

Full Length Research Paper

Evaluation of dry matter yield, yield components and nutritive value of selected alfalfa (*Medicago sativa* L.) cultivars grown under Lowland Raya Valley, Northern Ethiopia

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The experiment was conducted at Raya Azebo district, which is located in Southern Tigray, North Ethiopia, with the objective to investigate the highest dry matter yield and herbage nutritive value among the selected alfalfa cultivars. The experiment was conducted by randomized complete block design with four replications and five cultivars. The experimental cultivars were FG-10-09 (F), FG-9-09 (F), Magna-801-FG (F), Magna-788 and Hairy Peruvian. Harvesting cutting intervals was taken at an average of 57.78 ± 4.78 days of mid flowering at irrigation land. A total of 4 cutting cycles were taken from January 2016 to August 2016. The result of the study showed that dry matter (DM), organic matter (OM), crude protein (CP), neutral detergent fiber (NDF) and *in vitro* dry matter digestibility (IVDMD) was comparable across the five cultivars. Stand height was significant different ($P < 0.001$) among the cultivars. Alfalfa cultivars FG-10-09(F), FG-9-09(F), Magna-788 and Hairy Peruvian had significantly ($P < 0.001$) higher plant height as compared to Magna-801-FG (F). However, DM yield and leaf to stem ratio (LTSR) was not affected by cultivars ($P > 0.05$). Cutting cycle significantly affected stand height, DM yield and LTSR. Plant height and DM yield were significantly different ($P < 0.001$) among the cultivars across the cutting cycle. Cutting cycles 2, 3 and 4 had the highest stand height and DM yield as compared to cutting cycle 1 ($P < 0.001$). But, cutting cycles 2 and 1 were significantly higher in LTSR as compared to 3 and 4 ($P < 0.001$). Therefore, it can be conclude that all the cultivars evaluated had not shown significant difference in DMY and nutritive content, but Hairy Peruvian had relatively good DM yield and higher stand height, as a result, it is good to promote Hairy Peruvian cultivar for further demonstration and seed production.

Key words: Alfalfa, dry matter yield, nutritive content, cutting cycle, leaf to stem ratio.

INTRODUCTION

Feed scarcity in both quantitative and qualitative dimensions is one of the major constraints for the promotion of the livestock subsector in Ethiopia (Alemu,

1997). In many areas of the country, animals are kept on poor quality natural pasture that commonly occur on permanent grasslands, roadsides, pathways and spaces

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between cropped plots (Tewodros and Meseret, 2013). Such low quality feeds are associated with a low voluntary intake, thus resulting in insufficient nutrient supply, low productivity and even weight loss (Hindrichsen et al., 2001). Effective methods through which utilization of low quality roughages could be improved include supplementation with energy and nitrogen sources, chemical or physical treatment, and selection and breeding of crops, each of which ultimately depends on the economic benefits and applicability (McDonald et al., 2002). One way to optimize utilization of available feed resources is strategic supplementation of crop residues with plant protein sources such as leguminous forage crops which have the potential for alleviating some of the feed shortages and nutritional deficiencies experienced in the dry season on smallholder farms (Hove et al., 2001; Teferedegne, 2000). As a result, animals with access to leguminous forage crops perform better than those kept on natural pasture in milk yield, weight gain, reproductive performances and survival rates (Elbasha et al., 1999; Norton, 1994b).

