} – DMY_{LG} \times Zba) \quad (7)$$

where Zab is the seed rate proportion of the grass component and Zba is the seed rate proportion of the legume component in grass-legume mixture.

The dominance or aggressive ability of the perennial grasses against the perennial legumes in different seed rate mixtures was described by calculating the aggressivity index (AI) as indicated by McGilchrist (1965) and McGilchrist and Trenbath (1971):

$$AI_{GL} = (DMY_{GL}/DMY_{GG}) – (DMY_{LG}/DMY_{LL}) \quad (8)$$

For any replacement treatment other than 50:50, AI was calculated as:

$$AI_{GL} = (DMY_{GL}/DMY_{GG} \times Zab) – (DMY_{LG}/DMY_{LL} \times Zba) \quad (9)$$

$$AI_{LG} = (DMY_{LG}/DMY_{LL} \times Zba) – (DMY_{GL}/DMY_{GG} \times Zab) \quad (10)$$

After oven drying the fresh samples, representative thorough subsamples (250g) were taken from all the treatmentsfor chemical analyses. Dried samples were ground to pass a 1 mm sieve and stored in airtight containers until chemical analyses. Total ash was determined by igniting at 550ºC overnight, DM was determined by drying at 105ºC overnight (AOAC, 1990) and nitrogen (N) by auto-analyser (Chemlab, 1984). Crude protein (CP) was calculated as N x 6.25 and organic matter (OM) as DM - TA. Neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were determined according to van Soest *et al.* (1991). Hemicellulose and cellulose were calculated as NDF-ADF and ADF-ADL, respectively. All chemical analyses were done in duplicate to increase the precision of the results.

**Statistical analyses:** Analysis of variance (ANOVA) was carried out using the Generalized Linear Model (GLM) procedures using SPSS statistical package (version 16.0) for DM yield, RY, RTY, RCC, AI and chemical composition applied to a randomised complete block design. Proportional data were arcsine transformed to meet the assumption of normality and homogeneity of variance prior to carrying out the ANOVA. Mean separation was done using the Tukey–HSD test at P≤0.05.

## RESULTS

**Dry matter yield:** The DM yield of pure-stand grasses were higher than pure-stand forage legumes maintained as a control throughout the study. In the first year of pasture establishment, *C. gayana* and *M. alba* had a higher DM yield than all the grass-legume mixed pastures with 12 and 10.8 t $ha^{-1}$, respectively (Table 1). Among the pure-stands, *C. gayana* had a higher DM yield than other pure-stand pastures both in the first and second year of the pasture. The DM yield of the pure-stand grasses and forage legumes increased as the pasture period increased.

There was a significant (P<0.05) effect on the DM yield of the grass and legume components in the mixed pasture due to seed rate proportions in the present study (Table 1). Moreover, the grass component had a higher total DM yield of the mixed pasture than the forage legume component both in the first and second year of the pasture with an overall mean DM yield of 12.2 and 8.8 t $ha^{-1}$, respectively.The DM yields of the grass and forage legume components increased as the pasture period increased in the present study.*C. gayana* and *P. coloratum* mixed with *M. alba* at a seed rate proportion of 50:50 and *C. gayana* mixed with *M. alba* with a seed rate proportions of 67:33 and 75:25 provided higher mean grass DM yield component in the mixture, whereas *C. gayana* mixed with *M. alba* at a seed rate proportions of 33:67 and 50:50 gave the higher mean forage legume DM yield components of the pasture.

The grass-legume mixtures had a higher mean total DM yield of pasture compared to the pure-stand grasses and forage legumes maintained as a control (Table 1). The total DM yield of the grass-legume mixed pastures at different seed rate proportions was lower than the DM yield of the pure-stand grasses and forage legumes in the first year of pasture establishment period. However, the total DM yield of the grass-legume mixed pastures at different seed rate proportions was higher than the DM yield of the pure-stand grasses and forage legumes in the second year of the pasture. The total DM yield of all the mixed pastures varied between the first and second years, with a progressive increasein total DM yield of the mixtures in the second year of the pasture (Table 1). Similarly, 100 and 75 percept of the grass-legume mixed pastures was greater than the DM yield of pure-stand legumes and grasses, respectively throughout the study period (Table 1). *C. gayana* mixed with *M. alba* at seed rate proportion of 25:75 and *C. gayana* and *P. Coloratum* mixed with *M. alba* at a seed rate proportion of 50:50 provided higher DM yield in the first year of the pasture with a DM yield of 12.9; 11.4 and 13.3 t $ha^{-1}$, respectively. In 2005, *C. gayana* and mixed with *M. alba* at seed rates of 33:67 and 50:50 had a higher DM yield of 40.4 and 41.13 t $ha^{-1}$, respectively than other grass-legume mixed pastures and pure-stand grass and forage legume species. Higher mean total DM yields were obtained from *C. gayana* and *P. coloratum* mixed with *M. alba* at a seed rate proportions of 50:50 with 26.7 and 25.0 $tha^{-1}$, respectively, and *C. gayana* mixed with *M. alba* at a seed rate proportion of 33:67 with 26.1 t $ha^{-1}$than other grass-legume mixed pastures and pure-stand grasses and legumes throughout the pasture period.

