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Evaluation of multi-functional fodder tree and shrub species in mid-altitudes of South Omo Zone, Southern Ethiopia

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A study was conducted to evaluate the early growth performance and nutrient composition of some selected tree/shrub species in the fodder bank agroforestry system. *Moringa stenopetala*, *Terminalia brownii, Morus alba*, *Melia azedarach,* and *Sesbania sesban* were used for this study. Square quadrants of 16 m^2 plot sizes were established with the RCBD of three replications. Seedlings were planted with 1 m × 1 m spacing between rows and plants respectively. The growth and chemical composition of the studied tree/shrub species were evaluated with one way ANOVA. The growth parameters and nutrient composition of the studied fodder tree/shrub species are significantly ($P \leq 0.05$) varied. The nutrient composition of the studied tree/shrub species ranged between percentages of 88.3 - 90.6 of Dry Matter, 5.7 - 13 of Ash, 12.45 - 22.35 of Crude Protein, 11.8 – 23.5 of Acid Detergent Fiber and 18.1 - 33.6 of Neutral Detergent Fiber. *S. sesban* and *M. stenopetala* are the consistent and superior tree/shrub species with growth performance and nutrient content parameters respectively. In addition to this, the selected fodder tree/shrub species are well adapted in the fodder bank agroforestry system and have considerable nutrient constituents. Thus the studied tree species seems to be a potential alternative for complementing the basal feed.

Key words: Fodder bank, livestock feed, South Omo, nutrient composition, agroforestry.

INTRODUCTION

Livestock is one of the major building blocks of the agriculture sector which takes part in a potential pathway out of poverty for many smallholders in Ethiopia (Lijalem et al*.*, 2015). It contributes 15 - 17% of the national GDP and more than 50% of household income (Samson and Frehiwot, 2014). South omo zone is the leading zone with livestock population (that is, cattle, goat and sheep) and apparently, the contribution is expected to be higher especially in the areas where enormous livestock population, production, and livestock-based practices are carried out (CSA, 2017). Consequently, livestock husbandry is considered primarily as the main source of income followed to crop production. Despite this the impact of feed shortage is also more pronounced in areas

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with large concentrations of livestock (Nassoro, 2014). Similarly feed shortage both in quality and quantity combined with land shortage and low productivity of local breeds are the leading constraints for livestock productivity in Southern Ethiopia (Chalchissa et al*.,* 2014; Membere, 2014). The current feed source such as natural pasture and crop residues are characterized as poor quality in terms of nutrients and minerals (Tolera et al*.,* 2012; FAO, 2018). On the other hand, fodder trees and shrubs are increasingly recognized as important components of animal feed; fodder tree leaves were found to be rich in protein, soluble carbohydrates, minerals, and vitamins, and showed great potential as alternate feed resource (Bakshi and Wadhwa, 2007; Azim et al., 2011) especially where alternative options are expensive (Hamer et al., 2007).

However, areas under fodder production are continuously reducing mainly due to the competition with cash/food crops (Cheema et al., 2011) and in turn planting of fodder trees seems difficult in uplands otherwise it is reserved for annual crops (Franzel et al*.,* 2014). According to CSA (2007) census, the total population was estimated as 212, 389 and this makes the district highly populous than the remaining districts in the zone. Despite this, the livestock feed demand is continuously increasing while accessing land for planting trees tends to be more difficult primarily due to the positive relationship between population growth and annual crop production for satisfying the increasing food demand. As it happens more lands will subject to crop production and in turn competition between trees and annual crops is expected to be more intense. Hence, the possible solution from tree planting perspective would be as Raghuvansi et al. (2007) argued that exploring alternate feed resources that do not compete with human feed is crucial. On the other hand, strengthening the existing practices as Franzel et al. (2014) noted that planting of multi-purpose fodder tree species in neglected niches such as hedges around the homestead, along field boundaries and contour lines as soil erosion barriers. This will allow another opportunity for mitigating the current livestock feed problem. With this regard fodder bank agroforestry practice has been considered as one of the substantial crop-livestock production systems that fit for both alternatives. The main objective of this system is to overcome protein deficiency of livestock and/or to supplement basal feed sources while established in areas without causing space competitions against annual crops (ESGIP, 2008).

