

# Evergreen Fodder: A Review on Leaf Biomass Yield and Chemical Composition of Fodder Trees and Shrubs in Ethiopia

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## Abstract

The feed shortage is the key bottleneck of livestock production sector in Ethiopia. Ever green fodder of trees and shrubs in agroforestry systems provide an alternative solution to boost availability of feed throughout the year. The paper was reviewed leaf biomass yield and chemical composition of major fodder trees and shrubs in agroforestry systems across different agroecologies in Ethiopia. Biomass dry matter yields of indigenous fodder trees were significantly different ( $p < 0.05$ ) across agroecologies. In the high land, biomass yield/ha was greatest ( $p < 0.05$ ) for *E. brucei* followed by *H. abyssinica* and *V. amygdalina* while the lowest was for *A. alpine*. In the midland, *D. steudneri* had the highest ( $p=0.001$ ) biomass yield/tree while the least was observed in *M. ferruginea* and *V. amygdalina*. The highest biomass yield in the lowland was for *C. africana* and *E. racemose*. In general, the average dry matter biomass yields were 0.22– 15.43, 0.28– 23.1 and 10.81 –54.1 kg dry matter/tree for highland, midland and lowland, respectively. *Erythrina brucei*, *Dracaena steudneri* and *Cordia africana* had the highest biomass yield in highland, midland and lowland, respectively ( $p < 0.05$ ). There were significant differences in chemical composition among the fodder tree and shrub species. Chemical composition of the fodder species had on average 89.63% dry matter, 21.7% crude protein, 66.56% digestible dry matter, 52.95% neutral detergent fiber, 28.66% acid detergent fiber, 11.57% acid detergent lignin, 4.17% ether extract, 7.49% ash, 24.28 hemicelluloses and 17.09 cellulose.

**Key words:** Agroforestry systems, Chemical composition, Leaf yield, Shrubs, Trees, Ethiopia

Ethiopia is the country with the largest livestock population in Africa. Livestock plays an important role in providing export commodities, such as live animals, hides, and skins to earn foreign exchanges to the country [1]. Despite the number of livestock, productivity per head is very low [2]. This is mainly caused by feed shortage and poor quality of forage [3]. The major feed resources are crop residues and natural pasture. Inadequate feed supply is a major constraint to ruminant production during the dry season in Ethiopia which is one of the reasons for poor performance of livestock. In many rural areas, the available feeds from grazing are not sufficient to meet the maintenance requirements of grazing animals during dry periods [4]. Because of population pressure the available grazing land is shrinking which could lead to land degradation and reduced feed availability [5]. Thus, there is a need to fill the feed gap especially with protein source feed through increased utilization of evergreen fodder from trees and shrubs.

In Ethiopia, smallholder farmers carry out various agroforestry practices/systems depending on the socioeconomic and biophysical conditions such as coffee shade-based system, scattered trees on farmland, home gardens, woodlots, boundary planting and silvo pastures [6]. These agroforestry systems are endowed with indigenous and exotic fodder trees and shrubs thus considered as fodder banks. The fodder trees and shrubs are a viable way to increase the quality and availability of feeds

for livestock [7]. Fodder trees are recognized as an important component of animal feeds in many parts of the world [8], as they contain high levels of crude protein, mineral and continue to produce well in the dry season because of their deep root systems [9].

Fodder trees and shrubs are a potentially cheap protein supplement for ruminants and highly valued by farmers particularly during the critical periods of the year when the quantity and quality of herbage is limited and considered as a more reliable feed resource of high quality to develop sustainable feeding systems. Fodder trees and shrubs have been used for generations as a multipurpose resource and farmers preferred them for high biomass production multi-functionality, life span and compatibility to the cropping system [10]. The main features of trees as a feed resource is the high crude protein content ranging from 10 to 25% dry matter and may be considered as a more reliable feed resource of high quality to develop sustainable feeding systems and increasing livestock productivity [10].

Fodder or browse production from trees and shrubs is one of the benefits of agroforestry. Agroforestry is a dynamic ecologically based natural resource management system that through the integration of tree/woody perennials in to farm and rangelands diversifies and sustains production for increased social, economic and environmental benefits [11]. Azim *et al.* [12] also pointed out trees and shrubs are increasingly

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recognized as important components of animal feeding, especially as suppliers of protein. The importance of trees and shrubs for their nutrition quality for browsing and grazing animals, especially in areas of poor-quality pastures for ability of most browse species to remain green for a longer period is attributed to deep root systems, which enable them to extract water and nutrients from deep in the soil profile and this contributes to the increased CP content of the foliage.

