Available online at http://www.journalijdr.com

IJDR

International Journal of
DEVELOPMENT RESEARCH

ISSN: 2230-9926

*International Journal of Development Research*
*Vol. 06, Issue, 07, pp.8717-8726, July, 2016*

*Full Length Research Article*

# AGRONOMIC PERFORMANCE AND NUTRITIVE VALUES OF NAPIER GRASS (*PENNISETUM PURPUREUM* (L.) SCHUMACH) ACCESSIONS IN THE CENTRAL HIGHLAND OF ETHIOPIA

**[1,*]Gezahagn Kebede, [1]Fekede Feyissa, [1]Getnet Assefa, [2]Alemayehu Mengistu, [1]Muluneh Minta and [1]Tadesse T/Tsadik**

Ethiopian Institute of Agricultural Research, Holetta Research Center P.O. Box 2003, Addis Ababa, Ethiopia
Forage and Rangeland Scientist, Urael Branch, P.O. Box 62291, Addis Ababa, Ethiopia

**ARTICLE INFO**

***Article History:***
Received 28th April, 2016
Received in revised form
27th May, 2016
Accepted 15th June, 2016
Published online 31st July, 2016

***Key Words:***
Accessions,
Agronomic performance,
Napier grass,
Nutritive values.

**ABSTRACT**

Ten Napier grass accessions were evaluated for agronomic performance and nutritive values at Holetta agricultural research center during the main cropping seasons of 2011-2014. The experiment was conducted in randomized complete block design with three replications. Diammonium phosphate (DAP) fertilizer at the rate of 100 kg/ha was uniformly applied at planting and additionally urea at the rate of 50 kg/ha was top dressed after each forage harvesting. Combined analysis indicated that the tested accessions varied significantly ($P<0.05$) for number of tillers per plant, plant height and forage DM yield. The highest mean number of tillers per plant was recorded for accession 16817 (38.2) followed by 16794 (37.8) and 16783 (37.7) whereas the lowest (26.4) was recorded for accession 16815. The check accession gave the highest mean plant height (124.8 cm) followed by accession 16791 (115.9 cm) and 15743 (106.6 cm) whereas accession 16813 gave the lowest (75.1 cm). Mean DM yield ranged from 3.5 to 8.0 t/ha with a mean of 5.4 t/ha. Accordingly, accession 16791 gave the highest mean DM yield followed by accession 16819 (6.6 t/ha) and accession 15743 (5.7 t/ha) whereas the lowest obtained from accession 16815. Leaf to stem ratio and node length per plant also varied ($P<0.05$) significantly and the result indicated that the highest leaf to stem ratio was recorded for accession 16813 (4.8) followed by 16794 (2.1) and 16819 (1.9) whereas the lowest (1.1) was recorded for check accession. Accessions 16791, 16792 and 16819 gave 10.8, 10.4 and 10.1 cm node length per plant respectively. The nutritional quality (IVOMD and NDF) and CP and digestible yields varied ($P<0.05$) significantly and the result showed that accession 16783 gave the highest ash (153.6 g/kg DM), CP (63.7 g/kg DM) and IVOMD (534.2 g/kg DM). However, accession 16791 gave the highest CP yield (0.6 t/ha) and digestible yield (5.4 t/ha). Accession 16794 gave the highest ADF (496.9 g/kg DM) and ADL (86.4 g/kg DM) contents. On the other hand, accessions 16817, 16791 and 16819 gave the highest NDF (785.7 g/kg DM), cellulose (425.6 g/kg DM) and hemicellulose (324.0 g/kg DM) contents respectively. Generally, Napier grass accessions showed variations in terms of agronomic performance and nutritional qualities at Holetta, in the central highland of Ethiopia.



## INTRODUCTION

Napier grass (*Pennisetum purpureum* (L.) Schumach), also known as elephant grass, was originated from sub-Saharan tropical Africa (Clayton *et al.,* 2013) and occurs naturally throughout tropical Africa and particularly in East Africa (Lowe *et al.,* 2003; Mwendia *et al.,* 2006). It is the forage of choice not only in the tropics but also worldwide (Hanna *et al.,* 2004) due to its desirable traits such as tolerance to drought and adaptability to a wide range of soil conditions and high photosynthetic and water-use efficiency (Anderson *et al.,* 2008).

***Corresponding author: Gezahagn Kebede,***
*Ethiopian Institute of Agricultural Research, Holetta Research Center P.O. Box 2003, Addis Ababa, Ethiopia.*

It is a tall and deep-rooted perennial bunch grass well known for its high yielding capability and mainly used in cut-and-carry feeding systems (FAO, 2015). It is a pioneer species and performs well in low, mid and highland areas of Ethiopia (Seyoum *et al.,* 1998; Tessema, 2005). According to Fekede *et al.,* (2005), it grows best at high temperatures but can tolerate low air temperatures under which the yields can be reduced and ceases to grow at a temperature below 10°C. The grass is propagated vegetatively by using stem cuttings, root splits or shoot tips (Tessema, 2008) which usually vary across agro-ecologies (Getnet and Gezahagn, 2012). The grass can provide a continual supply of green forage throughout the year and best fits to all intensive small scale farming systems (Alemayehu, 1997). Amongst the improved forage crops promoted in Ethiopia, Napier grass could play an important role in providing a significant amount of biomass yield of 20-30 t DM/ha/year with good agronomic and management practices (Farrell *et al.,* 2002). Genotypic variation in growth characteristics of Napier grass has also been reported (Mwendia et al. 2006; Nyambati et al. 2010) and growth and morphological characteristics are correlated with DM yield and nutritional quality (Tudsri et al. 2002). Based on chemical composition and *in-vitro* dry matter digestibility (IVDMD), it could be categorized as high quality forage (Tessema, 2002) and extremely palatable when young and leafy (Cook *et al.,* 2005). The cultivation of high quality forages with a high yielding ability and adaptability to biotic and abiotic environmental stresses is one of the possible options to increase livestock production under smallholder farmers conditions (Tessema, 1999). Despite huge livestock population in the country, productivity of animals in Ethiopia is lower than the regional and continental average. Among the factors contributing to low productivity, availability of poor quality feed resources remains to be the major bottleneck to livestock production. To improve livestock production, sustainable solution to seasonal deficiencies in feed availability and quality are required through proper management and utilization of forage crops. Testing the adaptability and yield potential of Napier grass is very important to identify the best bet accessions for research and development works. Accordingly, there is a need to evaluate Napier grass accessions for basic quantitative and qualitative traits to address the feed demand of mixed farming systems in the country. Therefore, the objective of this study was to evaluate the agronomic performance and nutritive values of ten Napier grass accessions at Holetta, in the central highland of Ethiopia.

## MATERIALS AND METHODS

### Descriptions of the test environment

The experiment was conducted at Holetta Agricultural Research Center during the main cropping seasons. The test location represents the highland areas of Ethiopia. The farming system of the study area is mixed crop livestock production system. Descriptions of the test environment are indicated in Table 1.

### Experimental design and layout

The ten accessions of Napier grass considered for this experiment were 15743, 16783, 16791, 16792, 16794, 16813, 16815, 16817, 16819 and check (16984). The planting material of the accessions was collected from Bako Agricultural Research Center by D/zeit Research Center. The vegetative parts in the form of root splits were brought from D/zeit research center to evaluate their performance under Holetta environmental conditions. The experiment was conducted for four consecutive years during the main cropping seasons of 2011-2014. The accessions were planted in 4 m x 4 m plot using a randomized complete block design (RCBD) with three replications and the accessions assigned randomly to plots within block. Root splits were planted in four rows per plot and a total of 32 root splits were planted per plot with intra and inter row spacing of 0.5 m and 1 m respectively, giving a density of 20,000 plants/ha. There was an alleyway of 2 m width between blocks and 1m width between plots. A blanket basal phosphorus fertilize was uniformly applied to all plots in the form of diammonium phosphate (DAP) at the rate of 100 kg/ha. After every harvest, the plots were top dressed with 50 kg/ha urea of which one-third applied at the first shower of rain and the remaining two-third applied during the active growth stage of the plant. All other crop management practices were used uniformly to all accessions as required.