In Ethiopia, more attention, however, has been given to assessment of the environmental adaptation, herbage DM yield potential and seed bearing ability of candidate accessions, while data on their nutritive value is generally scarce (Geleti et al., 2014). Alfalfa has one of the highest crude protein contents among forage crops, but it is rapidly and extensively degraded by rumen microorganisms (Dong et al., 2009). It can produce around 25% more dry matter than pasture (Richard, 2011) and Yields of irrigated alfalfa have been shown to be up to 24 ton DM yield ha⁻¹ year⁻¹ (Brown et al., 2000). There are numerous cultivars of alfalfa, selected for specific abilities, such as winter hardiness, drought resistance, tolerance to heavy grazing or tolerance to pests and diseases (Frame, 2005). Selection of important cultivars in Ethiopia, has been given to assessment of the environmental adaptation, herbage DM yield potential and seed bearing ability of candidate cultivars (Geleti et al., 2014). Moreover, these five cultivars used in the current study were grown under different production systems and agro-ecological conditions in Ethiopia. As a result, testing the same cultivars in different agro-ecological zones has been an advantage to find suitable cultivars specifically to the study area. Therefore, this study was initiated to investigate the highest dry matter yield and herbage nutritive value among the selected five alfalfa cultivars in lowland agro ecology area of Raya value.

MATERIALS AND METHODS

Description of the study area

The study was conducted at Raya-Azebo district, Wargiba research site. The area is located at a distance of 660 km from Addis Ababa (capital city of Ethiopia) to the North and 120 km far from Mekelle

(capital city of Tigray regional state) to south direction. The altitude of the area is 1600 m above sea level. Geographically, it is located between 12.32-12.95°North latitude and 39.56-39.98°East longitude. The temperature of the district is within the range of 22 to 26°C. The mean annual rainfall is 600 mm and within the range of 400 to 800 mm. The distribution of the rainfall is the temporal situation and shows bimodal event. The area covered a total of 85% categorized as the mid land agro ecology and 15% covers a low land agro ecology. From February to April the rainfall is commonly little rain, but the main rain season is between July and September (OARD, 2016).

Experimental design and treatments

The experiment was conducted by randomized complete block design (RCBD) with four replications and five treatments. Each alfalfa cultivars were assigned randomly for each block. The cultivars were evaluated at Alamata Agricultural Research Center, Wargiba Research site at irrigated land. The experimental treatments used were FG-10-09 (F), FG-9-09 (F), Magna-801-FG (F), Magna-788 and Hairy Peruvian. The cultivars were planted in a plot size of 9 m² (3 m × 3 m), and spacing between rows and blocks 0.2 and 1 m, respectively. The seed rate used in the experiment was 10 kg ha⁻¹ and sowed drilled within the row. With this after sown the soil was slightly covered carefully and 100 kg ha⁻¹ of DAP was applied during sowing. Water was supplied every week and in every cutting hoeing applied. The other management practice like weeding, cutting and protection managements were done carefully as important.

Stand height, dry matter yield and leaf to stem ratio

Determination of stand height, dry matter yield and leaf to stem ratio data was recorded. Mean stand height of five randomly selected plants from a plot was recorded. The data of the plant height was taken at the stage of herbage biomass harvesting. Leaf to stem ratio was determined from the same sampling area of fresh biomass, after taking the sample of 300 g for dried DM yield. Then after, the harvested biomass was partitioning into leaf and stem fractions, and drying the fraction samples using similar procedures described above for herbage DM yield determination. From the total area of 9 m² plots, a net area of 1.8 m² was harvested randomly from three selected adjacent middle rows to estimate the fresh biomass yield and sample for DM yield. The fresh biomass was recorded after cutting using sickle and weighing using spring balance. To determine DM yield, 300 g sample was taken and dried in an oven at 65°C for 72 h. The harvested stage for estimation of good biomass and nutritive value was followed by Ball (1998), explained as a stage when open flowers emerge on average of 2 or more nodes and no seed pods present at the stage of full flowering stage.

Cutting intervals of herbage yield

With increasing alfalfa maturity in regrowth cycle, forage nutrient concentrations decrease while forage dry matter yield increase to about mid-flowering (Radović et al., 2009). To compromise, these yield and nutritive value, harvesting cutting intervals in this study was taken at an average of 57.78±4.78 days of mid flowering at irrigation land. A total of 4 cutting cycle were taken from January 2016 up to August 2016.