The eastern Ethiopia highlands have mixed crop livestock production systems with livestock production being dominated by the semi-arid to arid climatic conditions. Moreover, natural pasture and crop residue are the main sources of feed characterized by zero grazing system with stall-feeding technique. However, feed shortage mainly during the dry season (March to June) when farmers finish stored feed is a critical problem in the described study area [13]. To alleviate these problems there is a need to introduce fodder trees and shrubs to the area which can be integrated with the food and/ or cash crops, planted at the border of crop fields or on marginalized lands.

Similar observations have been reported in other regions that have similar production systems where fodder trees and shrubs become prominent in animal feeding towards the end of the dry season and the quality and quantity of grass is at its worst. For example, the farmers in Central Kenyan highlands have experienced the habit of planting fodder trees as a fodder bank around the compound or near the zero grazing units [14]. Belete *et al.* [15] also noted that browse species have

considerable potential for mixed crop livestock production system to overcome low nutritive value of crop residues and mature native pasture that limit livestock productivity. The paper reviews leaf biomass yield and chemical composition of fodder trees and shrubs in Ethiopia with the following specific objectives:

1. To review the leaf biomass yield of fodder trees and shrubs across three agroecology in Ethiopia
2. To review chemical composition of fodder trees and shrubs leaves at different locations in Ethiopia
3. To review the difference between dry and wet season chemical composition of fodder trees and shrubs leaves at the same site in Ethiopia

#### *Leaf biomass yield of major indigenous fodder tree species in three agro-ecologies of Ethiopia*

The biomass dry matter yield of indigenous fodder trees is presented in (Table 1). Biomass dry matter yields of IFT were significantly different ( $p < 0.05$ ) across agroecologies. In the high land, biomass yield/ha was greatest ( $p < 0.05$ ) for *E. brucei* followed by *H. abyssinica* and *V. amygdalina* while the lowest was for *A. alpine*. In the midland, *D. steudneri* had the highest ( $p=0.001$ ) biomass yield/tree while the least was observed in *M. ferruginea* and *V. amygdalina*. The highest biomass yield in the lowland was for *C. africana* and *E. racemose*. In general, the average dry matter biomass yields were 0.22- 15.43, 0.28–23.1 and 10.81 –54.1 kg dry matter /tree for highland, midland and lowland, respectively.

Table 1 Leaf biomass yields (kg) of major selected indigenous fodder trees of the three agroecology sites of Sidama, Ethiopia

Plant species	Density (plant/ha)	Biomass yield (kg dry matter /plant)	Total biomass (kg dry matter /ha)
Highland			
<i>Arundinaria alpina</i>	1523 <sup>a</sup>	0.22 <sup>d</sup>	335.1 <sup>c</sup>
<i>Hygenia abyssinica</i>	76.7 <sup>b</sup>	5.22 <sup>b</sup>	400.4 <sup>b</sup>
<i>Erythrina brucei</i>	43.3 <sup>c</sup>	15.43 <sup>a</sup>	668.1 <sup>a</sup>
<i>Vernonia amygdalina</i>	28.3 <sup>d</sup>	1.13 <sup>c</sup>	31.9 <sup>d</sup>
CV	18.3 <sup>e</sup>	44.12	24.8
p value	0.02	0.001	0.002
Midland			
<i>Cordia africana</i>	86.7 <sup>b</sup>	7.1 <sup>c</sup>	615.6 <sup>b</sup>
<i>Erythrina brucei</i>	23.3 <sup>d</sup>	8.07 <sup>b</sup>	188.0 <sup>d</sup>
<i>Mellettia ferruginea</i>	220 <sup>a</sup>	2.97 <sup>d</sup>	653.4 <sup>a</sup>
<i>Vernonia amygdalina</i>	31.7 <sup>c</sup>	0.28 <sup>e</sup>	8.88 <sup>e</sup>
<i>Dracaena steudneri</i>	18.3 <sup>c</sup>	23.15 <sup>a</sup>	4237 <sup>c</sup>
CV	18.2	16.27	22.3
p value	0.02	0.001	0.002
Lowland			
<i>Balanites aegyptiaca</i>	43.3 <sup>b</sup>	7.1 <sup>b</sup>	307.4 <sup>a</sup>
<i>Cordia africana</i>	20 <sup>c</sup>	10.81 <sup>a</sup>	216.2 <sup>c</sup>
<i>Acacia tortolis</i>	66.7 <sup>a</sup>	4.1 <sup>c</sup>	273.5 <sup>b</sup>
<i>Euclea racemose</i>	8.3 <sup>d</sup>	9.67 <sup>a</sup>	80.3 <sup>d</sup>
CV	26.1	24.44	25.1
p value	0.005	0.001	0.006