**Table 1. Descriptions of the test location for geographical position and physico-chemical properties of the soils**

| SN | Parameter | Holetta |
|---|---|---|
| 1 | Latitude | 9° 00'N |
| 2 | Longitude | 38° 30'E |
| 3 | Altitude (masl) | 2400 |
| 4 | Distance from Addis Ababa (km) | 29 |
| 5 | Annual Rainfall (mm) | 1044 |
| 6 | Daily minimum temperature (°C) | 6.2 |
| 7 | Daily maximum temperature (°C) | 21.2 |
| 8 | Soil type | Nitosol |
| 9 | Textural class | Clay |
| 10 | pH(1:1 $H_2o$) | 5.24 |
| 11 | Total organic matter (%) | 1.80 |
| 12 | Total nitrogen (%) | 0.17 |
| 13 | Available phosphorous (ppm) | 4.55 |

### Data collection and measurements

Measurements taken before and after each harvest were plant survival rate, number of tillers per plant, plant height, forage DM yield, leaf to stem ratio, number of nodes per plant and internode length per plant. Plant survival rate was calculated as the ratio of the number of alive plants per plot to the total number of plants planted per plot and then multiplied by 100. The number of tillers was also measured from the five culms after harvesting. Plant height was based on five culms taken randomly in each plot, measured using a steel tape from the ground level to the highest leaf. For determination of biomass yield, accessions were clipped at 5cm from the ground level from two rows next to the guard rows. Weight of the total fresh biomass yield was recorded from each plot in the field and the estimated 500 g sample was taken from each plot to the laboratory. The sample taken from each plot was weighed to know the total sample fresh weight using sensitive table balance and manually fractionated in to leaf and stem. The morphological parts were separately weighed to know their sample fresh weight, oven dried for 24 hours at a temperature of 105$^o$c and separately weighed to estimate the proportions of these morphological parts. Accordingly, leaves were separated from stems and the leaf to stem ratio (LSR) was estimated based on the dry weight of each component. Number of nodes per plant and internode length (cm) were taken from five randomly selected plants per plot.

### Chemical analysis and *in-vitro* organic matter digestibility

The oven dried samples at a temperature of 65$^o$C for 72 hours were used for laboratory analysis to determine chemical composition and *in-vitro* organic matter digestibility of the accessions. The dried samples then ground to pass a 1-mm sieve and used for laboratory analysis. Analysis was made for ash, CP, NDF, ADF, ADL and IVOMD nutritional parameters. Total ash content was determined by oven drying the samples at 105$^0$C overnight and by combusting the samples in a muffle furnace at 550$^o$C for 6 hours (AOAC, 1990). Nitrogen (N) content was determined following the micro-Kjeldahl digestion, distillation and titration procedures (AOAC, 1995) and the crude protein (CP) content was estimated by multiplying the N content by 6.25. The structural plant constituents (NDF, ADF and ADL) were determined according to Van Soest and Robertson procedure (1985). The *in-vitro* organic matter digestibility (IVOMD) was determined according to the Tilley and Terry procedure (1963). Hemicellulose and cellulose contents were estimated from subtracting ADF from NDF and ADL from ADF respectively. The CP yield in t/ha was calculated by multiplying CP with total dry biomass yield and then divided by 100. The digestible yield in t/ha was also determined by multiplying IVOMD with total DM yield and then divided by 100.

### Statistical analysis

Differences among accessions were tested using analysis of variance (ANOVA) procedures of SAS general linear model (GLM) to compare treatment means (SAS, 2002). Least significance difference (LSD) at 5% significance level was used for comparison of means. The data for combined analysis, the following model was used: $Y_{ijk} = \mu + A_i + Y_j + (AY)_{ij} + B_{k(j)} + e_{ijk;}$ Where, $Y_{ijk}$ = measured response of accession i in block k of year j; $\mu$ = grand mean; $A_i$ = effect of accession i; $Y_j$ = effect of year j; AY= accession by year interaction; $B_{k\ (j)}$ = effect of block k in year j; $e_{ijk}$ = random error effect of accession i in block k of year j. For each year analysis, the model was used: $Y_{ij} = \mu + A_i + B_j + e_{ij;}$ Where, $Y_{ij}$ = measured response of accession i in block j; $\mu$ = grand mean; $A_i$ = effect of accession i; $B_j$ = effect of block j; $e_{ij}$ = random error effect of accession i in block j.

## RESULTS AND DISCUSSION

### Establishment Performance

Study on establishment performance is an important consideration during forage crop cultivation due to substantial effect on forage productivity. The average survival rate of Napier grass accessions tested over years at Holetta is indicated in Figure 1. The result revealed that the survival rate varied among the accessions. The highest plant survival rate (93.8%) was recorded for accession 16783 followed by accession 16817 (92.7%) and accession 15743 (82.3%). On the other hand, accession 16815 showed the lowest (56.3%) plant survival rate followed by 16984 (66.7%) and accession 16813 (68.8%). According to Fekede *et al.* (2005), the average survival rate of Napier grass during the three years of experimental period was 73.8% and the reduction in the number of plants did not affect the herbage yield of the grass, and this could be attributed to the vigorous growth performance of the tillers produced by the remaining stands. Cuttings taken from the lower portion of the stem are more mature than those from the upper, younger portion and this affects the success of propagation (Woodard *et al.,* 1985). Plant development and yield are severely affected by soil conditions such as moisture and soil fertility. Agro-metrological variables such as rainfall, soil and air temperatures, wind, relative humidity or dew point temperature and solar radiation have major impacts on crop growth and development (Dapaah, 1997; Hoogenboom, 2000). As described by Pal (2004), seed size, sowing depth, land preparation and environment influences the emergence and establishment of seedlings. According to Fekede (2004), high germination rate, vigorous growth and dense establishment are among the desired characteristics for forage crop. Generally, Napier grass has a wide range of adaptation, vigorous growth, high biomass productivity and deep root system to survive under drought conditions (Lowe *et al.,* 2003; Anderson *et al.,* 2008; Tessema, 2008).

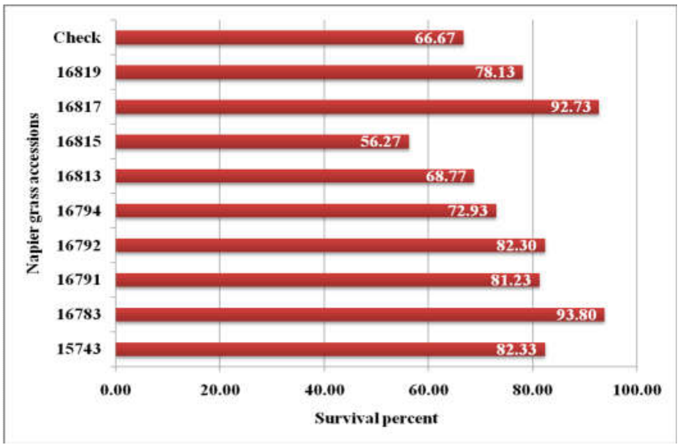


**Figure 1. Mean survival rate of Napier grass accessions during the experimental periods**

### Number of tillers per plant

Tillering performance is an important morphological characteristics to be considered during selection of appropriate forage crops to improve production and productivity. The mean tillering performance of the tested Napier grass accessions is indicated in Table 2. The combined analysis indicated that significant (P<0.05) variation was observed among the accessions. The highest number of tillers (38.2) over years was obtained from accession 16819 followed by accession 16794 (37.8) and 16783 (37.7)while accession 16817 gave the lowest (27.3). The difference in tillers produced per plant among the accessions of Napier grass could be attributed to genetic variations among the accessions and their interactions to the environment. Tillering performance also varies with production years due to variation in distribution and amount of rainfall. In the cool highland (Holetta), Napier grass could produce peak number of tillers during the third year of establishment and that fertilizer application enhances the production of more number of tillers (Fekede *et al.,* 2005). The variation in tiller number among different varieties of Napier grass was also observed in central Kenya (Mwendia *et al.,* 2006; Mwendia *et al.,* 2008). According to Tessema and Alemayehu (2010), Napier grass produces many tillers and dense vegetative growth as the pasture consolidates due to perennial nature of the grass. The number of tillers per plant of Napier grass increased with plant height at cutting (Tessema *et al.,* 2003). This may be due to the longer physiological growth phases of the plants in the reduced cutting frequency (Butt *et al.,* 1993). Increased tillering is probably an adaptive feature to tolerate frequent defoliation by re-establishing lost photosynthetic area and maintaining basal area. High tiller production not only indicates stable productivity (Mukhtar, 2006) but also is linked to better persistence after periods of unfavorable environmental conditions (Assuero and Tognetti, 2010).

