

Agronomic performance, dry matter yield stability and herbage quality of Napier grass (*Pennisetum purpureum* (L.) Schumacher) accessions in different agro-ecological zones of Ethiopia

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Abstract. Ten Napier grass accessions were evaluated for agronomic performance, dry matter (DM) yield stability and nutritional attributes at Holetta, Debre zeit, Adamitulu, Areka and Hawassa agricultural research centers during the main cropping seasons of 2011 to 2014. The experiment was conducted in randomized complete block design with three replications. At planting, diammonium phosphate (DAP) at the rate of 100 kg/ha was uniformly applied and additionally urea at the rate of 50 kg/ha was top dressed after forage harvesting. Combined analysis of variance indicated that the tested genotypes varied significantly ($P < 0.05$) for plant height and forage DM yield. However, the test environments displayed significant variations for all measured agronomic and quality traits except the crude protein (CP) content. The genotype by environment ($G \times E$) interaction effects also revealed significant differences for plant height, DM yield, ash content, CP yield, digestible yield and hemicelluloses content. Of the total variance of DM yield, environment main effect accounted for 40.6%, whereas genotype and $G \times E$ interaction effects accounted for 14.8% and 38.8% respectively. The highest mean DM yield was recorded at Adamitulu (13.06 t/ha) followed by Areka (12.80 t/ha), Hawassa (11.80 t/ha), Debre zeit (10.50 t/ha) and Holetta (7.05 t/ha). Different stability parameters and models indicated that Napier grass accessions such as 16817, 16783 and local were the most stable while accessions such as 16791 and 16815 were the most unstable genotypes across the tested environments. The CP and *in-vitro* organic matter digestibility (IVOMD) were higher in the highlands while CP yield, digestible yield and most fiber components were relatively higher in the mid altitude areas indicating that temperature and amount of rainfall and its distribution had an adverse affect on the feed quality of Napier grass. Generally, Napier grass accessions such as 16817, 16783 and local are recommended for wider cultivation due to better DM yield stability performance across the test environments.

Keywords: accessions, agronomic performance, napier grass, nutritive values, yield stability.

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 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). It is a tall and deep-rooted perennial bunch grass well known for its high yielding capability and mainly used in cut-and-carry 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), Napier grass grows best at high temperatures but can tolerate low air temperatures under which the yield can be reduced and ceases to grow at a temperature below 10°C. It does better on rich, deep soils such as friable loams but can grow on poorly drained clays with fairly heavy texture or excessively drained sandy soils with pH ranging from 4.5 to 8.2 (FAO, 2015; Cook *et al.*, 2005). Napier 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). For best establishment and productivity, it should be planted at a distance of 1 m between rows and 0.5 m between plants (Tessema, 2008). However, the spacing vary due to climatic condition of the area and the narrow spacing is used for moisture stress area when compared with high moisture areas.

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 to 30 t DM/ha/year with good agronomic and management practices (Farrell *et al.*, 2002). Napier grass can provide a continual supply of green forage throughout the year and best fits to all intensive small scale farming systems (Alemayehu, 1997). All forage crops respond dramatically to good management practices. Hence, higher yields, better forage quality and improved persistence results from paying attention to the basics of good forage management conditions. Cuttings can be done at 45 to 90 day intervals, depending on location (FAO, 2015), genetic variation and management. Based on chemical composition and *in-vitro* dry matter digestibility (IVDMD), Napier grass 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 the 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. However, the performance of forage species vary across locations due to differences in soil types, temperature and amount and distribution of rainfall. Testing the adaptability and yield potential of different forage crops across various agro-ecological zones is very important to identify the best-bet accessions for utilization. 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 objectives in this study were to evaluate the agronomic performance, DM yield stability and nutritive values of ten accessions of Napier grass in multiple environmental conditions of Ethiopia.

MATERIALS AND METHODS

Descriptions of the test environments

The experiment was conducted under field conditions at Holetta, D/zeit, Adamitulu, Areka and Hawassa Agricultural Research Centers during the main cropping seasons. The test locations represent the low, mid and highland areas ranging in altitude from 1650 to 2400 masl. The farming system of the study areas is mixed crop livestock production system. Descriptions of the test environments are indicated in Table 1.

Experimental design and layout

The ten accessions of Napier grass considered for this research experiment were 15743, 16783, 16791, 16792, 16794, 16813, 16815, 16817, 16819 and local check. The experiment was conducted under field conditions for four years during the main cropping seasons of 2011 to 2014. The accessions were planted at the beginning of the main rainy season in five agricultural research centers. The accessions were planted in 4 × 4 m plot using a randomized complete block design (RCBD) with three replications and the accessions assigned randomly to plots within block. Root splits at Holetta and stem cuttings at D/zeit, Adamitulu, Areka and Hawassa were planted in rows with four rows per plot. Stem cuttings with three nodes were planted to a depth of 15 to 20 cm at an angle of 45°. A total of 32 root splits/stem cuttings were planted per plot with the intra and inter row spacing of 0.5

Table 1. Description of the test locations for geographical position and physico-chemical properties of the soils.