Mean values in a column within Agroecology having different superscripts differ significantly each other  
kg = kilogram; DM = Dry mater; ha = hectare

The most widely utilized fodder trees identified in the current study were *A. alpine*, *H. byssinica*, *E. brucei*, *V. amygdalina*, *C. Africana*, *M. ferruginea*, *D. steudneri*, *B. aegyptiaca*, *A. tortolis* and *E. racemose* during dry season. The leaf biomass yield per hectare observed in the current study revealed that the fodder species had high leaf dry matter yield to supplement the poor-quality feed during the dry season [16]. This result was supported by previous studies concerning the

available shrubs and fodder trees in different agroecologies of Ethiopia [17-18]. The variation in biomass dry matter yield of IFT in the current study could be due to tree management and differences in growth and dominance of the species as suggested by Ayele *et al.* [17]. Moreover, the biomass yield in each species was affected by variation in agroecology, which is potentially attributed to altitudinal differences, climatic factors, soil fertility and land use system [18].

In agreement with the current finding, Ayele *et al.* [17] reported that on average mid land agroecology had less biomass yield of fodder trees (7.98–19.78 kg/tree) than lowland (9.87–178.06 kg/tree) in Kellem wolega, Ethiopia. Additionally, Shimelse *et al.* [15] reported similar results for leaf biomass dry matter yield of browse species which ranged from 77.6 to 871 kg/plant in Nechisar National Park, Ethiopia. In contrast to the current findings, Geta *et al.* [18] reported higher biomass yields of 24.55 kg/tree to 958.76 kg/tree of IFT in Wolayta zone, southern Ethiopia. The total biomass yield per hectare reported in the current study was less than the value (500–800 kg/ha) reported by Ayele *et al.* [17] in Kellem Wollega and 29 kg/ha – 959 kg/ha in Wolayta, south Ethiopia [18]. This variation may be due to difference in land use, soil fertility and amount of rain fall. Generally, the result revealed that the highest biomass yield was recorded in *E. brucei* followed by *M. ferruginea*, then *C. africana* in the three districts and lowest in *V. amygdalina*. In agreement with the current study Geta *et al.* [18] reported that *E. brucei* and *C. africana* have high crude protein content and can be sources of protein supplements for ruminant animals. Some possible inconsistencies in biomass yield and values of chemical composition reported by Mekoya *et al.* [9] could be

due to variations in season of samples collection, soil fertility and altitudinal differences of the sampling site.

#### Chemical composition of fodder trees and shrubs leaves in western Hararge, Ethiopia

The chemical composition leaves of fodder trees and shrubs are presented in (Table 2). The ash content of the selected fodder trees and shrubs ranged from 7.3 to 16.6%, being the highest for *Cordia africana* but the lowest for *Combretum molle*. This variation may be due to environmental factors and varietal difference of the plants. Generally, the high ash content of such fodder trees and shrubs is indicative for such feed resources to be rich in minerals and may satisfy mineral requirement of the animals. The crude protein content of *Acacia brevispica* was the highest (*Erythrina abyssinica* > *Cordia Africana* > *Combretum molle*). The crude protein content of *Acacia brevispica* was in agreement with the report of Rahim *et al.* [19] who found shrub leaves to contain of 16.6% crude protein. Likewise, the crude protein content of *Erythrina abyssinica* and *Cordia africana* was similar to the report of Simbaya [20] who noted fodder trees to have crude protein contents of about 14.29%.