**Competition function:** There was no significant (P>0.05) effect on RY of both the grass and legume components and RTY of their mixtures due to various seed rate proportions in this study (Table 2). However, different seed rate proportions had a significant (P<0.05) effect on RCC and AI of grass and legume components and their mixtures (Table 2). The mean RY of both the grass and legume components were greater than unity (1.04). Moreover, the 2 years mean RTY of all grass-legume mixtures in the study period were greater than one and ranged from 1.23-2.11. *Chloris gayana* mixed with *M. alba and M. sativa* at a seed rate proportion of 67:33 had a higher RTY than other grass-legume mixtures in the present study (Table 2).

The mean RCC values of both the grass and legume components in the mixtures were almost equal each other and also greater than unity (Table 2). *C. gayana* mixed with *M. sativa* at a seed rate proportion of 50:50 and *P. coloratum* mixed with *M. alba* at seed rate proportions of 50:50 and 25:75 produced a higher RCC values of the grass component, whereas *C. gayana* and *P. coloratum* mixed with *M. alba* at seed rate proportions of 50:50 and 25:75, respectively produced higher RCC values of the legume component compared to other grass-legume combinations. More than 75% of the grass/legume mixtures produced mean AI values of less than unity and closer to zero (range: -0.06 to +0.88) and the mean AI value of both the grass and legume components was low (0.29) (Table 2).

**Chemical composition:** A significant (P<0.05) difference on CP, NDF and hemicellulose contents was observed between pure-stand grasses and legumes, and their mixtures. However, there was no significant effect on DM, OM, TA, ADF, ADL, cellulose contents between pure-stand grasses and legumes, and their mixtures (Table 3). All pure-stand legumes and their mixture with grasses had a higher CP contents than pure-stand grasses. On the contrary, pure-stand grasses had a higher NDF contents compared to pure legumes and their mixtures.

The CP contents of all pure-stand grasses and legumes as well as their mixtures at various seed rate propitiations was greater than 18%, ranged from 17.92%-23.6%. Moreover, the NDF contents of all pure-stand grasses and legumes as well as their mixtures at various seed rate propitiationswere lower than 60% and ranged from 44.0%-58.8%. The CP and NDF contents of the grass-legume mixed pastures indicate that all the mixtures are categorized under goodquality forages. All pure-stand forage legumes and *C. gayana* mixed *M.* sativa at a seed rate proportion of 50:50 and *P. coloratum* and *C. gayana* mixed with *M. sativa* both at seed rate proportions of 25:75 provided a higher CP contents compared to pure-stand grasses and other mixtures in the present study (Table 3).

**Table 1. Dry matter yield (tha$^{-1}$) of *Chloris gayana* and *Panicum coloratum* mixed with *Melilotus alba* and *Medicago sativa* at various seed rate proportions at Haramaya University of eastern Ethiopia**