Parameter	Agricultural Research Centers				
	Holetta	D/zeit	Adamitulu	Areka	Hawassa
Latitude	9° 00' N	9° N	7° 9'N	7°06' N	7°04' N
Longitude	38° 30'E	39° E	38° 7'E	37°41' E	38°31' E
Altitude (masl)	2400	1850	1650	1711	1700
Distance from Addis Ababa (km)	29	48	167	300	275
Annual Rainfall (mm)	1044	800	760	1400	1100
Daily minimum temperature (°C)	6.2	12.2	12.6	14.5	12.9
Daily maximum temperature (°C)	21.2	25.7	27.0	25.8	27.3
Soil type	Nitosol	Alfisol	Andosol	Nitosol	Fluvisol
Textural class	Clay	Loam	Sandy loam	Silty loam	Clay loam
pH(1:1 H ₂ O)	5.24	7.26	7.88	5.2	4.9
Total organic matter (%)	1.80	2.83	2.38	2.65	4.60
Total nitrogen (%)	0.17	0.22	0.39	0.36	0.35
Available phosphorous (ppm)	4.55	10.84	37.41	2.75	2.62

and 1 m, respectively. There was an alleyway of 2 m width between blocks and 1m width between plots. A blanket basal phosphorus fertilizer 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.

Agronomic data collection and measurements

Measurements taken before and after each harvest were plant survival rate, plant height and forage DM yield. Plant survival rate was calculated as the ratio of the number of alive plants planted per plot to the total number of plants planted per plot and then multiplied by 100. 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 harvested at forage harvesting stage from two rows next to the guard rows of 5 to 10 cm above the ground level. 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 their sample fresh weight and then oven dried for 24 h at a temperature of 105°C to determine dry matter yield.

Chemical analysis and *in-vitro* organic matter digestibility

The oven dried samples at a temperature of 65°C for 72 h were used for laboratory analysis to determine

chemical composition and *in-vitro* organic matter digestibility of the accessions. The dried samples were then ground to pass a 1-mm sieve and the ground samples were used for laboratory analysis. Analysis was made for the different nutritional parameters (Ash, CP, NDF, ADF, ADL and IVOMD). Total ash content was determined by oven drying the samples at 105°C overnight and by combusting the samples in a muffle furnace at 550°C for 6 h (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). Hemicelluloses 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 analysis was made between the major quantitative, qualitative and between quantitative and qualitative traits. The data were analyzed using the following model: $Y_{ijk} = \mu + G_i + E_j + (GE)_{ij} + B_{k(j)} + e_{ijk}$; Where, Y_{ijk} = measured response of genotype i in block k of environment j ; μ =

Table 2. Combined analysis of variance for measured agro-morphological and quality traits of Napier grass genotypes/accessions tested over locations/environments.

SN	Traits	Mean squares		G × E	Mean	CV
		Genotype	Environment			
1	Plant height (cm)	**	***	**	114.93	17.02
2	Dry matter yield (t/ha)	**	***	**	11.04	25.70
3	Ash (g/kg DM)	NS	***	*	121.1	8.63
4	CP (g/kg DM)	NS	NS	NS	55.7	19.05
5	IVOMD (g/kg DM)	NS	***	NS	453.9	10.10
6	CP yield (t/ha)	NS	***	***	0.55	30.95
7	IVOMD yield (t/ha)	NS	***	***	4.40	28.88
8	NDF (g/kg DM)	NS	***	NS	789.9	2.97
9	ADF (g/kg DM)	NS	***	NS	451.8	5.40
10	ADL (g/kg DM)	NS	**	NS	75.9	17.94
11	Cellulose (g/kg DM)	NS	***	NS	375.8	6.53
12	Hemicelluloses (g/kg DM)	NS	***	*	338.1	6.47

* = P<0.05; ** = P<0.01; *** = P < 0.001; NS = Non-significant; G × E= Genotype by environment interaction.

grand mean; T_i = effect of genotype i ; E_j = effect of environment j ; GE = genotype and environment interaction; $B_{k(j)}$ = effect of block k in environment j ; e_{ijk} = random error effect of genotype i in block k of environment j .