Generally, tiller production is a key factor in the resistance of grasslands to deterioration by ageing (Lafarge and Loiseau, 2002).

**Table 2. Mean number of tillers of ten Napier grass accessions tested over years at Holetta**

| SN | Accessions | Year 2011 | 2012 | 2013 | 2014 | Combined over years |
|---|---|---|---|---|---|---|
| 1 | 15743 | 19.33 | 30.33 | 25.00 | $40.33^{bc}$ | $28.75^{b}$ |
| 2 | 16783 | 26.00 | 34.33 | 30.33 | $60.00^{ab}$ | $37.67^{a}$ |
| 3 | 16791 | 19.00 | 30.67 | 25.00 | $55.00^{ab}$ | $32.42^{ab}$ |
| 4 | 16792 | 20.33 | 28.00 | 24.33 | $38.00^{bc}$ | $27.67^{b}$ |
| 5 | 16794 | 36.33 | 26.33 | 31.67 | $57.00^{ab}$ | $37.83^{a}$ |
| 6 | 16813 | 26.33 | 26.67 | 27.00 | $51.00^{ab}$ | $32.75^{ab}$ |
| 7 | 16815 | 21.67 | 21.67 | 22.00 | $40.33^{bc}$ | $26.42^{b}$ |
| 8 | 16817 | 24.00 | 29.33 | 27.00 | $28.67^{c}$ | $27.25^{b}$ |
| 9 | 16819 | 26.00 | 28.00 | 27.33 | $71.33^{a}$ | $38.17^{a}$ |
| 10 | 16984 | 22.33 | 26.67 | 25.00 | $45.33^{bc}$ | $29.83^{b}$ |
| | Mean | 24.13 | 28.20 | 26.47 | 48.70 | 31.88 |
| | SEM | 0.54 | 0.36 | 0.40 | 0.66 | 0.28 |
| | P-value | 0.4407 | 0.0858 | 0.4281 | 0.0295 | 0.0460 |

Means followed by different superscript letters within a column are significantly different each other at P<0.05

## Plant height at forage harvesting

Mean plant height of Napier grass accessions were significantly (P<0.05) different in combined and each year analysis except in 2014 (Table 3). The combined analysis for plant height ranged from 75.1 to 124.8 cm with a mean of 96.3 cm. Generally, accession 16984 gave the highest mean plant height followed by accession 16792 (107.1 cm) and 15743 (106.6 cm) while accession 16813 gave the lowest plant height. This variation could be happened due to the differences in moisture content over years. Height at cutting is reported to affect the growth characteristics and productivity of Napier grass (Mureithi and Thrope, 1996). Other result also indicated that plant height at cutting significantly affects the fodder yield of Napier grass in Kenya (Muinga *et al.,* 1992). Amongst the major agronomic practices required, harvesting of Napier grass at appropriate cutting height and defoliation frequencies are very important to improve DM yield and nutritive values of this plant (Butt *et al.,* 1993; Tessema *et al.,* 2003). A higher cutting height of Napier grass may result in underutilization and the quality of forage is reduced by a higher cutting height (Butt *et al.,* 1993; Tessema *et al.,* 2003). Appropriate cutting management is essential for high production and quality of this species (Tessema *et al.,* 2010). High cutting frequency reduces growth and development, whereas long intervals between harvests lead to accumulation of fiber and reduction in quality (Tessema *et al.,* 2010). This is because Napier grass has high structural cell wall carbohydrates that increase rapidly with maturity causing decline in CP concentration and digestibility (Van Soest, 1994). Studies also demonstrate that the effects of cutting interval on yield and quality vary with cultivars (Cuomo *et al.,* 1996; Khairani *et al.,* 2013), management practices and environmental conditions (Chaparro *et al.,* 1996).

## Forage dry matter yield

Forage dry matter (DM) yield of Napier grass accessions showed significant (P<0.05) variation in combined and each year analysis except in 2014 (Table 4).

**Table 3. Mean plant height (cm) of ten Napier grass accessions tested over years at Holetta**

| SN | Accessions | Year 2011 | 2012 | 2013 | 2014 | Combined over years |
|---|---|---|---|---|---|---|
| 1 | 15743 | $87.93^{a}$ | $134.83^{b}$ | $104.90^{c}$ | 98.80 | $106.62^{c}$ |
| 2 | 16783 | $56.30^{cd}$ | $105.67^{e}$ | $84.73^{de}$ | 83.93 | $82.66^{ef}$ |
| 3 | 16791 | $82.93^{ab}$ | $154.00^{a}$ | $118.80^{ab}$ | 107.67 | $115.85^{b}$ |
| 4 | 16792 | $88.77^{a}$ | $127.73^{bc}$ | $106.00^{bc}$ | 105.70 | $107.05^{bc}$ |
| 5 | 16794 | $70.87^{bc}$ | $122.37^{bcd}$ | $97.10^{cd}$ | 97.07 | $96.85^{d}$ |
| 6 | 16813 | $48.80^{d}$ | $88.37^{f}$ | $82.40^{e}$ | 80.93 | $75.13^{f}$ |
| 7 | 16815 | $56.70^{cd}$ | $90.47^{f}$ | $79.90^{e}$ | 93.10 | $80.04^{ef}$ |
| 8 | 16817 | $69.17^{bc}$ | $110.27^{de}$ | $87.80^{de}$ | 77.33 | $86.14^{e}$ |
| 9 | 16819 | $60.43^{cd}$ | $115.07^{cde}$ | $95.43^{cd}$ | 82.37 | $88.33^{de}$ |
| 10 | 16984 | $96.67^{a}$ | $158.97^{a}$ | $127.23^{a}$ | 116.23 | $124.78^{a}$ |
| | Mean | 71.86 | 120.77 | 98.43 | 94.31 | 96.34 |
| | SEM | 0.55 | 0.51 | 0.50 | 0.73 | 0.30 |
| | P-value | 0.0001 | 0.0001 | 0.0001 | 0.0957 | 0.0001 |

Means followed by different superscript letters within a column are significantly different each other at P<0.05

The DM yield of combined analysis ranged from 3.5 to 8.0 t/ha with a mean of 5.4 t/ha. Generally accession 16791 gave the highest mean DM yield followed by 16819 and 15743. On the other hand, accessions 16815 gave the lowest DM yield. The variations in plant survival rate, tillering performance and plant height are the causes of difference in DM yield. Moreover, DM yield differences occurred due to variations among the tested genotypes, testing years and genotype by years interaction effects. DM yield of Napier grass may be affected by the harvesting day after planting. Boonman (1993) and Tessema *et al.,* (2003) reported that increasing foliage height increased DM yield. According to Tessema (2005) and Ishii et al. (2005), the taller varieties showed higher DM yields than the shorter varieties. The DM yield of Napier grass increased as frequency between cuttings increased and this indicates that a long harvest interval is necessary to achieve high DM yields (Tessema *et al.,* 2010). Yields of the grass vary depending on genotype (Schank *et al.,* 1993; Cuomo *et al.,* 1996), edaphic and climatic factors and management practices (Boonman, 1993). Generally, as grass matures, herbage yield is increased due to the rapid increase in the tissues of the plant (Minson, 1990). Amongst the promising forage species promoted in Ethiopia, Napier grass could play an important role in providing a significant amount of high quality forage to the livestock (Tessema, 2005) both under the smallholder farmers and intensive livestock production systems with appropriate management practices (Seyoum *et al.,* 1998; Alemayehu, 2004). Water supply is highly associated with nutrient uptake and accumulation of biomass because of an accelerated maturation process when other factors such as temperature, soil fertility and light intensity are not limiting for forage growth (Van Soest, 1982; Humphreys, 1991). However, Napier grass can withstand considerable periods of drought (Butt *et al.,* 1993), produces greater DM yield than other tropical grasses (Boonman, 1997), and is of high nutritive value for dairy animals particularly when supplemented with high quality feeds such as legumes (Nyambati *et al.,* 2003).

## Leaf to stem ratio at forage harvesting

The Leaf to stem ratio (LSR) of Napier grass accessions varied (P<0.05) significantly (Table 5). The result showed that LSR ranged from 1.13 to 4.84 with a mean of 1.92.

Accessions 16813 produced the highest LSR followed by 16794 and 16819. On the other hand, the lowest mean LSR was recorded for check (16984) accession. Due to the presence of genetic variations, the tested accessions respond differently for LSR. Growth characteristics such as tillering performance, plant height and age of harvesting also affect the proportion of leaf and stem of the plant. The research results indicated that the LSR of Napier grass ranged from 1.7 to 3.1 in Thailand (Tudsri *et al.,* 2002) and within the range of 1.65 to 6.1 in Kenya (Mwendia *et al.,* 2006).