| | 2008 | | | 2009 | | | Mean (2008 – 2009) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Grass | Legume | Total | Grass | Legume | Total | Grass | Legume | Total |
| *Chloris gayana* (R) | 12.0$^{a}$ | - | 12.0$^{abc}$ | 24.0$^{ab}$ | - | 24.0$^{cdef}$ | 18.0$^{a}$ | - | 18.0$^{bcdef}$ |
| *Panicum coloratum* (P) | 7.3$^{bc}$ | - | 9.8$^{bcdefgh}$ | 16.5$^{bcdefg}$ | - | 20.1$^{def}$ | 14.9$^{ab}$ | - | 14.9$^{ef}$ |
| *Melilotus alba* (M) | - | 10.8$^{a}$ | 10.8$^{bcdefg}$ | - | 18.3$^{ab}$ | 18.3$^{ef}$ | - | 14.6$^{a}$ | 14.6$^{ef}$ |
| *Medicago sativa* (A) | - | 8.6$^{ab}$ | 8.6$^{bcdefgh}$ | - | 14.8$^{abcde}$ | 14.8$^{f}$ | - | 11.7$^{abc}$ | 12.6$^{f}$ |
| R: M (50:50) | 7.4$^{bc}$ | 5.5$^{bcd}$ | 12.9$^{ab}$ | 24.3$^{a}$ | 16.1$^{abcd}$ | 40.4$^{a}$ | 15.9$^{ab}$ | 10.8$^{bcd}$ | 26.7$^{a}$ |
| R: A (50:50) | 3.5$^{cde}$ | 4.1$^{cde}$ | 7.6$^{fgh}$ | 23.5$^{abc}$ | 12.4$^{bcdef}$ | 35.9$^{abc}$ | 13.5$^{abcd}$ | 8.3$^{cdefg}$ | 21.8$^{bcde}$ |
| P: M (50:50) | 8.3$^{ab}$ | 3.1$^{cde}$ | 11.4$^{abcde}$ | 21.7$^{abcde}$ | 16.9$^{abc}$ | 38.6$^{ab}$ | 15.0$^{ab}$ | 10.0$^{bcde}$ | 25.0$^{b}$ |
| P: A (50:50) | 5.5$^{bcde}$ | 4.6$^{cde}$ | 10.1$^{abcdefgh}$ | 16.0$^{cdefg}$ | 10.3$^{def}$ | 26.3$^{bcdef}$ | 10.7$^{bcde}$ | 7.5$^{defg}$ | 18.2$^{bcdef}$ |
| R: M (67:33) | 5.6$^{bcde}$ | 5.5$^{bcd}$ | 11.0$^{abcdefg}$ | 23.1$^{abcd}$ | 12.6$^{bcdef}$ | 35.7$^{abc}$ | 14.3$^{abcd}$ | 9.0$^{bcdefg}$ | 23.4$^{bcd}$ |
| R: M (33:67) | 5.7$^{bcde}$ | 5.4$^{bcd}$ | 11.1$^{abcdefg}$ | 21.5$^{abcde}$ | 19.6$^{a}$ | 41.1$^{a}$ | 13.6$^{abcd}$ | 12.5$^{ab}$ | 26.1$^{ab}$ |
| P: M (67:33) | 5.6$^{bcde}$ | 2.6$^{cde}$ | 8.2$^{cdefgh}$ | 15.6$^{defg}$ | 11.7$^{cdef}$ | 27.4$^{bcdef}$ | 10.6$^{bcde}$ | 7.2$^{efg}$ | 17.8$^{cdef}$ |
| P: M (33:67) | 6.5$^{bcde}$ | 4.4$^{cde}$ | 10.8$^{abcdefg}$ | 16.0$^{cdefg}$ | 16.6$^{abc}$ | 32.6$^{abcd}$ | 11.2$^{abcde}$ | 10.5$^{bcde}$ | 21.7$^{bcde}$ |