Relative feed value

Relative Feed Value (RFV) is an index used to rank feeds relative

Table 1. Chemical composition, *in vitro* DM digestibility and RFV of selected alfalfa cultivars.

Cultivar	DM (%)	Ash (%)	CP (%)	OM (%)	NDF (%)	ADF (%)	ADL (%)	IVDMD (%)	RFV
FG-10-09(F)	91.43	13.73	17.48	86.27	39.49	28.56	5.74	76.96	121.33
FG-9-09(F)	92.09	12.58	16.34	87.42	42.31	31.09	6.15	72.61	110.88
Magna-801-FG (F)	90.74	13.02	17.7	86.98	39.29	29.28	5.25	76.68	120.74
Magna-788	90.91	13.78	19.37	86.22	39.74	26.88	3.62	79.53	123.25
Hairy Peruvian	90.88	13.28	18.3	86.72	38.75	30.56	6.33	73.58	120.15

DM = Dry matter, OM = Organic matter, CP = Crude protein, NDF = Neutral detergent fibre, ADF = Acid detergent fiber, ADL = Acid detergent lignin, IVDMD= *In vitro* dry matter digestibility, and RFV= Relative feed value.

to the typical nutritive value of full bloom alfalfa hay, containing 41% ADF and 53% NDF on a DM basis, and having a RFV of 100, which is considered to be a standard score. This index is widely used to compare the potential of two or more forages on the basis of energy intake (Schroeder, 2013).

$$\text{RFV} = \text{DDM} (\% \text{DM}) \times \text{DMI} (\% \text{BW}) / 1.29$$

where DDM is digestible dry matter, DMI is dry matter intake potential as % of body weight, and BW is body weight were calculated from ADF and NDF as followed (Uttam et al., 2010):

$$\text{DDM} (\% \text{DM}) = 88.9 - 0.78 \times \text{ADF} (\% \text{DM})$$

and

$$\text{DMI} (\% \text{DM}) = 120 / \text{NDF} (\% \text{DM})$$

Chemical analysis

Chemical composition of the cultivars were prepared from each replication and then finally pooled as one cultivar within each cutting cycle. The dry matter (DM%), crude protein (CP%) (Nx6.25) and ash were determined using the standard procedures of AOAC (1990). The neutral detergent fiber (NDF%), acid detergent fiber (ADF%) and acid detergent lignin (ADL) fractions were analyzed according to Van Soest (1994). The modified Tilley and Terry *in vitro* method (Van Soest and Robertson, 1985) was used to determine the *in vitro* dry matter digestibility (IVDMD).

Statistical analysis

The data obtained from the experiment was subjected to analysis of variance using the General Linear Model Procedure of SAS (1998). Significant treatment mean was separated using Tukey HSD. The model used for the analysis of all parameters was:

$$Y_{ijk} = \mu + a_i + b_j + e_{ijk}$$

where Y_{ijk} = response variable, μ = overall mean, a_i = i^{th} treatment effect, b_j = j^{th} block effect, and e_{ijk} = random error.

RESULTS

Chemical composition and *in vitro* DM digestibility of alfalfa cultivars

Chemical composition and *in vitro* DM digestibility of alfalfa cultivars are shown in Table 1. The study showed

that the DM content was comparable across the five cultivars. Similarly, the CP content of the present study also indicated comparable result within the treatments. The fiber (NDF, ADF and ADL) value of the experimental cultivars showed similar contents within the treatments. Likewise, the results of *in vitro* dry matter digestibility (IVDMD) content were also comparable across the five cultivars.

Stand height, leaf to stem ratio and dry matter yield

Stand height, dry matter yield and leaf to stem ratio of five alfalfa cultivars are shown in Table 2. The present study showed that plant height was significance differences ($P < 0.001$) among the five cultivars. Alfalfa cultivars FG-10-09 (F), FG-9-09 (F), Magna-788-FG (F) and Hairy Peruvian had significantly ($P < 0.001$) higher plant height as compared to Magna-801. However, DM yield and leaf to stem ratio (LTSR) was not affected by the cultivars ($P > 0.05$).