The highest LSR is obtained from short cultivars of Napier grass when compared to tall cultivars (Tudsri *et al.,* 2002; Tessema, 2005). The LSR has significant implications on the nutritive quality of the grass as leaves contain higher levels of nutrients and less fiber than stems. The result indicated that the LSR is an important factor affecting diet selection, quality and intake of forage (Smart *et al.,* 2004). The LSR is associated with high nutritive value of the forage because leaf is generally of higher nutritive value (Tudsri *et al.,* 2002) and the performance of animals is closely related to the amount of leaf in the diet. Decrease in LSR with longer cutting intervals is a function of the longer periods of physiological growth with reduced defoliation frequency stimulating stem growth at the expense of leaf production (Butt et al. 1993).

**Table 4. Mean DM yield (t/ha) of ten Napier grass accessions tested over years at Holetta**

| SN | Accessions | Year | | | | Combined over years |
|---|---|---|---|---|---|---|
| | | 2011 | 2012 | 2013 | 2014 | |
| 1 | 15743 | $0.68^{a}$ | 7.90ab | $8.35^{bc}$ | 5.97 | $5.72^{bc}$ |
| 2 | 16783 | $0.47^{bcd}$ | 6.10bc | $6.92^{bcd}$ | 8.00 | $5.37^{bc}$ |
| 3 | 16791 | $0.62^{ab}$ | 10.08a | $11.88^{a}$ | 9.58 | $8.04^{a}$ |
| 4 | 16792 | $0.50^{bc}$ | 5.14bcd | $6.59^{cd}$ | 7.79 | $5.00^{cd}$ |
| 5 | 16794 | $0.24^{ef}$ | 6.39bc | $7.88^{bc}$ | 6.42 | $5.23^{bc}$ |
| 6 | 16813 | $0.23^{ef}$ | 4.80cd | $6.26^{cd}$ | 5.42 | $4.18^{cd}$ |
| 7 | 16815 | $0.12^{f}$ | 3.08d | $4.52^{d}$ | 6.11 | $3.46^{d}$ |
| 8 | 16817 | $0.37^{cde}$ | 5.70bcd | $6.82^{bcd}$ | 5.97 | $4.72^{cd}$ |
| 9 | 16819 | $0.29^{def}$ | 6.81bc | $9.53^{ab}$ | 9.89 | $6.63^{ab}$ |
| 10 | 16984 | $0.41^{cde}$ | 7.43abc | $8.50^{bc}$ | 5.75 | $5.52^{bc}$ |
| | Mean | 0.39 | 6.34 | 7.72 | 7.09 | 5.39 |
| | SEM | 0.06 | 0.23 | 0.23 | 0.30 | 0.13 |
| | P-value | 0.0001 | 0.0058 | 0.0022 | 0.4441 | 0.0001 |

Means followed by different superscript letters within a column are significantly different each other at P<0.05

### Node number and internode length per plant

Though the accessions did not show significant (P>0.05) variation for number of nodes per plant, differences was observed among the tested Napier grass genotypes (Table 5). Number of nodes per plant ranged from 4.8 to 7.1 with a mean of 5.9. The highest number of nodes per plant was recorded for accession 15743 and 16815 while the check (16984) accession produced the lowest. The length of internode per plant showed significant (P<0.05) difference among the accessions of Napier grass (Table 5). The mean length of internode per plant ranged from 5.6 to 10.8 cm with a mean of 8.2 cm. The highest mean internode length per plant was recorded for accession 16791 followed by accession 16819 and 16815 while accession 16813 produced the lowest. Generally, as other agronomic traits, stem elongation also influenced by variation in temperature, amount and distribution of rainfall, genotypes and genotype by year interaction effects.

**Table 5. Mean leaf to stem ratio, number of nodes and internode length (cm) performance of ten Napier grass accessions tested at Holetta**

| SN | Accession | Leaf to stem ratio | Number of nodes per plant | Internode length per plant |
|---|---|---|---|---|
| 1 | 15743 | $1.57^{abc}$ | 7.07 | $6.80^{cd}$ |
| 2 | 16783 | $1.82^{abc}$ | 5.77 | $8.37^{abcd}$ |
| 3 | 16791 | $1.25^{b}$ | 6.93 | $10.77^{a}$ |
| 4 | 16792 | $1.36^{b}$ | 5.50 | $10.37^{ab}$ |
| 5 | 16794 | $2.09^{ab}$ | 5.87 | $7.43^{abcd}$ |
| 6 | 16813 | $4.84^{a}$ | 5.47 | $5.57^{d}$ |
| 7 | 16815 | $1.43^{b}$ | 7.07 | $8.93^{abcd}$ |
| 8 | 16817 | $1.82^{abc}$ | 5.33 | $6.87^{bcd}$ |
| 9 | 16819 | $1.92^{abc}$ | 5.60 | $10.13^{abc}$ |
| 10 | 16984 | $1.13^{c}$ | 4.77 | $7.13^{bcd}$ |
| | Mean | 1.92 | 5.94 | 8.24 |
| | SEM | 0.16 | 0.21 | 0.26 |
| | P-value | 0.0448 | 0.5164 | 0.0446 |

Means followed by different superscript letters within a column are significantly different each other at P<0.05

### Chemical compositions and *in-vitro* organic matter digestibility

### Non-fiber chemical compositions

The ash content of Napier grass showed non-significant difference (P>0.05) ranging from 133.7 to 153.6 g/kg DM with a mean of 144.6 g/kg DM (Table 6). The highest ash content was recorded for accession 16783 followed by check (149.5 g/kg DM) and 16791 (149.5 g/kg DM) whereas the lowest was recorded for accession 16815. The high ash content in forage could be an indication of high mineral concentration. The results suggest that the mineral content of most herbaceous plants was reduced with increased stage of maturity. Bayble *et al.,* (2007) also reported similar results, suggesting that the mineral contents of herbaceous forages declines as the stage of maturity advances. As grasses mature, the mineral content declines due to a natural dilution process and translocation of minerals to the roots (Minson, 1990). Mineral content drops as the season progresses due to oxidation, lignifications, evapo-transpiration and translocation from leaves to fruits and roots (Minson, 1981). Since the concentration of minerals in forages are affected by stage of maturity, climatic and seasonal changes (Minson, 1990), regular analysis has been recommended for formulating appropriate mineral supplementation schedules (Spears, 1994). Other studies also indicated that concentration of minerals in forage varies due to factors like plant developmental stage, morphological fractions, climatic conditions, soil characteristics and fertilization regime (McDowell and Valle, 2000; Jukenvicius and Sabiene, 2007). In many regions in the tropics, forages are deficient in one or more minerals and supplementation is necessary for optimal animal performance and/or health (McDowell and Conrad, 1990).

The CP content of Napier grass showed non-significant (P>0.05) difference, though the content varied among the accessions (Table 6). The CP content of the accessions ranged from 50.6 to 63.7 g/kg DM with a mean of 57.3 g/kg DM. The highest CP content was observed for accession 16783 followed by check (60.5 g/kg DM) and 16813 (59.9 g/kg DM) while it remained low for accession 16815. The CP yield of Napier grass also vary among the accessions, which generally related to the biomass yield (Table 6). The result showed that the CP yield ranged from 0.2 to 0.6 t/ha with a mean of 0.4 t/ha. Accordingly, accessions 16791 and 16815 had the highest and lowest CP yield respectively. In evaluating forage crops, CP content should not be used as the only parameter to be considered. It is the CP yield, which describes the overall and actual productivity of quality forage. Under high temperatures in the tropics, there is rapid growth and development of grasses resulting in a high rate of decline in the proportion of leaves in relation to stems which reduce CP content and digestibility (Mannetje, 1983; Humphreys, 1991). As Napier grass matured there was a decline in CP content and *in-vitro* OMD while the DM yield and detergent fibers increased (Van Soest, 1982; Cherney *et al.,* 1993). A decline in protein level has been reported as plant maturity advances (shalaby *et al.,* 1991; Seyoum *et al.,* 1998). The increase in age in grasses is usually negatively associated with CP content (Norton, 1981; Minson, 1990) and it has been recognized that the rate of decline in CP content in Napier grass is more rapid in stems than in leaves (Brown and Chavalimu, 1985). The other studies also indicated that the CP content of herbaceous species is higher at early stage of growth than at maturity (Singh *et al.,* 1997; Mahala *et al.,* 2009). Low quality forages are defined as those with less than 80 g/kg DM CP (Leng, 1990) and such forage would adversely affect rumen microbial activity (Van Soest, 1982).