| P: A (25:75) | 3.6$^{cde}$ | 4.7$^{cde}$ | 8.3$^{cdefgh}$ | 9.6$^{g}$ | 12.5$^{bcdef}$ | 22.1$^{def}$ | 6.6$^{e}$ | 8.6$^{cdefg}$ | 15.2$^{def}$ |
| P: A (75:25) | 6.1$^{bcde}$ | 3.5$^{cde}$ | 9.7$^{bcdefgh}$ | 17.5$^{abcdef}$ | 7.8$^{f}$ | 25.3$^{cdef}$ | 11.8$^{abcde}$ | 5.7$^{g}$ | 17.5$^{cdef}$ |
| P: M (25:75) | 3.2$^{de}$ | 4.2$^{cde}$ | 7.4$^{gh}$ | 12.1$^{fg}$ | 14.8$^{abcde}$ | 26.9$^{bcdef}$ | 7.7$^{cde}$ | 9.5$^{bcdef}$ | 17.2$^{cdef}$ |
| P: M (75:25) | 7.8$^{b}$ | 1.8$^{e}$ | 9.6$^{bcdefgh}$ | 20.2$^{abcde}$ | 9.7$^{ef}$ | 29.8$^{abcde}$ | 14.0$^{abcd}$ | 5.7$^{g}$ | 19.7$^{bcdef}$ |
| R: M (25:75) | 7.2$^{bcd}$ | 6.0$^{bc}$ | 13.3$^{a}$ | 15.3$^{efg}$ | 14.8$^{abcde}$ | 30.1$^{abcde}$ | 11.3$^{abcde}$ | 10.4$^{bcde}$ | 21.7$^{bcde}$ |
| R: M (75:25) | 7.0$^{bcd}$ | 2.2$^{de}$ | 9.3$^{bcdefgh}$ | 21.8$^{abcde}$ | 10.6$^{def}$ | 32.4$^{abcd}$ | 14.4$^{abc}$ | 6.4$^{fg}$ | 20.8$^{bcdef}$ |
| R: A (25:75) | 2.7$^{e}$ | 4.1$^{cde}$ | 6.8$^{h}$ | 12.2$^{fg}$ | 11.6$^{cdef}$ | 23.8$^{cdef}$ | 7.4$^{de}$ | 7.9$^{defg}$ | 15.3$^{def}$ |
| R: A (75:25) | 7.6$^{bc}$ | 2.7$^{cde}$ | 7.8$^{efgh}$ | 19.7$^{abcdef}$ | 8.4$^{f}$ | 24.6$^{cdef}$ | 10.7$^{bcde}$ | 5.6$^{g}$ | 16.2$^{def}$ |
| R: A (33:67) | 6.5$^{bcde}$ | 5.3$^{bcd}$ | 11.7$^{bcd}$ | 16.5$^{bcdefg}$ | 13.4$^{bcdef}$ | 29.9$^{abcde}$ | 11.5$^{abcde}$ | 0.3$^{bcdef}$ | 20.8$^{bcdef}$ |
| R: A (67:33) | 5.8$^{bcde}$ | 4.8$^{cde}$ | 10.6$^{bcdefg}$ | 21.1$^{abcde}$ | 9.3$^{ef}$ | 30.4$^{abcde}$ | 13.5abcde | 7.0$^{efg}$ | 20.5$^{bcdef}$ |
| P: A (33:67) | 5.8$^{bcde}$ | 4.0$^{cde}$ | 9.8$^{bcdefgh}$ | 18.2$^{abcdef}$ | 11.0$^{cdef}$ | 29.2$^{abcde}$ | 12.0$^{abcde}$ | 7.5$^{defg}$ | 19.5$^{bcdef}$ |
| P: A (67:33) | 6.1$^{bcde}$ | 5.3$^{bcd}$ | 11.3$^{bcdef}$ | 14.6$^{efg}$ | 10.3$^{def}$ | 24.9$^{cdef}$ | 10.3$^{bcde}$ | 7.8$^{defg}$ | 18.1$^{bcdef}$ |
| Mean | 6.2 | 4.7 | 10.1 | 18.2 | 12.9 | 28.5 | 12.2 | 8.8 | 19.3 |
| SEM | 1.42 | 0.90 | 1.58 | 3.24 | 1.55 | 3.38 | 1.74 | 0.90 | 1.86 |