Dynamics of forage production across cutting cycles

Cutting cycles of stand height, DM yield and leaf to stem ratio of selected alfalfa cultivars are shown in Table 3. Cutting cycle was significantly affected by stand height, DM yield and LTSR. Stand height and DM yield were significantly different ($P < 0.001$) among the cultivars across the cutting cycle. Cutting cycles 2, 3 and 4 had the highest stand height and DM yield as compared to cutting cycle 1 ($P < 0.001$). This might be due to additional tillers which created an impact on the increment of DM yield included in the other cutting cycles as compared to the 1st cutting cycle. But, cutting cycles 2 and 1 were significantly higher than LTSR as compared to 3 and 4 ($P < 0.001$).

DISCUSSION

Nutritive value of alfalfa cultivars

As Kazemi et al. (2012) reported high quality alfalfa had

Table 2. Stand height (cm), dry matter yield (tonha⁻¹) and leaf to stem ratio of selected alfalfa cultivars across year.

Cultivar	Stand height	DMY	LTSR
FG-10-09(F)	78.0 ^a	4.59	0.77
FG-9-09(F)	71.5 ^{ab}	3.96	0.87
Magna-801-FG(F)	66.6 ^b	3.98	0.93
Magna-788	72.3 ^{ab}	4.49	0.79
Hairy Peruvian	79.6 ^a	4.81	0.83
SEM	0.03	0.27	0.06
P-level	***	NS	NS

^{abc}Means within the same rows bearing a common superscript not significantly, ***($P < 0.001$), **($P < 0.01$), *($P < 0.05$), DMY=Dry matter yield, LTSR= Leaf to stem ratio, SEM= Standard error of mean, NS= Not significance.

Table 3. Effect of cutting cycles on stand height (cm), DM yield (ton ha⁻¹) and leaf to stem ratio of selected alfalfa cultivars.

Cutting cycle	Stand height	DMY	LTSR
Cycle 1	58.7 ^b	5.38 ^b	0.60 ^{ab}
Cycle 2	78.1 ^a	6.59 ^a	0.61 ^a
Cycle 3	84.3 ^a	6.81 ^a	0.54 ^b
Cycle 4	82.9 ^a	7.23 ^a	0.53 ^b
SEM	0.02	0.18	0.02
P-level	***	***	***

^{abc}Means within the same columns bearing a common superscript not significantly, ***($P < 0.001$), **($P < 0.01$), *($P < 0.05$), DMY=Dry matter yield, LTSR= Leaf to stem ratio, SEM= Standard error of mean, NS= Not significance.

to contain <40% NDF, <31% ADF and >19% CP in general, but particularly at full bloom stage alfalfa forage had to contain a CP>16%, ADF <41%, NDF <53% and RFV >100%. With this threshold of the aforementioned report, the nutritive value of the cultivars in the present study had fulfilled the full bloom stage. In addition, the fibrous content of FG-10-09(F), Magna-801-FG (F), Magna-788 and Hairy Peruvian also contains high rank quality alfalfa content unlike, the CP content. However, Hairy Peruvian cultivar in the present study had scored high quality alfalfa with the threshold content of CP%, NDF% and ADF%. The differences in nutritive value might have occurred due to many factors: harvesting management, varieties and harvest frequency. This implies that cutting at earlier stages might improve the crude protein content and decrease fiber content, but at the expense of yield (Dennis and Howard, 1993).