Table 2 Mean proximate chemical composition and cell wall constituents of selected fodder trees and shrub leaves in the West Hararghe, Ethiopia

Fodder tree and shrub species	Chemical composition on % dry matter basis								
	DM	% Ash	% CP	% NDF	% ADF	% ADL	Hcel	Cel	RFV
<i>Acacia brevispica</i>	93.3 <sup>c</sup>	8.7 <sup>c</sup>	17.5 <sup>a</sup>	47.49 <sup>c</sup>	24.87 <sup>d</sup>	19 <sup>b</sup>	22.6 <sup>a</sup>	5.8 <sup>b</sup>	136.3 <sup>a</sup>
<i>Cordia africana</i>	94.2 <sup>b</sup>	16.6 <sup>a</sup>	14.1 <sup>c</sup>	59.1 <sup>a</sup>	53.3 <sup>a</sup>	34.6 <sup>a</sup>	5.8 <sup>d</sup>	18.7 <sup>a</sup>	74.8 <sup>d</sup>
<i>Combretum molle</i>	95.9 <sup>a</sup>	7.3 <sup>d</sup>	8.9 <sup>d</sup>	48.4 <sup>b</sup>	33.4 <sup>c</sup>	23.4 <sup>b</sup>	15.1 <sup>b</sup>	10 <sup>b</sup>	121.3 <sup>b</sup>
<i>Erythrina abyssinica</i>	94.6 <sup>b</sup>	13.7 <sup>b</sup>	15.8 <sup>b</sup>	50.2 <sup>b</sup>	37.4 <sup>b</sup>	20.3 <sup>b</sup>	12.7 <sup>c</sup>	17.1 <sup>a</sup>	112.9 <sup>c</sup>
Mean	94.5	11.5	14.1	51.3	37.2	24.3	14.1	12.9	111.3
LSD (5 %)	0.4	1.0	1.6	2.1	2.2	6.5	2.3	6.1	5.7
P-value	**	**	**	**	**	**	**	**	**
CV (%)	0.5	9	11.4	4.2	6.2	27.5	16.4	48.5	5.3

Note: Means followed by different superscripts within a column are significantly different at  $P \leq 0.05$  level of significance; \*\*=significant at  $P < 0.01$ ; DM= dry matter; CP=crude; NDF=neutral detergent fiber; ADF= acid detergent fiber; ADL= acid detergent lignin; Hcel= hemicelluloses; Cel=cellulose and RFV= relative feed value

The neutral detergent fiber (NDF) contents of *Cordia africana* were significantly ( $P < 0.01$ ) highest. The result of this study (Table 2) shows that the NDF contents of fodder trees and shrub was higher than that reported by Azim *et al.* [12] for fodder tree leaves. This may be due to the season of sample leaf collection, stage of maturity of the plant, and environmental factors. The NDF content of roughage feeds with less than 45% was grouped as a high-quality feed, while feed with NDF content of 45-65% was categorized as medium quality feed. Therefore, all experimental fodder trees and shrubs had less than 65% of NDF content and can be categorized as medium quality feed. NDF content above 55% was reported to limit dry matter intake, indicating that the NDF content of the *Cordia africana* (59.14%) in this study could affect feed intake of animals, which may limit productivity.

The acid detergent fiber (ADF) content of the fodder tree and shrub species was significantly different ( $P < 0.05$ ) and was in the order of *Cordia africana* > *Erythrina abyssinica* > *Combretum molle* > *Acacia brevispica*. Cellulose and hemicellulose contents were also significantly different among plant species. Regarding the relative feed value (RFV), *Acacia brevispica* had significantly higher ( $P < 0.01$ ) RFV than *Combretum molle*, *Erythrina abyssinica* and *Cordia africana*.

#### Nutritional composition of fodder trees and shrubs in eastern Ethiopia

The nutrient chemical composition of different fodder trees and shrubs showed wide variations. The values of chemical composition variations in the present evaluated species ranged from 88.35 to 90% DM, 14.66 to 25.13% CP, 59.94 to 71.99% DDM, 1.83 to 2.52% DMI, 47.52 to 65.36% NDF, 21.7 to 37.16% ADF, 9.42 to 14.49% ADL, 3.04 to 5.78 EE, 7.51 to 12.60% Ash, 10.35 to 32.23 Hemicelluloses, 11.59 to 22.67 cellulose and 117.48 to 142.46 RFV (Table 3). These variations could be associated with the agroclimatic condition and morphological differences of the species. Solomon [21] noted that the high variability in the composition of different fodder trees and shrubs could be attributed to within species variability owing to factors such as plant part, harvesting regime, season and location. The difference in chemical composition between species and within genera associated with the inherent nature of the species [15].