SEM = standard error of the mean; within columns, means followed by the same letter are not significantly different at $P \leq 0.05$.

**Table 2.Effect of various seed rate proportions on relative yield (RY), relative total yield (RTY), relative crowding coefficients (RCC), and aggressivity index (AI) of the grass and herbaceous legumes grown in mixtures at Haramaya University, eastern Ethiopia**

| | RY (grass) | RY (legume) | RTY | RCC (grass) | RCC (legume) | AGI (grass) | AI (legume) |
|---|---|---|---|---|---|---|---|
| R: M¶ (50: 50) | 0.70 | 0.53 | 1.23 | 3.46 | 2.58 | 0.06 | -0.06 |
| R: A (50: 50) | 0.64 | 0.64 | 1.28 | 1.74 | 1.15 | -0.07 | 0.07 |
| P: M (50: 50) | 1.26 | 0.64 | 1.90 | 6.84 | 2.63 | 0.52 | -0.52 |
| P: A (50: 50) | 0.86 | 0.95 | 1.81 | 2.03 | 1.16 | 0.50 | -0.50 |
| R: M (33: 67) | 1.23 | 0.71 | 1.95 | 0.73 | 1.86 | -0.59 | 0.59 |
| R: M (67: 33) | 1.30 | 1.08 | 2.39 | 1.99 | 3.01 | 0.41 | -0.41 |
| P: M (67: 33) | 0.93 | 0.56 | 1.49 | 1.79 | 1.79 | -0.09 | 0.09 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| P: M (33: 67) | 1.00 | 0.83 | 1.82 | 0.44 | 1.59 | 1.56 | -1.56 |
| P: A (25: 75) | 0.63 | 1.09 | 1.72 | 1.81 | 1.96 | 1.28 | -1.28 |
| P: A (75: 25) | 0.77 | 0.64 | 1.41 | 0.46 | 1.37 | -0.42 | 0.42 |
| P: M (25: 75) | 0.70 | 0.75 | 1.44 | 3.54 | 5.20 | 1.33 | -1.33 |
| P: M (75: 25) | 1.08 | 0.35 | 1.43 | 0.68 | 1.53 | 0.09 | -0.09 |
| R: M (25: 75) | 0.64 | 0.84 | 1.48 | 1.25 | 1.45 | 1.27 | -1.27 |
| R: M (75: 25) | 0.92 | 0.60 | 1.52 | 1.09 | 1.89 | -0.59 | 0.59 |
| R: A (25: 75) | 0.42 | 0.96 | 1.38 | 0.90 | 0.67 | 0.34 | -0.34 |
| R: A (75: 25) | 0.73 | 0.76 | 1.49 | 0.22 | 1.42 | -0.88 | 0.88 |
| R: A (33: 67) | 0.87 | 1.08 | 1.95 | 1.75 | 1.44 | 0.63 | -0.63 |
| R: A (67: 33) | 0.67 | 1.45 | 2.11 | 0.52 | 1.44 | -0.44 | 0.44 |
| P: A (33: 67) | 1.29 | 0.70 | 1.99 | 1.29 | 0.61 | 1.52 | -1.52 |
| P: A (67: 33) | 0.78 | 0.78 | 1.56 | 1.19 | 1.76 | -0.55 | 0.55 |
| Mean | 0.87 | 0.80 | 1.67 | 1.70 | 1.71 | 0.29 | -0.29 |
| SEM | 0.25 | 0.20 | 0.35 | 1.97 | 0.84 | 0.30 | 0.30 |
| Prob. | NS | NS | NS | <0.001 | < 0.001 | < 0.001 | < 0.001 |

¶A = *Medicago sativa*; M = *Melilotus alba*; P = *Panicum coloratum*; R = *Chloris gayana;* SEM = standard error of the mean

**Table 3.Chemical composition (% in DM basis) of *Chloris gayana* and *Panicum coloratum* mixed with *Medicago sativa* and *Melilotus alba* at various seed rate proportions at Haramaya University of eastern Ethiopia.**