Several stability parameters have been developed to characterize yield stability when genotypes are tested across multiple environments. To select the desirable genotypes, the mean performance, regression coefficient (b_i) and deviation from regression (S^2d_i) were calculated following Eberhart and Russells model (1966). The regression model defines a stable variety as having above average mean grain yield, a regression coefficient of unity ($b_i = 1.0$), and non-significant mean square for deviations from regression ($S^2d_i = 0$). In addition, the $G \times E$ interactions were analyzed using Additive Main effect and Multiplicative Interaction (AMMI) analysis (Crossa, 1990; Gauch, 1992) to assess similarity and dissimilarity among testing environments and interaction patterns. Consequently, biplot generated using genotypic and environmental scores of the AMMI 1 components can help breeders have an overall picture of the behavior of the genotypes, the environments and $G \times E$ (Kaya *et al.*, 2002; Tarakanovas and Ruzgas, 2006). Genotypes and environments with large IPC1 scores (either positive or negative) have large interactions, whereas genotypes and environments with IPC1 scores near zero have small interactions. Yan and Hunt (2001) used a Genotype and genotype x environment (GGE) biplot, constructed from the first two principal components (PC1 and PC2) derived from principal component analysis of environment-centered yield data.

A GGE biplot is a biplot that display the G and GE interaction of a genotype by environment two-way data. An application of the biplot geometry is to visually identify the mean performance and stability of genotypes. In this

method an ideal genotype is the one that has both high mean yield and high stability. Generally, all stability analysis was carried out using the "CropStat" version 7.2 software computer packages. The stability parameters of DM yield were estimated after Finlay-Wilkinson (1963), with the model presented with the following equation: $F_{ij} = \mu + g_i + b_i t_j + \delta_{ij} + e_{ij}$, where, μ - an average yield of the i^{th} genotype in the j^{th} environment; g_i - an average yield of the i^{th} genotype in all environments; b_i - regression coefficient to the environmental index indicating a genotypic response to environmental changes; t_j - environmental index as a mean of all genotypes in the j^{th} environment reduced by a grand mean; δ_{ij} - deviation from regression of the i^{th} genotype in the j^{th} environment.

RESULTS AND DISCUSSION

Location and interaction effect on the performance of Napier grass genotypes/accessions

Combined analysis of variance for measured agronomic and nutritive values of Napier grass genotypes/accessions tested over locations/environments are indicated in Table 2. The result indicated that the tested genotypes varied significantly ($P < 0.05$) only for plant height and forage DM yield. On the other hand, the environments displayed significant ($P < 0.05$) differences for acid detergent lignin (ADL) content and highly significant ($P < 0.001$) variations was also observed for other agronomic and quality traits except crude protein (CP) content. The Genotype \times environment ($G \times E$) interaction effects also revealed significant differences for plant height, DM yield, ash content, CP yield, digestible yield and hemicelluloses content. Where environmental differences are greater, it

Table 3. Mean plant height (cm) of ten Napier grass genotypes/accessions tested across five locations/environments at forage harvesting stage.

SN	Accessions	Locations/environments					Combined
		Holetta	D/zeit	Adamitulu	Areka	Hawassa	
1	15743	106.60 ^c	124.27 ^{bc}	84.23 ^c	100.00	149.50 ^{ab}	119.59 ^{abc}
2	16783	82.67 ^{ef}	110.73 ^{bc}	88.13 ^{bc}	100.00	148.50 ^{ab}	106.04 ^{cd}
3	16791	115.83 ^b	124.97 ^{bc}	111.90 ^{bc}	100.00	139.50 ^{bcd}	118.44 ^{abc}
4	16792	107.03 ^{bc}	96.03 ^c	85.10 ^c	100.00	130.83 ^{cde}	103.80 ^d
5	16794	96.83 ^d	118.60 ^{bc}	115.33 ^{abc}	100.00	134.67 ^{bcd}	113.09 ^{bcd}
6	16813	75.13 ^f	99.97 ^c	119.90 ^{abc}	133.33	149.33 ^{ab}	115.53 ^{bcd}
7	16815	80.03 ^{ef}	104.80 ^{bc}	121.67 ^{ab}	133.33	128.00 ^{de}	113.57 ^{bcd}
8	16817	86.10 ^e	118.63 ^{bc}	112.90 ^{bc}	100.00	121.50 ^e	107.83 ^{cd}
9	16819	88.33 ^{de}	132.47 ^b	150.47 ^a	100.00	158.83 ^a	126.02 ^{ab}
10	Local	124.77 ^a	172.83 ^a	117.90 ^{abc}	100.00	144.67 ^{abc}	132.03 ^a
	Mean	96.33	120.33	110.75	106.67	140.53	114.93
	CV	6.09	14.56	18.90	22.82	6.31	17.02
	LSD	10.06	30.06	35.91	41.76	15.21	14.17

may be expected that the G × E interaction will also be greater.