Emmanuel and Tsado (2011) argued that of all fodder development works, legumes play a major role as they enrich the soil with nitrogen and produce highly digestible and protein-rich fodder. Moreover, the deep root of these multi-functional trees/shrubs extracts water and nutrients from deep in the soil profile enables them to maintain high protein in their parts especially during the dry season (Teferi et al., 2008; Wambugu et al*.,* 2011). The growth responses and nutrient contents of the readily available fodder tree/shrub species including the studied species in the fodder bank agroforestry system are yet unknown. Hence, this gap hinders further adoption of these tree/shrub species in the system and turn limits the potential benefits. With this context, the present study was aimed at assessing the early growth performance and nutritive values of the selected tree/shrubs in the fodder bank agroforestry system.

MATERIALS AND METHODS

Description of the study area

The present study was conducted for three years between 2016 and 2018 at Jinka Agricultural Research Centre on-station Debub Ari District, Southern Ethiopia. The station is geographically located between 05° 46' 30.4" - 05° 46' 47.8" N and 036° 33' 02.7" - 036° 33' 20.4" E with an altitude of 1383 m.a.s.l. The soil type is characterized as Cambisols with fine to very fine particles, with a pH range of 4.87 to 6.18 strongly acidic to slightly acidic (Kebede et al., 2017) which is a preferable range for majority of crop types that are potentially grown in the area. The study site has a bi-modal rainfall pattern with a shorter rainy season from March-May and the longest rainy season from August - November. The total annual rainfall is 1272.4 ± 250.7 mm. The annual mean minimum and maximum temperatures are 16.3 ± 0.9°C and 27.7 ± 1.4°C. The meteorology data was collected from Jinka station, there are some missing values for certain months and accordingly, the monthly average values for those climate elements were considered the available records only (Figure 1).

Experimental design, trial layout, and management

Moringa stenopetala (Bak.) Cuf., *Terminalia brownii* (Fres.)*, Morus alba* (L.), *Melia azedarach* (L.)*,* and *Sesbania sesban* (L.) Merr. were tested under the present study. The first two species are indigenous to southern Ethiopia and the latter three are introduced to Ethiopia during the last three decades. The multi-function, ecology, distribution and botanical characteristics of the studied tree/shrub species are described in different literatures (Stein-müller et al., 2002; Abuye et al., 2003; Jiru et al., 2006; Bekele, 2007; Chiffelle et al., 2008; Sultan et al., 2008; Orwa et al., 2009; Degefu et al. 2011; Oosting et al, 2011; Mani et al., 2011; Gomase et al., 2012; Nigussie and Alemayehu, 2013; Seifu, 2014). Square quadrants with 4 m × 4 m plot sizes were established horizontally along the strips with RCBD of three replications. Each plot was received sixteen tree/shrub individuals of the same species. Seedlings were planted during the onset of the rainy season (April, 2016) with 1 X 1 m spacing between rows and plants respectively. This spacing enables them to cut frequently and induce high herbage production (Jamala et al*.,* 2013). With the exceptions of *M. alba* cuttings for the rest of tree/shrub species seedlings were used. The following criteria are considered for choosing fodder tree/shrub species of the present study such as availability for further adoption, high survival rate, ease of propagation, and permit periodic pruning, high leaf yields and good nutritional value (Chakeredza et al., 2007). Diameter (1.3 m above ground) and height were measured by using caliper and meter tape respectively.

Sample collection and nutrient analysis

Every six months fresh leaf and tender branch/twig samples were collected from eight sample individuals (from interior two planting