The evaluated fodder trees and shrubs species found to have on average 21.7% CP. Inline to this study high CP content of different browse species ranges 17 to 22% was also reported by [22]. Among the present evaluated species, the lowest CP ranged from 14 to 16% was also recorded by the *Morus alba* species. These values are comparable to those reported by [12] indicated CP content of 15.46% from the same species.

High CP content of browse species provides vitamins and mineral elements, which are often lacking in mature natural grassland pastures, especially during the dry season [23]. Most

of the Ethiopian dry forages analyzed and roughages had on average 6.2% CP content, which suggests that the microbial requirement can hardly be met unless supplemented with protein rich feeds [24].

The neutral detergent fiber (NDF) values of the present fodder trees and shrubs species have also on average 52.95%. According to Garcia *et al.* [25] as NDF values increase, total feed intake will also decrease. In the present evaluated species, the highest NDF and Hemicelluloses contents which shows low fodder value and less potential to be preferred by livestock were recorded by the species *Cajanus cajan*. Comparable to this study Cheva Isarakul [26] reported 61% NDF value. However, the highest Cellulose content, which is the principle carbohydrate constituent of plant cell membranes and implying as potential source of carbohydrate to feed scared of livestock

was recorded in the species *Morus alba*. Moreover, based on the quality standard described by [25], [27] the CP value of the evaluated specie fall in the prime and very good quality standard, and NDF value ranged from very poor (>65%) to very good (47 to 53%). Similarly, the ADF content of most of the treatment species except *Morus alba* falls in the excellent to prime quality standard range (i.e. 31 to 35% and <31%, respectively). The DDM values of all species fall in the very good and prime quality standard. Moreover, DMI of the treatment species fall in the very good range except *Cajanus cajan* which falls in the fair range. Maximum DMI is very important factor in ensuring the release of adequate nutrients for maintenance and production. Therefore, among the studied species *Moringa oleifera* and *Morus alba* would be preferred for their high DMI values.

Table 3 Nutritional value of fodder trees and shrubs planted at Kersa experimental site, eastern Ethiopia

Trees / shrubs	DM%	CP%	DDM%	DMI%	NDF%	ADF%	ADL%	EE%	Ash%	Hem	Cel	RFV
<i>Sesbania esban</i>	89.8b	20.0ab	71.2a	2.3b	51.9b	22.6c	11.0ab	3.0c	9.2b	29.2ab	11.5b	127.9b
<i>Moringa oleifera</i>	88.3c	25.1a	71.9a	2.5a	47.0c	21.7c	9.4b	4.5b	9.8b	25.3b	12.2b	142.4a
<i>Cajanus cajan</i>	90.9a	27.1a	63.1b	1.8c	65.3a	33.1b	11.3ab	5.7a	7.5c	32.2a	21.8a	89.8d
<i>Morus alba</i>	89.3bc	14.6b	59.9c	2.5a	47.5c	37.1a	14.4a	3.3c	12.6a	10.3c	22.6a	117.4c
CV (%)	0.5	23.8	2.3	4.0	3.9	6.9	17.6	11.5	7.5	11.3	16.5	4.5
LSD	0.9	9.7	2.9	0.1	3.9	3.7	3.8	0.9	1.3	5.3	17.9	10.2