The G × E interaction is important for plant breeding because it affects the genetic gain and selection of cultivars with wide adaptability (Deitos *et al.*, 2006; Souza *et al.*, 2009). Statistically, G × E interactions are detected as significantly different patterns of response among the genotypes across environments, this will occur when the contributions (or level of expression) of the genes regulating the trait differ among environments (Bisford and Cooper, 1998). Major difference in genotypes stability is due to crossover interaction effect of genotype and environment; therefore, changes in their rank vary in different environmental conditions. According to Dixon and Nukenine (1997), the interaction is a result of changes in a cultivar's relative performance across environments due to differential responses of the genotypes to various edaphic, climatic and biotic factors. Therefore, evaluation of yield performance, adaptation patterns and stability of Napier grass genotypes in multiple environments is very important for proper management and utilization of the crop.

Plant height at forage harvesting

Mean plant height of Napier grass accessions were significantly ($P < 0.05$) different across all testing sites (Table 3). The result indicated that the highest mean plant height at forage harvesting was recorded from Hawassa followed by Debre zeit, Adamitulu, Areka and Holetta testing sites. The highest mean plant height was obtained from local accession at Holetta and Debre zeit while accession 16819 produced the highest plant height at Adamitulu and Hawassa. On the other hand accessions 16813, 16792, 15743 and 16817 produced the lowest plant height at Holetta, Debre zeit, Adamitulu

and Hawassa, respectively. At Areka, all accessions were harvested at the same height except accessions 16813 and 16815. Combined analysis for plant height also differed significantly ($P < 0.05$), which ranged from 103.80 to 132.03 cm with a mean of 114.93 cm. Generally, the local accession gave the highest mean plant height followed by accession 16819 and 15743 while accession 16792 gave the lowest plant height. This variation could be due to the differences in moisture content and soil fertility condition of the testing sites. 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).

Forage dry matter yield

A combined analysis of variance for DM yield of ten Napier grass genotypes/accessions tested across five environments is indicated in Table 4. The result showed that the main effect differences among genotypes, environments and the interaction effects were highly significant ($P < 0.001$). This highly significant ($P < 0.001$) G × E interaction effects indicating inconsistency in the performance of the genotypes across the environments and supporting the need for assessing performance in order to identify Napier grass genotypes with stable and

Table 4: Combined analysis of variance for DM yield of ten Napier grass genotypes/accessions tested across five environments

Source	DF	SS	MS	Explained SS (%)
Model	51	1770.19	34.71***	
Replication (R)	2	102.01	51.01**	5.76
Environment (E)	4	718.49	179.62***	40.59
Genotype (G)	9	262.16	29.13***	14.81
G x E	36	687.53	19.10***	38.84
Error	98	788.72	8.05	

*** Significant at the 0.001 probability level; ** Significant at the 0.01 probability level.

Table 5. Mean forage DM yield (t/ha) of ten Napier grass genotypes/accessions tested across five locations/environments at forage harvesting stage.

SN	Accessions	Locations/environments					Combined
		Holetta	D/zeit	Adamitulu	Areka	Hawassa	
1	15743	7.40 ^{bc}	11.34 ^{ab}	12.36 ^{cd}	11.98 ^{bcd}	8.43 ^{bcd}	10.30 ^{bc}
2	16783	7.00 ^{bcd}	10.82 ^{ab}	10.97 ^d	12.32 ^{bcd}	14.68 ^a	11.16 ^{abc}
3	16791	10.51 ^a	14.87 ^a	16.70 ^{ab}	12.56 ^{abcd}	7.88 ^d	12.50 ^a
4	16792	6.50 ^{bcd}	4.34 ^c	9.73 ^d	10.94 ^{bcd}	8.34 ^{cd}	7.97 ^d
5	16794	6.90 ^{bcd}	8.44 ^{bc}	11.87 ^d	6.95 ^d	15.26 ^a	9.88 ^{cd}
6	16813	5.49 ^{cd}	12.35 ^{ab}	11.77 ^d	13.87 ^{abc}	11.42 ^{abcd}	10.98 ^{abc}
7	16815	4.57 ^d	9.94 ^{abc}	11.27 ^d	18.20 ^a	12.71 ^{abc}	11.34 ^{abc}
8	16817	6.17 ^{bcd}	11.59 ^{ab}	12.55 ^{cd}	13.87 ^{abc}	13.17 ^{ab}	11.47 ^{abc}
9	16819	8.74 ^{ab}	11.72 ^{ab}	18.30 ^a	10.62 ^{cd}	13.49 ^a	12.57 ^a
10	Local	7.23 ^{bcd}	9.55 ^{abc}	15.06 ^{bc}	16.69 ^{ab}	12.57 ^{abcd}	12.22 ^{ab}
	Mean	7.05	10.50	13.06	12.80	11.80	11.04
	CV	22.66	34.59	12.69	26.39	23.50	28.45
	LSD	2.74	6.23	2.84	5.80	4.75	2.06