The IVOMD content showed significant (P<0.05) variation (Table 6). The IVOMD content of the accessions ranged from 488.0 to 534.7 g/kg DM with a mean of 507.4 g/kg DM. Accordingly, accession 16783 had the highest IVOMD followed by accession 16794 (518.8 g/kg DM) and 16792 (515.2 g/kg DM) while the lowest was recorded for accession 16815. The digestible yield of the tested accessions also showed significant (P<0.05) variations (Table 6). The digestible yield of the accessions ranged from 2.2 to 5.4 t/ha with a mean of 3.6 t/ha. Generally, accession 16791 gave the highest digestible yield followed by accession 16819 (4.4 t/ha) and accession 16783 (3.8 t/ha). On the other hand, the lowest digestible yield was recorded for accession 16815.

It is important to bear in mind that climate, soil fertility, cutting interval and other management practices have profound influence on chemical composition and digestibility of Napier grass. The nutritive value of forages is mainly determined by voluntary intake, crude protein and structural carbohydrates. Forage intake is influenced by digestible DM and CP content and the extent of degradation (Minson, 1990). The organic matter digestibility varies with the proportion of cell contents and cell wall constituents. The cell contents are digestible, while cell wall digestion depends on the degree of lignifications, the activity of rumen microbes and the time forage is retained in the rumen (Minson, 1990). The decline in digestibility as Napier grass matured may be attributed to the observed declines in CP content, and an increase in detergent fibers and degree of lignifications. According to Wilson *et al.,* (1986) and Ducrocq and Duru (1997), DM digestibility of tropical and sub-tropical grasses tended to increase with water stress. Seasonal differences in digestibility of forages were reported to be caused by changes in temperature and water availability to the forage (Van Soest, 1982; Minson, 1990).

**Table 6. Mean ash (g/kg DM), CP (g/kg DM), IVOMD (g/kg DM), CP yield (t/ha) and digestible yield (t/ha) of ten Napier grass accessions at Holetta**

| SN | Accession | Ash | CP | IVOMD | CPY | DY |
|---|---|---|---|---|---|---|
| 1 | 15743 | 133.7 | 57.7 | $497.4^{cd}$ | $0.4^{bc}$ | $3.7^{bc}$ |
| 2 | 16783 | 153.6 | 63.7 | $534.7^{a}$ | $0.5^{ab}$ | $3.8^{bc}$ |
| 3 | 16791 | 149.5 | 57.1 | $510.3^{bc}$ | $0.6^{a}$ | $5.4^{a}$ |
| 4 | 16792 | 145.1 | 54.9 | $515.2^{abc}$ | $0.4^{bc}$ | $3.4^{bcd}$ |
| 5 | 16794 | 147.7 | 59.0 | $518.8^{ab}$ | $0.4^{bc}$ | $3.6^{bcd}$ |
| 6 | 16813 | 142.1 | 59.9 | $503.9^{bcd}$ | $0.3^{bc}$ | $2.8^{cd}$ |
| 7 | 16815 | 133.6 | 50.6 | $488.0^{d}$ | $0.2^{c}$ | $2.2^{d}$ |
| 8 | 16817 | 142.9 | 56.6 | $496.1^{cd}$ | $0.3^{bc}$ | $3.1^{bcd}$ |
| 9 | 16819 | 147.9 | 52.5 | $496.1^{cd}$ | $0.5^{ab}$ | $4.4^{ab}$ |
| 10 | 16984 | 149.4 | 60.5 | $512.0^{bc}$ | $0.4^{bc}$ | $3.7^{bc}$ |
| | Mean | 144.6 | 57.3 | 507.4 | 0.4 | 3.6 |
| | SEM | 0.17 | 0.17 | 0.20 | 0.06 | 0.17 |
| | P-value | 0.1388 | 0.7462 | 0.0074 | 0.0425 | 0.0161 |

Means followed by different superscript letters within a column are significantly different each other at P<0.05

## Fiber chemical compositions

The NDF content of Napier grass showed significant (P<0.05) difference (Table 7). The result showed that the NDF content ranged from 728.5 to 785.7 g/kg DM with a mean of 770.0 g/kg DM. The highest NDF content was recorded for accession 16817 followed by accession 16819 (785.5 g/kg DM) and accession 16815 (782.9 g/kg DM) whereas the lowest was recorded for check accession. The fiber content of a feed is particularly important for determining quality within the parameter of digestibility. Fiber is the structural part of plants, namely, components of the cell wall: soluble pectins, waxes, insoluble lignin, cellulose and hemicellulose (Van Soest, 1994). The content of NDF above 600 g/kg DM at which grasses are classified as poor quality while grasses with NDF content from 500 to 600 g/kg DM could be classified as of moderate quality (Van Soest, 1982). The decline in digestibility may, therefore, have been mainly due to the fiber chemistry and anatomical structure of the cell wall rather than its content (Wilson and Hatfield, 1997). The differences in solubility and potential degradation are dependent on the cellular structure of the components being degraded (Hagerman *et al.,* 1992) and on inherent attributes of the NDF and CP present (Kaitho, 1997). Generally, tropical forages are more fibrous than temperate forages and a higher proportion of their nitrogen is not available to ruminants because it is bound within the indigestible vascular bundles (Van Soest, 1982). The ADF content of Napier grass did not differ significantly (P>0.05), though the accessions showed variations (Table 7). The ADF content ranged from 461.4 to 496.9 g/kg DM with a mean of 474.6 g/kg DM. The highest ADF content was recorded for accession 16794 followed by accession 16791 (492.8 g/kg DM) and accession 15743 (479.5 g/kg DM) while the lowest was obtained from accession 16819. The nutrient composition of forage crops is variable depending on many factors such as genotypic characteristics, environmental conditions and harvesting stages of the plants (Rotili *et al.,* 2001; Lamb *et al.,* 2006). High temperature and low rainfall tend to increase cell wall polysaccharides and then decrease the soluble carbohydrates (Pascual *et al.,* 2000). Digestibility decreased with advancing age. This decline resulted from the interaction of factors such as increased fiber concentration in plant tissue, increased lignifications during plant development and decreased leaf to stem ratio (Wilson *et al.,* 1991).

For forage ADF, the recommended minimum is 170- 210 g/kg DM, but as with NDF, a higher minimum is required for forage ADF depending on various factors that also affect NDF such as particle size, feeding methods, supplements and rate and extent of ferment ability of fiber source (NRC, 2001). Forage with higher ADF, thus has lower cellulose digestibility in the rumen, thereby reducing the energy available to the lactating cow for milk production.

The ADL content of Napier grass did not show significant (P>0.05) difference, though the content varied among the accessions (Table 7). The ADL content ranged from 53.0 to 86.4 g/kg DM with a mean of 70.4 g/kg DM. The highest ADL content was recorded for accession 16794 followed by check accession (85.1 g/kg DM) and accession 16792 (84.4 g/kg DM) while the lowest was obtained for accession 16817. Lignin is a component which attributes erectivety, strength and resistance to plant tissue thereby limiting the ability of rumen microorganisms to digest the cell wall polysaccharides, cellulose and hemicellulose contents (Reed *et al.,* 1988). Lignin content was reported by Van Soest and Robertson (1979) and Van Soest (1982) to affect digestibility of forage more than any other chemical component. Van Soest (1982) reported a lignin content value above 60 g/kg DM to affect digestibility of forage negatively. Generally, the presence of insoluble fiber, particularly lignin, lowers the overall digestibility of the feed by limiting nutrient availability (Van Soest, 1994; Mustafa *et al.,* 2000).

The higher content of structural component (NDF, ADF and ADL) found during dry season might be due to high lignifications with the advanced stage of plant maturity (Hussain and Durrani, 2009). The cellulose content of Napier grass did not show significant (P>0.05) difference, though the content varied among the accessions (Table 7). The result indicated that the cellulose content ranged from 378.9 to 425.6 g/kg DM with a mean of 404.2 g/kg DM. The highest cellulose content was recorded for accession 16791 followed by accession 16817 (418.6 g/kg DM) and accession 15743 (412.9 g/kg DM) whereas the lowest was recorded for check accession. The content of cellulose are influenced by harvesting stage (Adane, 2003) and morphological fractions (Seyoum *et al.,* 1996; Fekede, 2004). The presence of cellulose limits the digestion of intact cell walls (Moore and Hatfield, 1994; Cardinal *et al.,* 2003).