| | Chemical composition (% DM basis)£ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | CP | DM | OM | TA | NDF | ADF | ADL | Cell | HC |
| *Chloris gayana* (R) | 18.5$^{efg}$ | 93.0 | 86.6 | 13.4 | 55.7$^{ab2}$ | 33.8 | 5.9 | 28.0 | 21.9$^{ab}$ |
| *Panicum coloratum* (P) | 17.9$^{g}$ | 93.4 | 87.2 | 12.8 | 58.8$^{a}$ | 34.4 | 5.3 | 29.2 | 24.4$^{a}$ |
| *Melilotus alba* (M) | 23.1$^{ab}$ | 93.1 | 88.2 | 11.8 | 46.5$^{efg}$ | 47.4 | 6.9 | 40.5 | 11.1$^{f}$ |
| *Medicago sativa* (A) | 23.6$^{a}$ | 93.1 | 87.4 | 12.6 | 51.1$^{bcdefg}$ | 48.6 | 6.9 | 41.6 | 14.9$^{cdef}$ |
| R: M (50:50) | 18.6$^{efg}$ | 93.5 | 89.1 | 10.9 | 48.9$^{bcdefg}$ | 35.6 | 6.4 | 29.2 | 13.27$^{ef}$ |
| R: A (50:50) | 22.2$^{abc}$ | 93.0 | 88.0 | 12.0 | 46.9$^{defg}$ | 31.1 | 6.3 | 24.8 | 15.8$^{bcdef}$ |
| P: M (50:50) | 20.37$^{cdefg}$ | 93.3 | 87.7 | 12.3 | 54.9$^{abc}$ | 34.7 | 6.2 | 28.5 | 20.2$^{abcd}$ |
| P: A (50:50) | 21.0$^{abcde}$ | 93.6 | 88.3 | 11.7 | 46.2$^{efg}$ | 34.7 | 6.8 | 27.9 | 11.6$^{ef}$ |
| R: M (67:33) | 19.8$^{cdefg}$ | 93.0 | 88.2 | 11.9 | 49.1$^{bcdefg}$ | 35.0 | 5.8 | 29.3 | 14.1$^{cdef}$ |
| R: M (33:67) | 18.3$^{efg}$ | 91.9 | 88.0 | 12.0 | 47.9$^{cdefg}$ | 37.0 | 6.3 | 30.7 | 14.3$^{cdef}$ |
| P: M (67:33) | 19.3$^{defg}$ | 93.1 | 88.2 | 11.8 | 51.2$^{bcdef}$ | 34.9 | 6.7 | 28.5 | 16.3$^{bcdef}$ |
| P: M (33:67) | 18.3$^{efg}$ | 93.5 | 87.4 | 12.7 | 52.9$^{abcde}$ | 35.7 | 6.4 | 29.3 | 17.2$^{bcdef}$ |
| P: A (25:75) | 21.6$^{abcd}$ | 92.9 | 87.7 | 12.3 | 44.0$^{g}$ | 33.3 | 6.2 | 27.1 | 10.7$^{f}$ |
| P: A (75:25) | 20.0$^{cdefg}$ | 93.0 | 87.0 | 13.0 | 52.1$^{abcdef}$ | 34.9 | 6.5 | 28.4 | 17.1$^{bcdef}$ |
| P: M (25:75) | 19.9$^{cdefg}$ | 93.1 | 87.4 | 12.6 | 45.9$^{efg}$ | 34.4 | 6.0 | 28.5 | 11.5$^{f}$ |
| P: M (75:25) | 19.0$^{defg}$ | 93.0 | 89.1 | 12.6 | 54.1$^{abcd}$ | 33.5 | 5.5 | 28.1 | 20.5$^{abc}$ |
| R: M (25:75) | 18.6$^{efg}$ | 92.8 | 86.3 | 10.9 | 48.8$^{bcdefg}$ | 34.6 | 6.0 | 28.0 | 14.2$^{cdef}$ |
| R: M (75:25) | 18.2$^{fg}$ | 93.4 | 87.9 | 13.7 | 52.4$^{abcdef}$ | 34.1 | 5.4 | 28.8 | 18.3$^{abcde}$ |
| R: A (25:75) | 20.9$^{abcdefg}$ | 92.6 | 87.7 | 12.1 | 45.6$^{fg}$ | 32.5 | 6.0 | 26.5 | 13.16$^{ef}$ |
| R: A (75:25) | 19.9$^{cdefg}$ | 93.1 | 87.9 | 12.3 | 49.4$^{bcdefg}$ | 33.0 | 6.6 | 26.4 | 16.4$^{bcdef}$ |
| R: A (33:67) | 19.6$^{cdefg}$ | 93.2 | 87.4 | 12.1 | 49.0$^{bcdefg}$ | 33.4 | 6.4 | 27.0 | 15.6$^{bcdef}$ |
| R: A (67:33) | 20.69$^{bcdefg}$ | 93.5 | 88.4 | 11.6 | 45.9$^{bcdefg}$ | 32.2 | 6.4 | 25.8 | 13.7$^{def}$ |
| P: A (33:67) | 20.2$^{cdefg}$ | 93.4 | 87.6 | 12.4 | 47.5$^{efg}$ | 31.6 | 6.4 | 25.2 | 15.9$^{bcdef}$ |
| P: A (67:33) | 19.4$^{defg}$ | 92.9 | 87.2 | 12.8 | 50.5$^{bcdefg}$ | 33.1 | 6.4 | 26.7 | 17.4$^{bcdef}$ |
| Mean | 19.9 | 93.1 | 87.7 | 12.3 | 48.6 | 35.1 | 6.2 | 28.9 | 13.4 |
| SEM | 0.97 | 0.37 | 0.64 | 0.64 | 2.52 | 3.74 | 0.43 | 3.82 | 4.66 |

£ADF = Acid detergent fibre; ADL = Acid detergent lignin; BS = Biogenic silica; CP = Crude protein DM = Dry matter; OM = Organic matter; TA= Total ash; NDF = neutral detergent fiber; Cellu = Cellulose; HC = Hemicelluloses; SS = Sand silica; SEM = standard error of the mean; within columns, means followed by the same letter are not significantly different at $P \leq 0.05$

# DISCUSSION

**Dry matter yield:** Grass-legume mixtures are preferred over pure-grass forage stands throughout the world because they often increase the total yields of herbage (Cinar *et al*., 2014). In the current study, *C. gayana* and *P. coloratum* mixed with *M. alba* at a seed rate proportion of 50:50, and *C. gayana* mixed with *M. alba* at a seed rate proportion of 33: 67 provided higher DM yield productions than other grass-legume mixed pastures and pure-stand grasses and legumes throughout the pasture period. Moreover, 100 and 75% of the grass-legume mixed pasture was higher than the total DM yield of pure-stand grass and herbaceous forage legume species, respectively, indicating the contribution of various seed rate proportions of both pure-stand grass and forage legume species on the total DM yield of their grass-legume mixtures. The results of the total DM yield of the grass-legume mixed pastures in the present study are in agreement with previous reports (Diriba, 2002; Tessema and Baars, 2006). However, according to Lemma *et al.* (1991) pure-stand *C. gayana* produced a higher DM yield than a *C. gayana*-forage legume mixed pasture in the second and third year of establishment in the western parts of Ethiopia.