superior yield across the environments. Of the total variance of DM yield, environment main effect accounted for 40.59%, whereas genotype and G × E interaction effects accounted for 14.81 and 38.84%, respectively. This result shows that DM yield was significantly affected by changes in environment followed by G × E interaction and genotypic effects. The large variance for environments indicated that the environments were diverse, with large differences among environmental means causing most of the variation in DM yield performance of Napier grass genotypes. The highly significant environment effect and its high variance component could be attributed to the large differences among the test environments in altitude, soil types, temperature and differences in both amount and distribution of annual rainfall and other agro-climatic factors. In presence of G × E interaction, a genotype does not exhibit the same phenotypic characteristics under test environments and various genotypes respond differently to a specific environment. According to Pham and Kang (1988) report, G × E interaction minimizes the utility of genotypes by confounding their yield performances. When genotypes perform consistently

across locations, breeders are able to effectively evaluate germplasm with a minimum cost in a few locations for ultimate use of the resulting varieties across wider geographic areas (Gemetchu, 2012). However, with high genotype by location interaction effects, genotypes selected for superior performance under one set of environmental conditions may perform poorly under different environmental conditions (Ceccarelli, 1997). Therefore, development of cultivars or varieties, which can be adapted to a wide range of environments, is the ultimate goal of plant breeders in a crop improvement program.

Forage DM yield showed significant ($P < 0.05$) variation among the tested Napier grass accessions across the testing sites (Table 5). The highest mean DM yield was recorded at Adamitulu followed by Areka, Hawassa, Debre zeit and Holetta. Accession 16791 gave the highest mean DM yield at both Holetta and Debre zeit. Similarly, accessions 16819, 16815 and 16794 gave the maximum DM yield at Adamitulu, Areka and Hawassa respectively. On the other hand, accessions 16815, 16794 and 16791 gave the lowest DM yield at Holetta, Areka and Hawassa respectively. Similarly, accession

Table 6. Mean DM yield (t/ha), linear regression coefficient (b_i) and deviation from regression (S^2d_i) for DM yield of ten Napier grass genotypes tested across five environments.

SN	Genotypes	DM yield (t/ha)	DM Rank	Stability for DM yield	
				b_i	S^2d_i
1	15743	10.3 ^{bc}	8	0.698	2.80
2	16783	11.2 ^{abc}	6	0.881	4.21
3	16791	12.5 ^a	2	0.490	14.28
4	16792	8.0 ^d	10	0.705	5.16
5	16794	9.9 ^{cd}	9	0.651	14.10
6	16813	11.0 ^{abc}	7	1.176	2.68
7	16815	11.3 ^{abc}	5	1.701	9.14
8	16817	11.5 ^{abc}	4	1.202	1.13
9	16819	12.6 ^a	1	1.026	9.23
10	Local	12.2 ^{ab}	3	1.471	2.80

16792 produced the minimum DM yield at Debre zeit and Adamitulu. Combined analysis indicated that DM yield varied significantly ($P < 0.05$) among the tested accessions. Accordingly, forage DM yield ranged from 7.97 to 12.57 t/ha with a mean of 11.04 t/ha. Generally, accession 16819 and 16792 gave the highest and lowest DM yield respectively. 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 environments and genotype \times environment interaction effects.

Herbage 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 biomass yield. According to Zewdu (2005) and Ishii *et al.* (2005), the taller varieties showed higher dry matter 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 herbage 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). 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). 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).

Dry matter yield stability analysis

The overall mean forage DM yield, regression coefficient (b_i) and deviation from regression (S^2d_i) are indicated in Table 6. According to Eberhart and Russell (1966) model, genotypic performance generally expressed in terms of three parameters; mean yield, regression coefficient (b_i) and the deviation from regression (S^2d_i). According to this model, a genotype should have a high mean yield, $b_i=1$ and $S^2d_i=0$ to decide its stability. According to Finlay and Wilkinson (1963), b_i approximating close to 1.0 indicates average stability, but always be associated and interpreted with the genotype mean yield to determine adaptability. When the regression coefficients for genotypes are approximately to 1.0, deviation from regression close to zero and are associated with high mean yield, genotypes are adapted to all environments. But when associated with low mean yield, genotypes are poorly adapted to all environments. Genotypes such as local, 16817 and 16783 had higher and above grand mean DM yield, minimum deviation from regression and regression coefficient close to 1.0. Based on the criteria of Eberhart and Russell (1966) regression model, these Napier grass genotypes can be considered as the most desirable and stable ones among the 10 genotypes evaluated in this study. Genotypes 16792, 16813, 15743 and 16794 had regression coefficient close to 1.0 and minimum deviation from regression with low yield, so they were poorly adapted to all environments. On the other hand, genotypes 16791, 16819 and 16815 had high mean DM yield but less stable when compared to other genotypes included in this study.