#### Chemical compositions and in vitro digestibility values of fodder trees in north eastern Ethiopia

All the chemicals analyzed varied significantly ( $p < 0.001$ ) among the tree species. The mean dry matter varied from 909 g kg<sup>-1</sup> for *C. sinensis* and *D. glabra* to 935.3 g kg<sup>-1</sup> for *A. nilotica*, whereas the organic matter varied from 933.2 g kg<sup>-1</sup> for *T. indica* to 971.4 g kg<sup>-1</sup> for *A. nilotica*. The ash content was the lowest for *A. nilotica* and the highest for *T. indica*. The CP content was the highest for *B. discolor* and the least for *D. glabra*. The NDF content of the cell wall ranged from 329 g kg<sup>-1</sup> for *T. indica* to 636.5 g kg<sup>-1</sup> for *Z. spina-christi*, and that of the ADF varied from 265.8 g kg<sup>-1</sup> for *A. tortilis* to 381.8 g kg<sup>-1</sup> for *Z. spina-christi*. The leaves of *D. glabra* were the least lignified and those of *A. nilotica* were the most lignified. The in vitro digestibility test indicated that *A. tortilis* had the most digestible OM in the DM while *C. sinensis* had the least digestibility in the leaves compared to other tree and shrub species (Table 4). The crude protein, which protein was the highest for *B. discolor* (181.9 g kg<sup>-1</sup> DM) and the least for *D. glabra* (116.4 g kg<sup>-1</sup>) indicating that *B. discolor*, is discolor was the most protein rich of all the rest. The comparison between the leguminous and the non-leguminous types of species revealed significant differences ( $p < 0.05$ ) between the two types for all chemicals but CP. The leguminous species had significantly higher DM, OM, lignin and in vitro digestibility, whereas the non-leguminous species had significantly higher ash, NDF, ADF and hemi-cellulose.

The dry matter content of the sampled leaves indicated that the leaves had very high proportion of organic matter, which ranged from 908.8 to 935.3 g kg<sup>-1</sup> DM. Figures for dry matter could go way below 900 g kg<sup>-1</sup> DM depending on species and season of harvest [28-29]. The ash content was the lowest for *A. nilotica* and the highest for *T. indica* indicating that the latter was mineral rich compared to the other tree species. The ash content was generally lower compared to reported for leaves of some fodder trees and browse forages including *T. indica* [29-30], which may be due to soil fertility differences, season of harvest and harvesting stages among sites. The CP content of all the seven fodder tree species was

well above the minimum (70–80 g kg<sup>-1</sup> DM) level required for ideal ruminal fermentation, but it was below the content reported for five planted forage legumes, *Moringa spp.* and foliage of four highland fodder tree species [31-32]. It was within the range reported for leaves of some fodder trees [29], [33] including *Acacia nilotica*, *A. tortilis* and *Ziziphus spina-christi* [34] and browse forages [30]. And this is in contrary to CP of pre dominantly leaves and twigs of 21 fodder tree species of which seven of them had content below the minimum required level [35].

The neutral detergent fibre content of the cell wall (i.e., the insoluble) ranged from 329.9 g kg<sup>-1</sup> DM in *T. indica* to 636.5 g kg<sup>-1</sup> in *Z. spina-christi* indicating that the latter is the richest in its energy content compared to the others. The NDF contents are lower when compared with some reported studies for browse forages [30], comparable to higher with the content for some fodder species reported by [31], [29] and much higher to *Moringa* species [32].

The hemi-cellulose ranged from 42.1 in *Brachylaena discolor* to 263.9 g kg<sup>-1</sup> in *Dobera glabra*, and this is partly lower and partly within reported range for browse species [30]. The acid detergent fibre ranged from 265.8 in *Acacia tortilis* to 381.8 g kg<sup>-1</sup> in *Ziziphus spina-christi*. The acid detergent fibre content fall within the reported range for some fodder trees [33], lower to comparable with figures reported for forage species. It was comparable to higher than the reported figures for some tree fodders and browse species [29-30] and higher to that of *Moringa* species [32]. The analysis of the lignin content indicated that the leaves of *Dobera glabra* were the least lignified and those of *Acacia nilotica* were the most lignified. The lignin content of the seven fodder tree species is generally low when compared to reported contents for leaves of some fodder trees [33]. The estimation of the in vitro digestibility indicated that the *Acacia tortilis* (686.7 g kg<sup>-1</sup>) had the most digestible leaves and *Clonorchis sinensis* (511.4 g kg<sup>-1</sup>) had the least digestible organic matter (OM) in the dry matter (DM). The digestibility of the tree species is within reported ranged for some tree fodders [29] and comparable and even higher to digestibility of predominantly leaves and twigs of 21 fodder tree

species [35]. Generally, the observed variations in chemical compositions with reported works earlier on some of the species could be due to provenance differences, climatic influences on

foliage growth and nutrient accumulation, soil fertility differences, season of harvest and harvesting stages among sites [36-38].