The total DM yields of all grass-legume mixed pastures varied between the first and second years, and total DM yield production increased as the pasture swardincreases. This might be due to the fact that all the grassand forage legume species as pure-stands and in the mixtures grew well and vigour's from the time of establishment to flowering because grasses and legumes usually produce more tillers and branches, respectively that could contribute to the higher total DM yield for the grass-legume mixed pastures. In addition, forage legumes had fast re-growth after each harvest than grass species that could contribute to a higher total DM yield productions of the grass-legume mixtures throughout the study (personal observation). Moreover, as the growth pattern of forage legumes and grasses is variable over drier and wetter parts of the year, selection of the correct grass-legume combination could make sustained animal feed available year round under smallholder farming conditions in Ethiopia. This indicates that higher total DM yields of grass-legume combinations could be obtained as the pasture sward advances.

Previous studies elsewhere in Ethiopia and other tropical areas of world have indicated that grass and legume mixed pastures could significantly contribute to a higher total herbage yield (Daniel, 1996; Tessema and Baars, 2006). According to Cinar *et al*. (2014) the mixture of Dallis and Guinea grass with alfalfa had a highest DM yield (22.6 t $ha^{-1}$) in Turkey. Similarly, the DM yield from natural pasture grown with *Stylosanthes guianensis* was found to be promising in subtropical areas of Ethiopia (Diriba, 2002; Baba *et al.,* 2011). Principally, when a pure grass pasture is grown tie up of N in below ground parts, it eventually suffers yield losses through N depletion. Conversely pure legume pasture fixes N in excess of its requirement that attract insects invading non-legume weeds or grasses (Lemma *et al*., 1991, Ahmad *et al*., 2016).

**Competition function:** The 2 years mean RTY of all grass-legume mixtures in the experimental periods were greater than one (range: 1.23-2.11) reflecting that there was a yield advantage of 23-111% over the pure-stands of grasses and legumes. This may probably suggested the occurrence of biological nitrogen fixation in the root nodules of the legumes, which transferred from the legume component to the grasses, hencesupported the growth of grasses and their mixture in the pasture sward. This would also imply that the grass-legume mixtures were, at least, partly complementary in resource use. This may happen when the growth periods of the mixtures are partly overlapping or when they are using plant growth resources from varying soil depths. The results of the RY and RTY in the current study were in agreement with Daniel (1990) and Diriba (2002) for the *Chloris-Medicago* and *Panicum* - *Stylosanthes* mixtures, respectively. Tessema and Baars (2006) also reported a RTY values to have ranged from 1.29 to 1.48 in a 50:50% perennial grass/legume mixture in north-western part of Ethiopia. This situation could be attributed to the efficient utilization of plant growth factors by species in the mixture due to either temporal or spatial differences of their demands (Baba *et al.,* 2011).

Both grasses and legumes in the mixture produced RCCs in excess of unity indicating that all produced a higher yield in the mixture than expected in pure-stands at different seed rates. Moreover, the mean RCCs for both the grass and legume components were almost equal indicating that they perform similarly in DM production in the mixture. This may indicate that the grasses were highly benefited from the legume components, which could contributed to increased DM productions of the mixtures. Forage legumes benefits in terms of increased herbage and animal production in smallholder agricultural production systems by their ability to fix atmospheric nitrogen (Baba *et al.,* 2011; Ahmad *et al.,* 2016). Morrison (1984) also suggested that legumes such as *Medicago* and clovers increase the yield of the grasses when grown in combination with them. More than 75% of the grass/legume mixtures produced mean AI values of less than unity and closer to zero (range: -0.06 to +0.88) and the mean AI value of both the grass and legume components was low (+0.29 and -0.29, respectively) indicating that there was small dominance in both components and they were almost equally competitive and both contributed more in DM production of the entire mixture throughout the study. The AI values of the present study is similar with the result of Tessema and Baars (2006) who reported that the AI values for *Chloris* mixed with *Desmodium* and *Chloris* mixed with *Medicago* were +0.07 and +0.23, respectively.