Table 7. AMMI analysis of variance for DM yield of ten Napier grass genotypes tested across five environments

Source	DF	SS	MS	Explained SS (%)
Genotype (G)	9	87.39	9.71***	15.72
Environment (E)	4	239.50	59.87***	43.07
G × E	36	229.18	6.37***	42.21
AMMI IPCA- 1	12	101.30	8.44*	44.20
AMMI IPCA- 2	10	83.43	8.34*	36.40
AMMI IPCA- 3	8	29.59	3.70 ^{ns}	12.91
AMMI IPCA- 4	6	14.86	2.48 ^{ns}	6.48
Total	49	556.06		

*** Significant at the 0.001 probability level; * Significant at the 0.05 probability level; ns= non-significant.

Additive main effects and multiplicative interaction (AMMI) analysis

AMMI model of analysis of variance (ANOVA) of ten Napier grass genotypes evaluated for DM yield across five environments is indicated in Table 7. The results of AMMI analysis showed significant ($P < 0.05$) difference for the first two interaction principal component axes (IPCA). From the total treatment sum of square of the model, 43.1% attributed to environmental effects and the rest to genotypic effects (15.7%) and the G × E interaction (42.2%). The larger sum of square and highly significant mean squares of environments indicated that the environments were diverse, with large differences among environmental means causing most of the variation in yield which is in agreement with the findings of different researchers (Alberts, 2004; Solomon *et al.*, 2008; Abdurahman, 2009). Results from AMMI analysis also showed that G × E interaction component of variation was partitioned into four possible interaction principal component axes (IPCA) along their contribution of sum of squares with decreasing importance. The interaction variance was explained in these four IPCA scores to capture the entire total pattern contained in the G × E interactions. The first three AMMI IPCA of the interaction captured 44.20, 36.40 and 12.91% of the G × E interaction sum of squares. The first three AMMI IPCA explained 90.5% of the total G × E interaction sum of square, thus, the three IPCA can be taken to interpret this data. Therefore, the interactions of the ten Napier grass genotypes with five environments were best predicted by the first two IPCA. Similarly, many other researchers reported that the most accurate model for AMMI can be predicted by using the first two principal components (Zobel *et al.*, 1988; Gauch and Zobel, 1996; Yan *et al.*, 2000).

AMMI-1 biplot of ten Napier grass genotypes evaluated at five environments was generated using genotypic and environmental mean DM yield plotted against their first IPCA scores (Figure 1). The AMMI analysis provided a biplot of main effects and the first principal component scores of interaction (IPCA 1) of both genotypes and

environments. This biplot helped in the interpretation of the interaction effects among genotypes and environments and for assessment of the stability of genotypes across environments. In the AMMI-1 biplot, if genotypes have zero or nearly zero IPCA-1 scores, then they are stable across their testing environments. However, if a genotype is farther from zero, it is highly responsive and does not perform consistently across environments (Samonte *et al.*, 2005). If a genotype and an environment have similar signs on the IPCA score, then the interaction between them is positive and this genotype is well adapted to this environment. Nevertheless, if they have opposite sign of IPCA-1 scores, their interaction is negative and the environment is not favorable to this genotype (Crossa *et al.*, 1990). Based on the biplot analysis, environments and genotypes show high variability in both main effects and interaction effects (IPCA-1) for mean DM yield. This model (AMMI-1) classified genotypes and environments into two broad groups based on their IPCA-1 scores and within a group the genotypes and environments interact positively and generally adapted the genotypes for those environments. Accordingly, Areka and Hawassa had positive IPCA-1 scores and positively interacted with genotypes 16815 and local which also had a positive IPCA-1 score. On the other hand, Holetta, Debre zeit and Adamitulu had negative IPCA-1 score and positively interacted with genotypes 15743, 16783, 16791, 16792, 16794, 16813, 16817 and 16819 which had a negative IPCA-1 score.