Table 4 Mean nutritional compositions of seven fodder tree species (on g kg<sup>-1</sup> DM), N = 80

Tree species	DM	OM	Ash	CP	NDF	ADF	Hemicellulose	Lignin	IVDOMD
<i>A. nilotica</i>	935.3a	971.4a	28.6a	157.6a	342.1a	284.7ae	57.4a	110.7a	622a
<i>A. tortilis</i>	920.2b	943.7b	56.3b	152.9a	338.4b	265.8b	72.6b	108.2b	686.7b
<i>B. discolor</i>	930.4a	957.7c	42.3c	181.9b	329.9c	287.8e	42.1c	102.1c	647.5ab
<i>C. sinensi</i>	908.9c	935.2bd	64.8bd	159.3ab	630.9d	379.5c	251.3d	78.2d	511.4d
<i>D. glabra</i>	908.8c	938.9bd	61.1bd	116.4c	635.2e	371.3d	263.9e	72.3e	555.9e
<i>T. indica</i>	922b	933.2bd	66.8bd	159.3ab	329c	279.7a	49.3f	101.1c	669.6bc
<i>Z. spina-christi</i>	906.3	941bd	59b	162.7ab	636.5e	381.8c	254.8d	74.9f	550.4e
Mean	918.4	945.9	54.1	155	469.8	323.4	146.4	92.3	603.6
SE	1.33	1.71	1.71	2.82	16.74	5.58	11.28	1.77	7.78
F value	52.9	29.5	29.5	13.4	49,581.9	1764.9	6536.5	984.1	54.2

SE standard error of the overall mean for each parameter;

Means in same column with different superscript are significantly different P < 0.05

#### Chemical composition and in-vitro organic matter digestibility of fodder trees in southern Ethiopia

Chemical composition and in vitro organic matter digestibility of multipurpose fodder trees are presented in (Table 5). The highest (p<0.05) ash content was recorded for *M. alba* in dry and wet season while the lowest (p<0.05) was for *Ehretia cymosa* in the dry season. The current ash content for *Morus alba* was shown higher result than reported earlier for

*Gongronema latifolium*, *Azadirachta indica* and *Vernonia amygdalina* [39-41]. However, the ash content observed for *Ehretia cymosa*, *Myrmeciza ferruginea* and *V. amygdalina* was comparable with the result reported by [42] for *E. capensis*, *F. sycomorus*, *Maesa lanceolata* and *Rehmannia glutinosa*. The highest (p<0.05) CP content was for *M. alba* during dry and wet season and *M. ferruginea* during wet season while the lowest (p<0.05) was for *Commiphora africana* in the dry season.

Table 5 Chemical composition and in vitro organic matter digestibility of selected multi-purpose fodder trees

Season	Species	Chemical composition and in vitro organic matter digestibility (%DM)							
		DM%	Ash	EE	CP	NDF	ADF	ADL	IVOMD
Dry	<i>Balanites aegyptiaca</i>	97.2c	16.8b	1.0d	17.0b	34.9e	20.2f	11.9e	71.1c
	<i>Commiphora africana</i>	98.1b	15.5c	1.4c	10.6e	61.2a	35.0b	22.2a	57.2e
	<i>Ehretia cymosa</i>	98.4a	11.4e	4.3a	13.6d	53.4b	38.0a	17.3b	62.3d
	<i>Myrmeciza ferruginea</i>	95.2d	12.2d	1.6c	16.5b	50.9c	32.4c	14.1c	76.1b
	<i>Morus alba</i>	98.4a	21.1a	1.7b	19.2a	42.0d	20.6e	12.1d	81.3a
	<i>Vernonia amygdalina</i>	95.6d	12.1d	0.7e	14.3c	43.1d	21.0d	10.2f	81.5a
Wet	<i>Balanites aegyptiaca</i>	95.8d	16.9b	1.4b	17.9b	29.8e	17.1	8.6e	79.1c
	<i>Commiphora africana</i>	97.8c	11.5	1.2e	13.3d	56.9a	32.8a	18.0a	65.6e
	<i>Ehretia cymosa</i>	98.0b	11.6c	4.6a	16.5c	50.9b	32.2b	17.3b	70.2d
	<i>Myrmeciza ferruginea</i>	94.9e	11.9c	1.3c	20.1a	50.6b	28.5c	15.2c	83.2b
	<i>Morus alba</i>	96.3c	18.6a	1.3c	20.7a	40.0c	21.2d	11.8d	83.1b
	<i>Vernonia amygdalina</i>	94.9e	10.6d	1.3d	17.3b	36.2d	15.1f	8.7e	84.8a
P-value	Species	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
	Season	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
	Species * Season	0.0001	<.0001	0.7048	<.0001	0.0849	0.0167	0.0035	<.0001