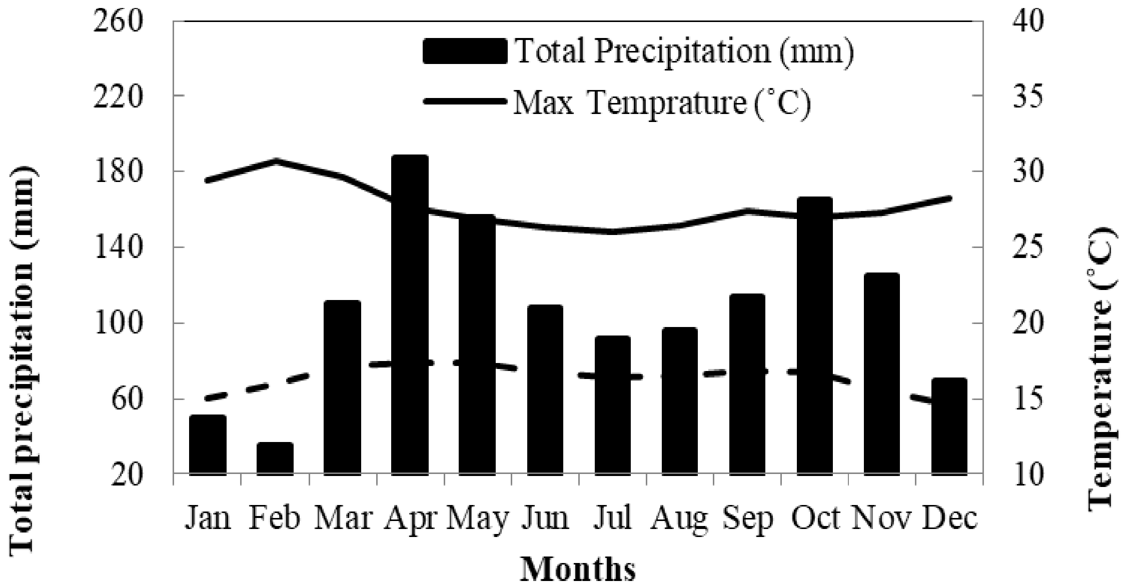

Figure 1. Climate diagram for the monthly average of the total rainfall, minimum temperature, and maximum temperature values from Jinka meteorology station of the South Omo Ethiopia. The climate data was spanned for 20 years (1996 - 2015).

rows). Composite samples were prepared for nutrient analysis from each tree/shrub species. The collected leaves were dried separately in a forced air oven at 55°C, ground to pass a 2 mm sieve, eventually labeled, stored in air-tight plastic bags and nutrient analysis was done in a laboratory at Hawassa University. Dry matter (DM) content was determined by drying the sample at 105°C in a forced-air oven untill the constant weight was obtained. Ash content was measured after igniting the sample in a muffle furnace at 550°C for 4 h. Nitrogen was determined using the micro-Kjeldahl method (AOAC, 2000). Crude protein (CP) was calculated as N X 6.25. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined by methods of Van Soest et al. (1991) without the use of alpha-amylase but with the use of sodium sulfite.

Data analysis

Early establishment growth parameters such as Height, Root Collar Diameter (RCD), Diameter at Breast Height (DBH) and Branch number (BNO) were analyzed, while the nutrient composition parameters such as Ash, crude protein, Acid Detergent Fiber, and Neutral Detergent Fiber were evaluated by one-way Analysis of variance (ANOVA) among the fodder tree/shrub species. Mean separation for mean differences was computed among the mean values and Linear regression was computed both between RCD with height and Height with BNO. The data analysis was run through employing SPSS (Version 20) and for data organization Microsoft excel worksheet was used.

RESULTS AND DISCUSSION

Early performance of the selected fodder tree/shrub species

Growth performance of tree/shrub species was measured in terms of gains in Height (H), Root collar diameter (RCD), and branch number (BNO) during both year one and year two monitoring except for diameter at breast height (DBH) (considered during the second year). All the investigated growth parameters showed significant variation ($P \leq 0.05$) among the studied fodder tree/shrub species. Except height, both root collar diameter and branch number were non-significant during the first of year monitoring. *S. sesban* and *M. alba* gained significantly the highest mean height during the first and second year of monitoring and followed by *T. brownii*. Also *S. sesban* had consistent and significantly ($P<0.05$) highest mean values of RCD, DBH and BNO (Table 1).

The utilization of resources from the environment by any species is a combination of space, resource and time (Jose et al., 2004). These components influence the growth performance, root development and nutrient acquisition of individual plants in several agroforestry practices (Rao et al., 1998). According to Makumba et al. (2009), management and/or environmental and physiological factors are controlling plant growth, as a result, species response to the environment within simultaneous systems is modified by the presence of the others as well (Akinnifesi et al*.,* 2004). Similarly, the growth difference among the studied tree/shrub species is related to the inherent physiological nature of the species in response to spacing and the resource pool. Apparently, spacing determines the intensity of inter and intraspecific competitions and fine root biomass (Singh et al., 2016) in turn influences tree growth (Hébert et al., 2016) and also determines the nutrient contents of leaves (Walker, 2007; Shinde et al., 2012). For instance, *M. alba* had higher leaf yield and growth was obtained with 1 m × 1 m and 1 m × 1.5 m spacing and this difference

Table 1. growth responses of the selected fodder tree/shrub species during two years of experimentation.