Hawassa environment had IPCA- 1 scores near to zero when compared with others and then it had relatively small interaction effects indicating that it was favorable environments for the performance of all genotypes. Holetta and Debre zeit were the least favorable environments for all genotypes with different environmental IPCA-1 score and different yield response of 7.1 and 10.5 t/ha, respectively, which is below average DM yield. In the biplot display, genotypes or environments that appear almost on a perpendicular line of a graph had similar mean yields and those that fall almost on a horizontal line had similar interactions

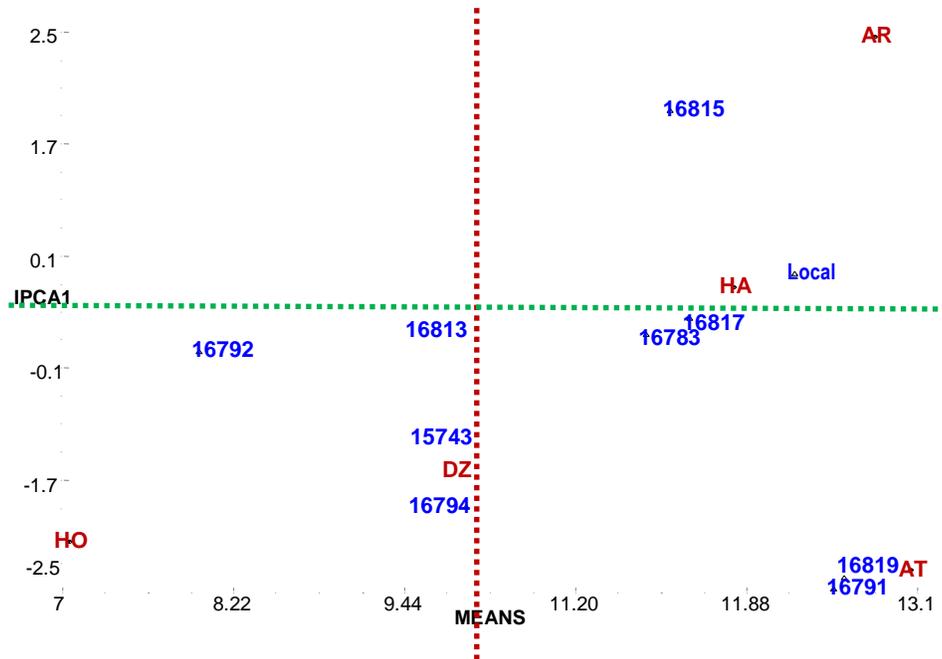


Figure 1. AMMI-1 biplot of main effects and interactions for DM yield of Napier grass genotypes over environments. HO = Holetta, DZ = D/zeit, AT = Adamitulu, HA = Hawassa, AR = Areka.

(Crossa *et al.*, 1990). Genotypes or environments with large negative or positive IPCA scores have high interactions, while those with IPCA1 scores near zero (close to horizontal line) have little interaction across environments and vice versa for environments (Crossa *et al.*, 1990) and are considered more stable than those further away from the line. Genotypes or environments on the right side of the midpoint of the perpendicular line have higher yields than those on the left side. The genotypes categorized under favorable environments with above-average means were 16783, 16791, 16815, 16817, 16819 and local. Among these, local, 16817 and 16783 were found to be more stable with IPCA-1 score near to zero and higher DM yield. Genotypes grouped under low yielding environments are showed in the left quadrants of the AMMI-1 biplot. Generally, 16791 was the most unstable genotypes identified by the AMMI-1 model followed by 16815. Genotypes that are close to each other tend to have similar performance (Muthuramu *et al.*, 2011). However, in the current finding genotypes and environments were dispersed in the biplot, except genotypes 16791 and 16819; and 16783 and 16817, which showed similar performance for DM yield and interaction effect.

AMMI-2 biplot presents the spatial pattern of the first two IPCA of the interaction effects and helps in visual interpretation of the $G \times E$ interaction patterns and identify genotypes or environments that exhibit low, medium or high levels of interaction effects. It was generated by using the first two-interaction principal component axes (IPCA 1 and 2) scores of ten genotypes

and five environments (Figure 2). According to Yan *et al.* (2000), in the SREG-based GGE biplot, the best genotype is the one with large PC1 scores (high mean yield) and near zero PC2 scores (high stability). The IPCA scores of genotypes in the AMMI analysis is an indication of stability or adaptation over environments (Gauch and Zobel, 1996). The greater the IPCA scores, the more specifically adapted is a genotype to certain environments (Sanni *et al.*, 2009). The more the IPCA scores approximate to zero, the more stable or adapted the genotype across the test environments. The genotypes 16817, 16813 and local were the best performing as they had large PC1 values, indicating high-yielding ability and close to zero PC2 values, indicating high stability. Hawassa and Areka were the most discriminating environments among the genotypes evaluated as indicated by the longer vectors projected from the origin, indicating that these locations gave good information on the performance of the genotypes. The GGE biplot can be a useful tool for the identification of ideal test environments (Yan and King, 2003). Therefore, the conditions observed at Areka would be considered an ideal environment for exploiting maximum yield potential and differentials among the genotypes tested in this study. Among all environments, Holetta identified as the least interactive environment with the tested genotypes as indicated by the shortest length vector from origin (zero), which indicates lower interaction of this location with the genotypes evaluated. Genotypes near the origin are non-sensitive to environmental interactive forces and those distant from the origin are sensitive and have large