While cellulose is composed of simple linear chains of glucose, the individual chains are very tightly packed into large fiber bundles which results in slower cellulose digestion by rumen microbes than digestion rates observed for hemicellulose or pectin (Hatfield and Weimer, 1995; Weimer, 1996). However, all cell wall polysaccharides are completely degradable if non-lignified. The structural polysaccharides composed primarily of cellulose and hemicelluloses are primary restrictive determinants of nutrient intake. The digestibility of forages in the rumen is related to the proportion and extent of lignifications (Van Soest, 1994). Lignin, which forms a complex with hemicellulose, also protects cellulose from enzymatic and microbial attack (Hartfield, 1993).

**Table 7. Mean NDF, ADF, ADL, cellulose and hemicellulose contents of ten Napier grass accessions grown at Holetta**

| SN | Accessions | Nutritional qualities (g/kg DM) | | | | |
|---|---|---|---|---|---|---|
| | | NDF | ADF | ADL | Cellulose | Hemicellulose |
| 1 | 15743 | 767.7[a] | 479.5 | 66.6 | 412.9 | 288.2 |
| 2 | 16783 | 762.3[a] | 467.7 | 56.9 | 410.8 | 294.6 |
| 3 | 16791 | 778.4[a] | 492.8 | 67.3 | 425.6 | 285.6 |
| 4 | 16792 | 775.9[a] | 475.5 | 84.4 | 391.0 | 300.4 |
| 5 | 16794 | 771.8[a] | 496.9 | 86.4 | 410.5 | 274.9 |
| 6 | 16813 | 761.6[a] | 465.1 | 64.7 | 400.4 | 296.5 |
| 7 | 16815 | 782.9[a] | 471.4 | 72.0 | 399.4 | 311.5 |
| 8 | 16817 | 785.7[a] | 471.6 | 53.0 | 418.6 | 314.2 |
| 9 | 16819 | 785.5[a] | 461.4 | 67.2 | 394.2 | 324.0 |
| 10 | 16984 | 728.5[b] | 464.0 | 85.1 | 378.9 | 264.5 |
| | Mean | 770.0 | 474.6 | 70.4 | 404.2 | 295.4 |
| | SEM | 0.22 | 0.28 | 0.24 | 0.30 | 0.28 |
| | P-value | 0.0044 | 0.6280 | 0.3170 | 0.6413 | 0.1457 |

Means followed by different superscript letters within a column are significantly different each other at P<0.05

The hemicellulose content of Napier grass did not show significant (P>0.05) difference, though the content varied among the accessions (Table 7). The hemicellulose content ranged from 264.5 to 324.0 g/kg DM with a mean of 295.4 g/kg DM. The highest hemicellulose content was recorded for accession 16819 followed by accession 16817 (314.2 g/kg DM) and accession 16815 (311.5 g/kg DM) whereas the lowest was recorded for check accession. The composition and content of cell walls are the key factors affecting herbage digestibility. Cell walls are predominately composed of cellulose, hemicellulose and lignin. This experiment confirms that, among the cell wall constituents, cellulose is the dominant followed by hemicellulose and lignin and experiments reported by Diriba (2003) and Fekede (2004) also support this result. The higher hemicellulose content in the feed limits forage intake and digestibility (Lundvall *et al.,* 1994; Wolf *et al.,* 1993), its content in the feed vary among morphological fractions (Fekede, 2004) and increased with advancing age of the pasture (Adane, 2003; Yihalem, 2004).

## Conclusion

Napier grass accessions respond differently for agronomic performance and nutritive values to Holetta environmental conditions. Measured traits such as plant survival rate, tillering performance, plant height, forage dry matter yield, leaf to stem ratio, number of node, internode length, chemical composition and *in-vitro* organic matter digestibility showed variations among the tested napier grass accessions. The result reveled that accessions 16817, 16984, 16791, 16813 and 16783 gave the highest number of tillers per plant, plant height at forage harvest, forage DM yield, leaf to stem ratio and CP yield respectively. This indicate that different accessions have different characteristics in terms of agronomic performance and nutritional qualities. Accessions which had optimum quantitative and qualitative traits should be selected for cultivation. Generally, accession 16791 gave the highest forage DM yield, CP yield and digestible yield thereby recommended for production and utilization at Holetta, in the central highland of Ethiopia.

## Acknowledgements

We would like to thank the Eastern Africa Agricultural Productivity Project (EAAPP) for the financial support of this study.

## REFERENCES


Adane Kitaba, 2003. Effects of stage of harvesting and fertilizer application on dry matter yield and quality of natural grass land in the high lands of north Showa. M.Sc. Thesis. The School of Graduate Studies, Alemaya University, Alemaya, Ethiopia. 96p.

Alemayehu Mengistu, 1997. Conservation based forage development for Ethiopia. Self Help Development International and Institute for Sustainable Development. Berhanena Selam Printing Press, Addis Ababa, Ethiopia. Pp 197.

Alemayehu Mengistu, 2004. Rangelands Biodiversity: Concepts, Approaches, and the Way Forward. Addis Ababa, Ethiopia.

Anderson, W.F., Dien, B.S., Brandon, S. K., Peterson, J. D. 2008. Assessment of Bermuda grass and bunch grasses as feed stocks for conversion to ethanol. *Applied Biochemistry and Biotechnology,* 145:13–21. DOI: 10.1007/s12010-007- 8041-y

AOAC, 1990. Official Methods of Analysis, 15th ed. Assoc. Off. Anal. Chem., Washington, DC, USA.

AOAC, 1995. Official Methods of Analysis. 16th ed. Association of Official Analytical Chemists, Arlington, VA.

Assuero, S.G., Tognetti, J.A. 2010. Tillering regulation by endogenous and environmental factors and its agricultural management. *The Americas Journal of Plant Science and Biotechnology*, 4:35–48. http://goo.gl/0JnnCJ

Bayble, T., Melaku, S. and Prasad, N. K. 2007. Effects of cutting dates on nutritive value of Napier *(Pennisetum purpureum)* grass planted sole and in association with Desmodium *(Desmodium intortum)* or Lablab (*Lablab purpureus*). Livestock Research for Rural Development. Volume 19, Article #11. Retrieved September 10, 2015, from http://www.lrrd.org/lrrd19/1/bayb19011.htm

Boonman, J.G. 1993. East Africa's grasses and fodders: Their ecology and husbandry. Kluwer Academic Publishers, Dortrecht, Netherlands, p. 341.

Boonman, J.G. 1997. Farmers' success with tropical grasses: Crop/pastures rotation in mixed farming in East Africa. Ministry of Foreign Affairs, The Hague, Netherlands, p. 95.

Brown, D. and Chavalimu, E. 1985. Effects of ensiling on five forage species in western Kenya: *Zea mays* (maize stover), *Pennisetum purpureum* (Pakistan napier grass), *Pennisetum spp.* (Bana grass), *Ipomoea batatas* (sweet potato vines) and *Cajanus cajan* (pigeon pea leaves). *Anim. Feed Sci. Technol*. 13:1- 2.

Butt, M. N., Donart, G. B., Southward, M. G., Pieper, R. D., Mohammad, N. 1993. Effect of defoliation on plant growth of Napier grass. Trop. Sci., 33: 111-120.

Cardinal, A. J., M. Lee, K. J. Moore, 2003. Genetic mapping and analysis of quantitative trait loci affecting fiber and lignin content in maize. *Theor Appl Genet* 106: 866-874.

Chaparro, C.J., Sollenberger, L.E., Quesenberry, K.H. 1996. Light interception, reserve status and persistence of clipped Mott elephant grass swards. *Crop Science,* 36:649–655. DOI: 10.2135/cropsci1996.0011183x003600030022x

Cherney, D. J., R Cherney, J. H. and Lucey, R. F. 1993. *In vitro* digestion Kinetics and quality of perennial grass as influenced by forage maturity. *Journal of Dairy Science*, 76: 790- 797.

Clayton, W. D., Govaerts, R., Harman, K. T., Williamson, H., Vorontsova, M. 2013. World checklist of poaceae. Richmond, UK: Royal Botanic Gardens, Kew.