**Chemical composition:** According to Cinar *et al.* (2005) grass-legume mixtures are more preferred over pure-stand grass forages because of increased CP and balanced nutrition. As expected, all pure-stand legumes and their mixtures with grasses had higher CP values compared to pure-stand grasses in the present study.The CP level required for maintenance and production of cattle is 150 g $kg^{-1}$ DM (Norton, 1982; Van Soest, 1982) indicating that all the pure grasses and legumes, and their mixtures are above (range: 179.2 - 236.4 g $kg^{-1}$ DM) the recommendation. Pure grasses had higher NDF, ADF, cellulose and hemicellulose values compared to pure legumes and their mixtures in this study. The leaf stem ration of the grass and legume components in the mixture was greater than unity as reported by Tessema (2008), which might have contributed to the higher CP and lower fibre fractions in all grass/legume mixtures compared to pure-stand grasses. The threshold level of NDF in tropical grass beyond which DM intake of cattle is affected is 600 g $kg^{-1}$ DM (Meissner *et al*., 1991); however, all the pure grasses and legumes, and their mixtures have lower than this value (range: 440-588 g $kg^{-1}$DM). In the present study, the hemicellulose (range: 107.0 - 240.0 g $kg^{-1}$ DM) contents of all the pure grasses and legumes, and their mixtures were lower than those of most tropical grasses, 354 g $kg^{-1}$ DM (Moore and Hatfield, 1994; Manaye *et al*., 2009).

Accordingly a combination of grasses and legumes is therefore usually far preferable to any mixture of grasses alone, without legumes so that they may utilize fixed N that improves the feeding value of the sward (Larbi *et al*., 1995; Tessema, 1996). This showed that the forage legume increases the digestibility and the palatability of the grass component and the mixed pasture sward as a whole. According to Diriba and Diriba (2013) mixing *S. guianensis* with *P. coloratum* at a seed rate of proportion 25:75% improved the CP content, IVDMD and reduced NDF content in western Ethiopia. Grass and legume mixtures significantly contribute to the quality of the pasture sward as reported by many authors (Daniel, 1990; Lemma *et al*., 1993; Diriba 2002). The animal production from natural pasture over sown by *S. guianensis* was found to be promising in subtropical areas of Ethiopia (Lemma *et al*., 1993). The other advantage of perennial legumes in a mixed pasture is their higher protein value at any given time than the accompanying grass species (Lemma *et al.,* 1991). Grass-legume mixtures improved forage quality due to the high nutrient concentration in the legumes (Larbi *et al*., 1995; Manaye *et al*., 2009). Also, legumes are important to increase the amount of CP, extend the grazing periods of the dry season and provide nitrogen for the companion grasses (Crowder and Chedda, 1982; Ahmad *et al.,* 2016).

Crowder and Chedda (1982) indicated that *Chloris and Molasses* grasses have high initial dry matter digestibility (DMD) (70-85%) but this sharply declines with the advancement of maturity. Similarly, Daniel (1996) and Larbi *et al*. (1995) reported a higher CP and IVDMD of *C. gayana* mixed with *M. sativa* and a decline of CP and IVDMD after maturity in the central highlands of Ethiopia. However, the reduction of DMD with the advancement of maturity could be improved by growing grasses with perennial forage legumes such as *Desmodium* and *Medicago* (Larbi *et al*., 1995). This might be due to the fact that the grass-legume mixtures increase CP through atmospheric nitrogen fixation and then reduces the fiber fractions of the pasture, which are indicators of good quality forages (Mannteje, 1984; Minson, 1990) and thereby this increases DMD. This showed that the forage legumes increased the quality of the grass component and the mixed pasture sward as a whole (Tessema and Baars, 2004; Manaye *et al*., 2009). The combination of grass and forage legumes are therefore far preferable to any pure-stand grass swards because the forage legume species in the mixture can fix N and the grasses may utilize the fixed N that improves the feeding value of the grass-legume sward (Morrison, 1984). This also implies that the grass-legume mixtures are, at least, partly complementary in resource use and this may usually happen when the growth periods of the mixtures are partly overlapping or when they are using plant growth resources from varying soil depths (Morrison, 1984; Larbi *et al*., 1995). This biological nitrogen fixation is environmentally friendly for sustainable production of grass-legumes, as it reduces the need for application of nitrogenous fertilizers, which is detrimental to the environment (Ezeaku *et al.,* 2017).

**Conclusions:** Both forage legumes and their mixtures with perennial grass species had a higher CP and a lower fiber contents compared to pure-stand grass species. Hence, *C. gayana* mixed with *M. alba* at a seed rate proportions of 50:50 and 33:67 can be introduced under smallholder crop-livestock farming system conditions in the eastern parts of Ethiopia.

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