Different letters in the column shows significant (P < 0.05) difference DM = Dry matter, OM = Organic matter, EE = Ether extract, CP = Crude protein, NDF = Neutral detergent fiber, ADF = Acid detergent fiber, ADL = Acid detergent lignin, IVOMD=In-vitroorganic matter digestibility

Crude protein content for *Morus alba* in wet season is comparable with the result reported by [10] for *B. polystachya* and *M. lanceolata* but higher than the result reported earlier [43], [39] for *Vernonia amygdalina*, *Ehretia cymosa* and *Commiphora africana* and [40] for *E. capensis*, *F. sycomorus*, *M. lanceolata* and *Rehmannia glutinosa*. However, it was lower than the result reported for *Vernonia amygdalina* and *Gongronema latifolium* [39]. The CP content for *Commiphora africana* and *Vernonia amygdalina* in the current study was lower than the result reported by [2]. The CP content for

*Balanites aegyptiaca* during dry period was higher than the result reported by [2] but it is comparable with the result reported for *Balanites aegyptiaca* and other MPTs in the dry season [44].

*Ehretia cymosa* and *Commiphora africana* shown the highest (p<0.05) neutral detergent fiber (NDF) content and the lowest (p<0.05) was recorded for *B. aegyptiaca* during dry and wet season. The NDF content observed for *B. aegyptiaca* in the current study was shown lower result than the result reported by [45] for *M. alba* leaf collected during dry period and for

*Commiphora africana* reported by [46]. The NDF content for *Commiphora africana* in the current study is higher but the neutral detergent fiber (NDF) content for *Balanites aegyptiaca* is lower than the result reported by [43], [2], [46]. However; the neutral detergent fiber (NDF) content for *Commiphora africana* is comparable with the value reported for *Ficus sycomorus* and *Maesa lanceolata* [42].

The lowest ( $P < 0.05$ ) ADF value was recorded for *B. aegyptiaca* during dry season and *Vernonia amygdalina* during wet season. The highest ( $p < 0.05$ ) ADF was recorded for *E. cymosa* and *C. africana* during dry and wet season. The ADF content observed in the current study for *Morus alba* in dry and wet season was lower than the result reported earlier for *Vernonia amygdalina*, *E. cymosa* and *Commiphora africana* by [10], [43] for *B. polystachya*, *Maesa lanceolata* and *Vernonia amygdalina*. The lowest ADL content was observed for *Vernonia amygdalina*. The ADL content recorded in this study for *Balanites aegyptiaca* and *Vernonia amygdalina* in wet season was lower than the result reported earlier [10] for *B. polystachya*, *Maesa lanceolata* and *Vernonia amygdalina* and within the range of the result reported by Takele *et al.* [43] for *Vernonia amygdalina*, *Ehretia cymosa* and *Commiphora africana*. The highest ( $P < 0.05$ ) *In-vitro* organic matter digestibility (IVOMD) was recorded for *Morus alba* and

*Vernonia amygdalina* during dry season. The IVOMD value for *Morus alba*, *Vernonia amygdalina* and *Millettia ferruginea* in the current is higher than the result reported by [10] for *Buddleja polystachya*, *Maesa lanceolata* and *Vernonia amygdalina*, [45] for *Morus alba* leaf harvested in wet season and [47] for leaf, twig, pod and whole forage of *Moringa oleifera* and *Moringa stenpetala*.

## CONCLUSION

Fodder trees and shrubs provide evergreen leaf fodder around the year to supplement nutritionally poor dry forage during dry season in Ethiopia. Tree leaf biomass fodder contains rich crude protein (cp), minerals than other feed sources. Fodder trees and shrubs produce cheapest and high leaf biomass fodder per a unit area which is accessible throughout dry season for livestock. *Erythrina brucei*, *Dracaena steudneri* and *Cordia africana* had the highest biomass yield in highland, midland and lowland, respectively. The chemical composition of fodder trees and shrubs leaves shown variation due to species, altitude, soil fertility, season, and others. Thus, I recommend the intensive fodder trees and shrubs planting via agroforestry campaigns to ensure sustainable feeding system in the whole Ethiopia.

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