Cook, B. G., Pengelly, B. C., Brown, S. D., Donnelly, J. L., Eagles, D. A., Franco, M. A., Hanson, J., Mullen, B. F., Partridge, I. J., Peters, M., Schultze-Kraft, R. 2005. Tropical forages. CSIRO, DPI&F(Qld), CIAT and ILRI, Brisbane, Australia

Cuomo, G.J., D.C. Blouin and J.F. Beatty. 1996. Forage potential of dwarf napiergrass and a pearl millet x napiergrass hybrid. Agron. J., 88: 434-438.

Dapaah, H.K. 1997. Environmental influences on the growth, development and yield of pinto beans (*Phaseolus vulgaris* L.). Ph.D. Thesis, Lincoln University, Christchurch, New Zealand.

Diriba Geleti, B. Robert and M. Y. Kurtu, 2003. Variations in dry matter yield and nutritive value of *Panicum coloratum* and Stylosanthes guianensis mixed pasture as influenced by harvesting cycles. In: Proceedings of the 10th annual conference of the Ethiopian Society of Animal Production (ESAP) held in Addis Ababa, Ethiopia, August 21-23, 2003.

Ducrocq, H. and Duru, M. 1997. *In vitro* digestibility of green lamina of Cocksfoot *(Dactylis glomerata L.)* in relation to water deficit. *Grass and Forage Science*, 52: 432-438.

Farrell, G., Simons, S. A. and Hillocks, R. J. 2002. Pests, diseases and weeds of Napier grass, Pennisetum purpureum: a review. *Journal of pest management,* 2002, 48 (1) 39-48.

Fekede Feyissa, 2004. Evaluation of potential forage production qualities of selected oats (*Avena sativa* L.) genotypes. M.Sc. Thesis. Alemaya University of Agriculture, Ethiopia.

Fekede Feyissa, Getnet Assefa, Lulseged G/Hiwot, Muluneh Minta and Tadesse T/Tsadik. 2005. Evaluation of Napier grass-vetch mixture to improve total herbage yield in the central highlands. In: Proceedings of the 13th annual conference of the Ethiopian Society of Animal Production (ESAP), August 25 – 26, 2005, Addis Ababa, Ethiopia.

Food and Agricultural Organization (FAO), 2015. Grassland Index. A searchable catalogue of grass and forage legumes. FAO, Rome, Italy.

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

Hagerman, A. E., Robbins, C. T., Weerasuriya, Y., Wilson, T. C. and McArthur, C. 1992. Tannin chemistry in relation to digestion. *J . Range Mgt*. 45:57-62.

Hartfield, R. D. 1993. Cell wall polysaccharide intractions and degradability. In: Jung H.G., Buxton, D.R., Hartfield, D.R. and Ralph J. (Eds). Forage cell wall structure and digestibility. *Amer. Soc. Agron*. Madison, US.

Hatfield, R. D. and P. J. Weimer, 1995. Degradation characteristics of isolated and in situ cell wall lucerne pectic polysaccharides by mixed ruminal microbes. *J. Sci. Food Agric*. 69:185-196.

Hoogenboom, G. 2000. Contribution of agro-meteorology to the simulation of crop production and its application. Agricultural and Forest Meteorology 103: 137-157.

Humphreys, L. R. 1991. Tropical pasture utilization. Camb. University press. Great Britain.

Hussain, F. and M. J. Durrani, 2009. Nutritional evaluation of some forage plants from Harboi rangeland, Kalat, Pakistan. *Pakistan J. Bot*. 41: 1137-1154.

Ishii, Y., Yamaguchi, N. and Idota, S. 2005. Dry matter production and in vitro dry matter digestibility of tillers among Napier grass (*Pennisetum purpureum Schumach*) varieties. *Grassland Science* 51: 153-163.

Jukenvicius, S. and N. Sabiene, 2007. The content of mineral elements in some grasses and legumes. *Ekologija*. 53:44-52.

Kaitho, R. J. 1997. Nutritive value of browses as supplements to poor quality roughages. PhD thesis, Wageningen Agricultural University, The Netherlands.

Khairani, L., Ishii, Y., Idota, S., Utamy, R.F., Nishiwaki, A. 2013. Variation in growth attributes, dry matter yield and quality among 6 genotypes of Napier grass used for biomass in year of establishment in Southern Kyushu, Japan. *Asian Journal of Agricultural Research,* 7:15–25. DOI: 10.3923/ ajar.2013.15.25

Lafarge, M. Loiseau, P. 2002. Tiller density and stand structure of tall fescue swards differing in age and nitrogen level. *European Journal of Agronomy,* 17:209–219. DOI: 10.1016/s1161-0301(02)00011-4

Lamb, F.S.J., C.C. Sheaffer, H.L. Rhodes, R.M. Sulc, J.D. Undersander and E.C. Brummer, 2006. Five Decades of Alfalfa Cultivar Improvement: Impact on Forage Yield, Persistence, and Nutritive Value. *Crop Science*, 46: 902-909.

Leng, R.A. 1990. Factors affecting the utilization of poor quality forages by ruminants particularly under tropical conditions. *Nutritional Research Reviews*, 3: 277-303.

Lowe, A. J., Thorpe, W., Teale, A., Hanson, J. 2003. Characterization of germplasm accessions of Napier grass (Pennisetum purpureum and P. purpureum x P. glaucum hybrids) and comparison with farm clones using RAPD. *Genetic Resources and Crop Evolution* 50:121–137

Lundvall, J.P., D.R. Buxton, A.R. Hallauer, and J.R. George, 1994. Forage quality variation among maize inbreeds: in Vitro digestibility and cell-wall components. *Crop Sci*., 34: 1671-1678.

Mahala, A. G., I. V. Nsahlai, N. A., D. Basha and L.A. Mohammed, 2009. Nutritive evaluation of natural pasture at early and late rainfall season in Kordofan and Butana, Sudan, *Aust J Basic Appl Sci* 3: 4327-4332.

Mannetje, C. T. 1983. Nutritive value of topical and sub-tropical pastures with special reference to protein and energy deficiency in relation to animal production. In: Gilchrist, F. M. C. and Mackie, R.I. (Eds.), Herbivore Nutrition in the Sub-tropic and Tropics. Science Publication, Pretoria, pp. 55-66

McDowell, L. R. and Conrad, J. H. 1990. Mineral imbalances of grazing livestock in tropical countries. *Int. J. Anim. Sci*. 5:21-32.

McDowell, L. R. and G. Valle, 2000. Major minerals in forages. In: D.I. Givens, E. Owen, R.F.E. Axford and H. M. Omed (eds.). Forage Evaluation in Ruminant Nutrition. CABI Publishing, New York, NY. p. 373-397.

Minson, D. J. 1981. Nutritional differences between tropical and temperate pastures. In: F. H. W. Morley (ed) Grazing Animals-World Animal Science, Elsevier Scientific Publishing Company, Netherlands: pp 143-156.

Minson, D. J. 1990. Forage in ruminant nutrition. Academic press, Inc. San Diego.

Moore, K. J., and R. D. Hatfield, 1994. Carbohydrates and forage quality. In: Fahey G.C. (ed) Forage quality, evaluation, and utilization. ASA-CSSA-SSSA, Madison, pp 229-280.

Muinga, R. W., Thorpe, W. and Topps, J. H. 1992. Voluntary food intake, live-weight change and lactation performance of crossbred dairy cows given ad libitum Pennisetum purpureum (napier grass var. Bana) supplemented with leucaena forage in the lowland semi-humid tropics. *Anim. Prod.,* 55 (3): 331-337.

Mukhtar, M. 2006. Dry matter productivity of the dwarf and normal elephant grasses as affected by the planting density and cutting frequency. *Indonesian Journal of Animal and Veterinary Sciences,* 11:198–205. http://goo.gl/d5hpyL

Mureithi, J.G and W. Thorpe, 1996. The effects of herbaceous legume intercropping and mulching on the productivity of Napier grass (Pennisetum purpureum) and total forage yield in coastal lowland Kenya. *In*: Jean Ndikumana and Peter de Leeuw (eds.) Sustainable Feed Production and Utilization for Smallholder Livestock Enterprises in Sub-Saharan Africa. African Feed Resources Network (AFRNET) Workshop held in Harare, Zimbabwe 6-10 December 1993. AFRNET, Nairobi, Kenya, 45-50.