List of tree/shrub species	Year one			Year two			
	H (m)	RCD (mm)	BNO	H (m)	RCD (mm)	BNO	DBH (cm)
Morus alba L.	3.4 (±1.95)^{a}	3.6 (±0.9)	10 (±1)	2.6 (±0.4)^{a}	3.2 (±0.2)^{b}	24 (±7)^{b}	2.0 (±0.1)^{ab}
Terminalia brownii Fres.	1.8 (±0.23)^{ab}	4.2 (±1.9)	14 (±5)	2.2 (±0.1)^{b}	3.7 (±0.4)^{b}	40 (±18)^{b}	1.7 (±0.5)^{b}
Melia azedarach L.	0.9 (±0.05)^{b}	2.2 (±0.9	7 (±2)	1.3 (±0.3)^{c}	2.2 (±0.2)^{c}	23 (±11)^{b}	1.1 (±0.4)^{c}
Moringa stenopetala (Bak.) Cuf.	0.9 (±0.4)^{b}	2.5 (±2.4)	4 (±2)	0.8 (±0.02)d	3.4 (±0.02)^{b}	18 (±7)^{b}	-
Sesbania sesban (L.) Merr.	3.3 (±1.2)^{a}	4.4 (±1.4)	26 (±25)	2.9 (±0.02)^{a}	5.2 (±0.3)^{a}	84 (±24)^{a}	2.3 (±0.3)^{a}

Mean ± Standard deviation values with different letters within the column are significantly different at (α ≤ 0.05), H= height, RCD = Root collar diameter, BNO = branch number and DBH = diameter at breast height (1.3 m from the ground), m=meter, mm= millimeter, cm= centimeter.

is more visible over time (Eltayb et al., 2013).
The root geometry and architecture of each tree/shrub species influence the intensity of competition, carbon turn over, successful growth and survival. Though for the majority of tree species, the root density varies with increasing soil depth (Mekonnen et al*.,* 1999), soil texture and organic matter contents (Savon et al*.,* 2016). Both *S. sesban* and *M.alba* establish a deeper rooting system (Mani et al., 2011; Savon et al*.,* 2016). This important rooting feature may enable these trees to explore large volumes of soil and such trees are a beneficiary in the sense of intercept leached nutrients (Akinnifes et al., 2004), and moisture capturing from the lower horizon. Due to this reason, both the tree species have revealed a considerable performance in all growth explicit parameters.

Moringa spp such as *Moringa oliefera* and *Moringa stenopetala* have a tuberous, larger taproot and wide-spreading lateral roots (Sanchez, 2006). The observed least growth performance of *M. stenopetala* may be related to the intensity within competition particularly for space and in turn nutrients and moisture competition between individual trees. Despite the species capacity to produce a large quantity of fresh biomass even with higher planting density, competition within is also caused to reduce biomass production during the second year (Sanchez et al*.,* 2006). Similarly, the average fine root biomass of *M. azedarach* is reported highest at the upper soil depth (0-15 cm) (Singh et al*.,* 2016). This implies that there is evidence of higher competition of nutrients and moisture especially during the dry season and/or when the water becomes depleted the competition becomes intense (Miller and Pallardy, 2001). When the resource competition for space and soil nutrients is becoming more intense, the growth and performance of individual trees are influenced such as height, branch number, and DBH. The same is true with the growth performance of both *M. azedarach* as well as *M. stenopetala* in the present study.

The present result revealed that there is no significant correlation between Height and branch numbers (r= 0.511: P= 0.052), while there is a significant positive relationship (r= 0.57: P= 0.026) between root collar diameter and height during the first year of establishment. This result agreed with Samuel et al. (2016)'s argument, root collar diametere is used as an indicator for taller growth especially during early establishment. With the exceptions, *T. brownii* and *M. azedarach* all the tree/shrub species showed a decreasing trend of average height values (Table 1 and Figure 2). This is due to all the tree/shrub species are subjected to frequent lopping of leaves and tender twigs during the experimentation. Bishit et al*.* (2014) reported that when the lopping intensity of *Dalbergia sissoo* increases there is decreased height and DBH. This practice may directly influence the physiological processes of plants predominantly respiration and photosynthesis rate. Hence, the rate of changes in height increment seems to decrease when the age of the studied trees/shrubs increases. Despite the height, increment in growth parameters expresses the adaptation and growth response of these tree/shrubs to the environment with fodder bank agroforestry system at least during the experimentation period.