The current study also ranged comparable result of the quality of alfalfa hay reported by Redfearn and Zhang (2011) as the first prime NDF < 40-46, ADF < 31-40, CP% >17-19 and RFV <125-151. The cultivars FG-10-09(F), Magna-801-FG (F), Magna-788 and Hairy Peruvian had a value of NDF 39.49, 39.29, 39.74 and 38.75%, respectively which facilitates the rate of passage

unlike, FG-9-09(F) cultivar resulted in 42.31% NDF with greater than the bench mark. This result was comparable with Gävan et al. (2013) where NDF levels greater than 40% begin to slow rate of passage down, creating a gut-fill effect. This resulted in lower dry matter intake as higher gut-fill occurred. In general, between yield and nutritive value, the greatest impact on timing of harvests made in spring and early summer in humid environments, and in early and late summer in more arid regions led to negative association (Brink et al., 2010).

The DM content of the current study was comparable with Gashew et al. (2015), while higher DM content was indicated as compared to Geleti et al. (2014) for the same cultivars. The DM (%) content of FG-10-09(F) was comparable with the report of Walie et al. (2016), but the other four cultivars of the current study had less DM (%) content as compared to the same author. *In vitro* dry matter digestibility (IVDMD) ranged from 73.58 to 79.53% in this study showed less value as compared to the report of Diriba et al. (2014) which ranged from 83.07 to 87.35%, but higher value of IVDMD was recorded as compared to Walie et al. (2016) ranging from 61.58 to 62.37%. Similarly, small value of IVOMD were also reported for 14 alfalfa varieties, with values ranging from

59.15 to 66.33% (Kamalak et al., 2005) with less value as compared to the current study. The differences in IVDMD might occur from the time of harvesting. As the lignin levels increase with maturity in stems, digestibility will decrease in many forage crops such as alfalfa, because lignin concentration correlates negatively with forage digestibility (Dianging et al., 2001).

Relative feed value (RFV) has been used for years to compare the quality of legume and legume/grass hays and silages (Peter and Alvaro, 2004). As Moore and Undersander (2002a) demonstrated, forages with RFV greater than 100 are of higher quality than full bloom alfalfa hay, and forages with a value lower than 100 are of lower value than full bloom alfalfa. The RFV index of the cultivars of the current study indicated greater than the threshold of 100, which illustrated the cultivars to have higher quality standard. This RFV was proposed to reflect how well an animal will eat and digest a particular forage species when it is fed as the only source of energy (Kazemi et al., 2012). However, the RFV index of this study indicated lower value ranged from 110.88 to 123.25 as compared to Diriba et al. (2014) whose report ranged from 154.01 to 189.55 for the same cultivars. In general, the result of the current study id ranked 2nd prime standard quality classification as reported by Redfearn and Zhang (2011) as 1st and 2nd prime ranging from CP(17-19%), NDF(40-46%), ADF(31-40%) and RFV (125-151), and CP(14-16%), NDF(47-53%), ADF(36-40%) and RFV (103-124), respectively.

Stand height, leaf to stem ratio and dry matter yield

Alfalfa forage production may be related to plant density, disease resistance, cutting cycle and cultivar difference (Cook et al., 2005). The stand height of the current study was significantly different ($P < 0.001$) among cultivars. This result was true with the report of Walie et al. (2016) and Diriba et al. (2014) for the same selected alfalfa cultivars. Hairy Peruvian showed higher stand height (79.6 cm) as compared to the other cultivars. Agreed with the study by Diriba et al. (2014) and Heuzé (2013) who reported that, Hairy Peruvian had higher stand height as compared to respective evaluated cultivars, but superior stand height for this cultivar shown as compared to the current study (86.5 cm and 1 m), respectively. On the contrary, Walie et al. (2016) had indicated higher stand height for FG-9-09(F) as compared to the other cultivars. In general, stand height of the current study lay in the range of different scholars for different cultivars (Turan et al., 2017; Walie et al., 2016; Diriba et al., 2014; Taherian, 2009).