Mustafa, A.F., J. J. McKinnon and D. A. Christensen, 2000. The nutritive value of thins tillage and wet distillers' grains for ruminants. *Asian-Aus. J. Anim. Sci*. 13: 1609-1618.

Mwendia, S. W., Wanyoike, M., Nguguna, J.G.M., Wahome, R.G., Mwangi, D. M. 2006. Evaluation of Napier grass cultivars for resistance to Napier head smut. Proceedings of the 10th KARI Biennial Scientific Conference, KARI, Nairobi, Kenya, pp 85-97.

Mwendia, S.W., Mwangi, D.M., Wahome, R.G., Wanyoike, M. 2008. Assessment of growth rate and yields of three Napier grass varieties in Central Highlands of Kenya. *E. Afr. Agric. For. J.,* 74(3): 211-217.

Norton, B. W. 1981. Differences between species in forage quality. In: Hacker, J.B. (ed). Nutritional limits to animal production from pasture. CAB, Farnham Royal, UK. pp. 89-110.

NRC, 2001. *Nutrient Requirements of Dairy Cattle*. 7th edn. National Research Council, National Academy of Sciences, Washington, DC. ISBN-13: 978–0–309–06997–7

Nyambati, E.M., Sollenberger, L.E., Kunkle, W.E. 2003. Feed intake and lactation performance of dairy cows offered Napier grass supplemented with legume hay. *Liv. Prod. Sci.,* 83: 179-189.

Pal, U.R. 2004. Crop physiology. Teaching material. Alemaya University. Ethiopia. Pp. 24-25.

Pascual, J. J., Fernandez, C., Diaz, J. R., Garces, C., Rubert-Aleman, J. 2000. Voluntary intake and in vivo digestibility of different date-palm fractions by Murciano-*Granadina (Capra Hircus*). *Journal of Arid Environments*, 45: 183-189.

Rotili, P., G. Gnocchi, C. Scotti and D. Kertikova, 2001. Breeding of the alfalfa plant morphology for quality. Proceedings of the XIV Eucarpia Medicago sp. Group Meeting. Zaragoza, 45: 25-28.

Schank, S.C., D.P. Chynoweth, C.E. Turick and P.E. Mendoza, 1993. Napier grass genotype and plant parts for biomass energy. *Biomass Bioenergy*, 4: 1-7.

Seyoum Bediye, Zinash Shileshi and Tesfaye Mengiste, 1996. Tef (*Eragrostis tef*) straw quality as influenced by variety and locations. In: Proceedings of the 4th annual conference of the Ethiopian Society of Animal Production. April 18-19, 1996, Addis Ababa, Ethiopia, pp. 145-152.

Seyoum Bediye, Zinash Sileshi, Tadesse Tekletsadik and Liyusew Ayalew, 1998. Evaluation of Napier grass (*Pennisetum purpureum*) and Pennisetum Hybrids (*Pennisetum purpureum x Pennisetum typhoides*) in the central highlands of Ethiopia. In: Fifth National Conference of Ethiopian Society Of Animal Production. 15-17 May 1997, Addis Ababa, Ethiopia.

Shalaby, A.S., G.M. Abdul Aziz, M.A. Gabra and M.G. Beshy, 1991. Preservation of Napier grass (*Pennisetum purpureum*) and fodder beet (*Beta vulgaris*) leaves as hay and their nutritional evaluation. Abstracts on Tropical Agriculture. 16: Abstract No 76047.

Singh, K.K., S. Bandla and K.S. Ramachandra, 1997. Chemical changes with maturity and its impact on in sacco dry matter degradation of some range grasses and legumes. *Indian J. Anim. Nutr*. 14: 254-257.

Smart, A.J., Schacht, W.H., Moser, L.E., Volesky, J.D. 2004. Prediction of leaf/stem ratio using near-infrared reflectance spectroscopy (NIRS): A Technical Note. In: Agronomy & Horticulture Faculty Publications, Vol. 39. http://goo.gl/QFvzF9

Spears, J. W. 1994. Minerals in forages. In: Fahey, G.C. (ed). Forage quality, evaluation and utilisation. *Amer. Soc. Agron*., Madison, Wisconsin, USA. pp. 281-317.

Statistical Analysis System (SAS), 2002. SAS/STAT guide for personal computers, version 9.0 editions. SAS Institute Inc., Cary, NC, USA.

Tessema Zewdu and Alemayehu Mengistu, 2010. Management of Napier Grass (Pennisetum Purpureum (L.) Schumach) for High Yield and Nutritional Quality in Ethiopia: A Review. *Eth. J. Anim. Prod. 10(1) – 2010: 73 –94. ©Ethiopian Society of Animal Production* (ESAP) EJAP ISSN: 1607-3835 Volume 10, Number 1, 2010.

Tessema Zewdu, Baars R, Alemu Yami, Dawit N. 2002. In sacco dry matter and nitrogen degradability and their relationship with *in- vitro* dry matter digestibility of Napier grass (Pennisetum purpureum (L.) Schumach.) as influenced by plant height at cutting. *Australian J. Agric. Research*, 53: 7-12.

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

Tessema, Z. 1999. Napier Grass Adapts Well in North Western Ethiopia. *AgriTopia*. EARO, Vol.14 No. 1 1999.

Tessema, Z. 2005. Variation in growth, yield, chemical composition and in vitro dry matter digestibility of Napier grass accessions (Pennisetum purpureum). Tropical Science 45:67–73. DOI: 10.1002/ts.51

Tessema, Z. 2008. Effect of plant density on morphological characteristics, yield and chemical composition of Napier grass (Pennisetum purpureum (L.) Schumach). East *African Journal of Sciences* 2:55–61. DOI: 10.4314/eajsci.v2i1.40365

Tilley, J. M. A. and Terry, R. A. 1963. A two stage technique for the in vitro digestion of forage crops. *J. Brit. Grassl. Soc.* 18, 104-111.

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

Van Soest, P. J. 1982. Nutritional ecology of the ruminant. O & B books, Corvallis, Oregon, USA.

Van Soest, P. J. 1994. Nutritional Ecology of the Ruminant, 2nd ed., Cornell University, Ithaca, NY, pp. 476.

Van Soest, P. J. and Robertson, J. B. 1979. Systems of analysis for evaluating fibers feed. In: Pigden, W.J., C.C. Balch and Michael Graham (Eds.), Standardization of Analytical Methodology for Feeds. Workshop proceeding, 12-14 March, Ottawa, Canada, pp. 49-60

Van Soest, P. J. and Robertson, J. B. 1985. Analysis of Forages and Fibrous Foods. A Laboratory Manual for Animal Science 613. Cornel University, Ithaca. New York, USA, 202p.

Weimer, P. J. 1996. Why don't ruminal bacteria digest cellulose faster? *J. Dairy Sci*. 79:1496- 1502.

Wilson, J. R. and Hatfield, R. D. 1997. Structural and chemical change of cell-wall types during stem development: consequences of fibre degradation by rumen microflora. *Australian Journal of Research*, 48: 165-180.

Wilson, J. R., B. Deinum, and F. M. Engels, 1991. Temperature influences on anatomy and digestibility leaf and stem of tropical and temperate forage species. *Neth J. Agric. Sci*., 39: 31.

Wilson, J. R., Jones, P. N. and Minson, D. J. 1986. Influence of temperature on the digestibility of and growth of *Macroptilium atropurpureum* and *Panicum maximum* var. *Trichoglume* in sub-tropical and tropical Australia. Tropical Grasslands, 20: 145-165.

Wolf, D. R., J. G. Coors, K. A. Albrecht, D. J. Undersander and P. R. Carter, 1993. Forage quality of maize genotypes selected for extreme fiber concentrations. *Crop sci*. 33: 1353-1359.

Woodard, K.R., G.M. Prine, and W.R. Ocumpaugh, 1985. Techniques in the establishment of elephant grass (Pennisetum purpureum Schum*.). Soil Crop Sci. Soc. Fla. Proc.* 44:216–221.

Yihalem Denekew, 2004. Assessment of Botanical Composition and Stage of Harvesting of selected Natural Pasture for Optimum Utilization as Hay at Andassa Livestock Research Center, Northwestern Ethiopia. M.Sc. Thesis the School of Graduate Studies, Alemaya University. 99p.

Zewdu, T. 2005. Variation in growth, yield, chemical composition and in vitro dry matter digestibility of Napier grass varieties (*Pennisetum purpureum*). *Trop. Sci.* 45: 67-73.

*******