Chemical composition of the studied tree/shrub species

The present result revealed that the nutrient contents of the fodder tree/shrub species are significantly varied (P ≤ 0.01) consistently across all the parameters. *M. stenopetala* had the highest Ash and CP contents. *T. brownii* had the highest

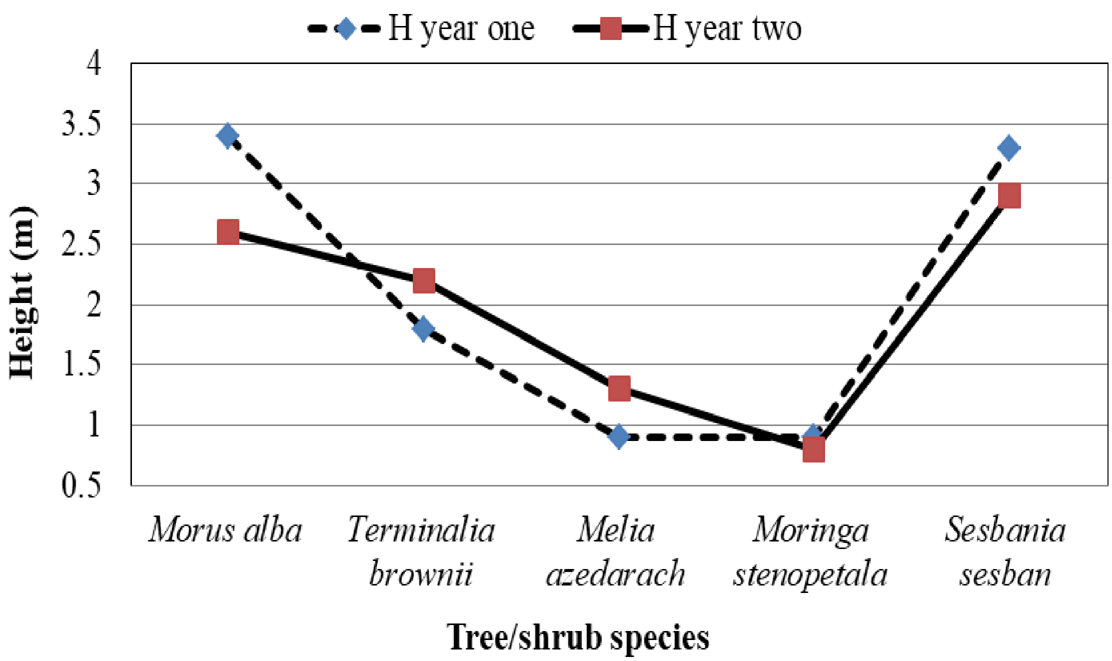

Figure 2. Trends of height measurement for the studied tree/shrub species between Year one and Year two. Height is measured in meter.

ADF, NDF and DM contents, while it had the least contents of CP and Ash. *M.alba* and *S.sesban* exhibited the least ADF and NDF values respectively, while comparable in terms of Ash and DM contents. *M.azedarach* recorded the highest DM contents (Table 2). These differences among the studied tree/shrubs may concede with different factors such as environmental factors (Jiru et al., 2006), genotypic variations and plant maturity (Aganga and Tshwenyane, 2003; Upreti and Shrestha, 2006) and differences in accumulation of protein in the leaves during growth (Cheema et al., 2011). The nutrient contents of the studied tree/shrub species were compared with study carried out by other workers in species like *M. stenopetala* (Abuye et al., 2003; Jiru et al., 2006; Melesse et al., 2009; Melesse, 2011), *S. sesban* (Tessema and Baars, 2004; Debela et al., 2011; Gomase et al., 2012), *M.alba* and *M. azedarach* (Schmidek et al., 2002; Singh and Makkar, 2002; Sultan et al., 2008; Cheema et al., 2011) and *T. brownii* (Osuga et al., 2019). The nutrient contents for the majority of roughages are less than 9% and even decline with time (Distel et al., 2005), which is inadequate to meet out required protein for microbial activities unless supplemented with protein-rich feeds (Seyoum and Zinash, 1989). Fodder trees are nutrient-rich and enable them to produce bulky biomass almost year-round makes a significant alternative for animals feed. *S. sesban* tree has a high level of foliage nitrogen and is an excellent supplement to protein-poor roughage (Manaye et al., 2009; Orwa et al., 2009; Sabra et al., 2010). There is an increasing experience of feeding *S. sesban* leaves and young twigs to supplement a basal diet for ruminants in Ethiopia (Tessema and Baars, 2004). It is easily digestible when consumed by ruminants (Gomase et al., 2012). Similarly, the nutritive value of *M.alba* is considered good, with better digestibility than that found in the leaves of many tropical pasture plants; thus it can be an alternative for totally and partially replacing concentrates (Savon et al., 2016). According to Sultan et al. (2008), the potential intake of *M. alba* is higher and in turn, it has a higher rate of preferences.