Leaf to stem ratio (LTSR) of the current study had no significant differences ($P > 0.05$) among the cultivars, this was comparable with the report of Diriba et al. (2014) and Afsharamanesh (2009) unlike, Gashaw et al. (2015) for the same alfalfa cultivars. While, the evaluated value of

LTSR alfalfa cultivars in the present study ranged from 0.77 to 0.87 and it was inferior as compared to the value reported by Diriba et al. (2014) ranging from 0.95 to 1.21 for the same cultivars. This might have occurred due to the difference of soil type, management and harvesting stage. Similarly, Katic et al. (2006) reported that the proportion of leaves and stems in alfalfa hay can vary greatly, depending on maturity at harvest, cultivars, handling, and rain damage. Among the evaluated selected alfalfa cultivars, Magna-801 FG (F) had superior LTSR in the current study. Leaf to stem ratio is an important trait in the selection of appropriate forage cultivar as it is strongly related to forage quality (Sheaffer et al., 2000). Alfalfa leaves have significantly higher nutritive value than stems, so to advance forage quality has been to develop cultivars which possess a greater proportion of leaves than stem (Ray et al., 1999a). Because, leaves have a stable protein content that is much higher than that of the stems. Stem develops at the expense of leaves and their cell walls and lignin content increases with maturity (Veronesi et al., 2010).

Dry matter yield (DMY) of the present study does not show any significant differences among the cultivars ($P > 0.05$), and this agreed with the result reported by Gashaw et al. (2015) for the same cultivars. Unlike this finding, other reports observed significant different among cultivars (Turan et al., 2017; Walie et al., 2016; Diriba et al., 2014). The DMY of the current study ranged from 3.96 to 4.81 ton ha⁻¹, which was comparable to Basafa and Taherian (2009), Geleti et al. (2014), Befekadu and Yunus (2015), and Walie et al. (2016) reported a values of 2.84-4.23, 4.22-4.77, 4.12 and 4.00-4.87 ton ha⁻¹ for different cultivars, respectively. But, Gashaw et al. (2015) reported inferior result (2.4-2.8) ton ha⁻¹ for the same cultivars with the aforementioned scholars and the present study. The difference in value of dry matter yield (DMY) might be observed due to the attributed varietal or environmental and/or their interaction differences reported (Diriba et al., 2014). In this study, Hairy Peruvian showed relatively higher DMY as compared to FG-10-09, FG-9-09, Magna-788 and Magna-801, but in other scholars, FG-9-09 cultivar had scored higher DMY as compared to FG-10-09(F), Hairy Peruvian, Magna-788 and Magna-801-FG(F) (Gashaw et al., 2015; Diriba et al., 2014). This yield differences might be due to the growth stage, leaf to stem ratio, moisture conditions at harvest and processing method (Veronesi et al., 2010).

Dynamics of forage production across cutting cycles

Stand height and DMY of the present study showed highest values at cutting cycles of 2, 3 and 4 as compared to the 1st cutting. However, for LTSR there was no increment with cutting cycle increases from 1st to 4th cutting. This report quite agreed with Diriba et al. (2014), Gashaw et al. (2015), and Walie et al. (2016) who

showed the values of stand height and DMY to increase as the cutting cycle increased for the same alfalfa cultivars. Different reports indicated that the optimal harvest interval for alfalfa is between 30 and 35 days (Sheaffer, 2000). But, in the current study, longer time interval was recorded, around 57 days as compared to the benchmark indicated. This could be observed due to the difference in varieties, temperature, soil texture and management. The variation of harvesting interval might be based on a compromise between yield, quality, regrowth, and persistence (Sheaffer, 2000). But, a maximum yield on alfalfa is achieved at reproductive maturity when the nutritive value of the forage is at a minimum (Collins and Fritz, 2003).

CONCLUSION AND RECOMMENDATION

It can be concluded that all the alfalfa cultivars had not shown any significant difference in DMY and nutritive content, but Hairy Peruvian had relatively good DMY, LTSR and higher stand height, as compared to FG-10-09(F), FG-9-09(F), Magna-801-FG(F) and Magna-788. As a result, it will be good to promote Hairy Peruvian cultivar for further demonstration and seed production.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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