The ash contents of the studied fodder tree/shrub species are laid between the ranges of 5.7 - 13% with mean values of 9.7±2.3%. This agreed with the reports of Mandal (1997) who argued that the ash contents for most of the tree leave varied from 6 to 15%. This seemingly studied fodder tree species have considerable mineral concentrations that therefore be suggested as livestock feed supplement with low-quality roughage (Nassoro, 2014). Different factors are influencing the mineral concentration of plants such as minerals in the soil and availability to the plant, soil type, and soil pH and stage of growth (Lukhele and Van Ryssen, 2003).

Alam and Djajanigra (1994) argued that the minimum threshold for CP is 10%; if it is lower than this value it will affect rumen fermentation. The studied tree/shrub species had average CP contents between the ranges of 12.35 - 22.35%; 15.8 ±3.8%) and it is moderately higher from the threshold. All the tree/shrub species are satisfying at least 8% crude protein required for maintenance of livestock (Rubanza et al., 2003). Crude protein with this amount is adequate to support the

Table 2. Chemical composition (g/100g DM) of foliage samples from fodder tree/shrub species across the parameters (n=10).

List of tree/shrub species	ASH (%)	CP (%)	ADF (%)	NDF (%)	DM (%)
Morus alba L.	10.3^{b}	12.35^{c}	12.05^{d}	27.95^{b}	89.7^{b}
Terminalia brownii Fres.	5.85^{c}	12.45^{c}	23.35^{a}	33.55^{a}	89.7^{ab}
Melia azedarach L.	9.8^{b}	16.4^{b}	16.35^{b}	24^{c}	90.6^{a}
Moringa stenopetala (Bak.) Cuf.	12.5^{a}	22.35^{a}	13.1^{cd}	25.05^{c}	88.3^{c}
Sesbania sesban (L.) Merr.	9.75^{b}	15.4^{b}	13.35^{c}	18.9^{d}	89.8^{ab}

Means with different subscripts within the column are significantly different at ($\alpha \leq 0.05$), ASH= ash content, CP= crude protein, ADF= Acid detergent fiber, NDF= neutral detergent fiber, and DM= dry matter.

requirements of cattle, sheep, and goats at low to medium production levels (Jamala et al., 2013). When the protein content decreased accompanied by increased fiber content this makes a feed low quality and relatively indigestible for livestock.

Moreover, the contents of CP also influence the digestion of structural carbohydrates by interfering with microbial growth (Orskov, 1982). A high level of CP results in increased ruminal ammonia N concentration (Hristov et al*.,* 2004). Increased ruminal ammonia N status enhances microbial activity and growth resulting in greater DM digestibility (Griswold et al., 2003). The ADF and NDF contents of the studied tree/shrub species are laid between 11.8 -23.5 (15.6 ± 4.3) and 18.1- 33.6 (25.9 ± 5.1) respectively. Lower values of ADF in these tree leaves such as *M.alba, M.stenopetala,* and *S.sesban* indicate a good potential for ruminant feed (Bakshi & Wadhwa, 2007). *T. brownii* had the highest ADF and NDF values than the rest of the studied tree/shrub species. Though, it showed a lower average value than the reports of Osuga et al. (2019) in all parameters. Moreover, the values of ADF and NDF are lower in vegetative parts of leaves than mature leaves. This indicates the vegetative leaves have a relatively smaller proportion of woody parts (Sultan et al., 2008). The concentration of NDF and ADF is negatively correlated with a relative preference of livestock and in turn palatability (Sultan et al., 2008).

Conclusion

The variation of the studied tree/shrub species in terms of growth and nutrient composition is attributed to different factors such as the inherent nature of the tree species in response to spacing and resource acquisition, genotype, the season of plant harvest and maturity. Especially the latter three are more explained with nutrient composition differences. *Sesbania sesban* and *Moringa stenopetala* are the superior fodder tree/shrub species in terms of growth performances and nutrient composition respectively. All the selected fodder tree/shrub species are well adapted in fodder bank agroforestry system and have a considerable constituent of Ash, Crude protein, Acid detergent Fiber, Neutral detergent Fiber and Dry matter for maintaining livestock production. These enable the studied tree species to be potential alternatives for complementing the basal feed.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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