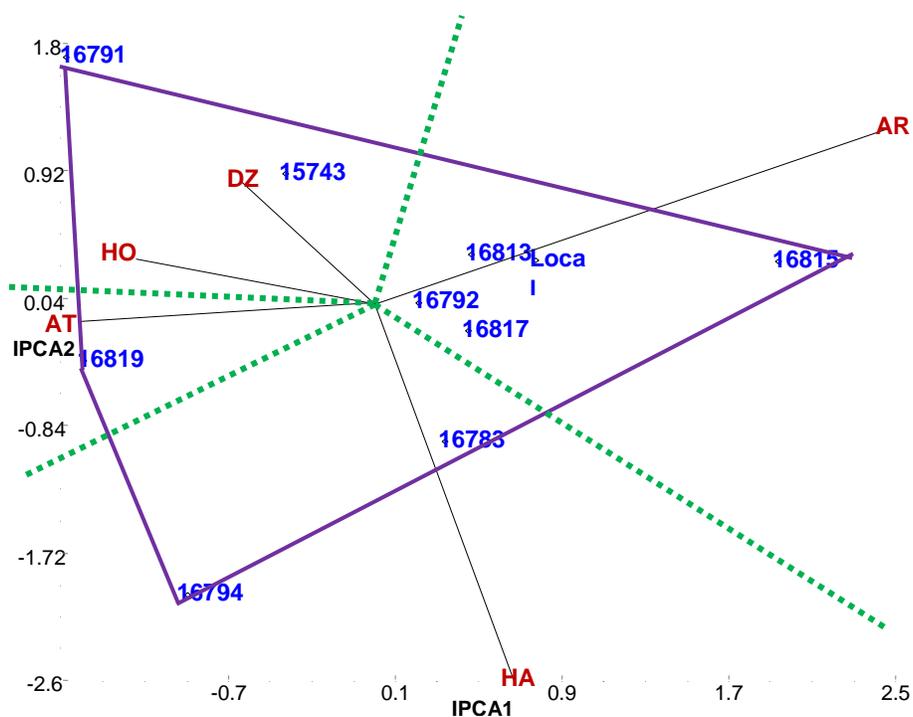


Figure 2. AMMI-2 interaction biplot for DM yield of 10 Napier grass genotypes tested at 5 environments. HO = Holetta, DZ = D/zeit, AT = Adamitulu, HA = Hawassa, AR = Areka.

interactions (Samonte *et al.*, 2005). Accordingly, genotypes 16792, 16813, 16817 and local were less sensitive to environmental interactive forces and hence, these genotypes are considered as stable genotypes. On the other hand, 16791, 16815, 16794 and 16819 were highly influenced by the interactive force of environment and sensitive to environmental changes, so these genotypes were considered as unstable genotypes due to the long projections from the origin.

Genotypes or environments that are near each other have similar interaction patterns while points distant from each other have different interaction patterns. The interaction pattern at Holetta and Debre zeit was showed closer relationships among these environments, indicating they had similar interaction pattern with the genotypes. Similar to that of environment, some genotypes also showed similar interaction pattern with the environments, such as genotype 16792, 16813 and local had similar interaction pattern with the environments in the biplot. The polygon view of a genotype and $G \times E$ interaction biplot explicitly displays the which-won-where pattern, and hence is a concise summary of the $G \times E$ pattern of a multi environment trials data set (Yan, 2002). The polygon in Figure 2 is formed by connecting the markers of the genotypes that are further away from the biplot origin such that all other genotypes are contained in the polygon. In the GE biplot (AMMI-2 biplot), the vertex genotype for each section had the highest yield in all environments that fell in the sector (Yan *et al.*, 2000; Yan, 2002). Accordingly, 16791, 16815, 16794 and

16819 were the genotypes which were further away from the biplot origin and used to connect the polygon. Based on the GE biplot classification environments were classified in to four groups. The first group consists of Areka and the vertex genotype for this section was 16815, suggesting that this particular genotype was relatively the best yielder in this locations. The second group consists of Hawassa and the vertex genotype for this section was 16794, which is the best DM yielder in this location. The third group consists of Adamitulu and the vertex genotype for this section was 16819, which is the best DM yielder in this environment. The fourth group consists of Holetta and Debre zeit locations. The vertex genotype in this section was 16791, indicating that this genotype was the best DM yielder in both environments.

Chemical compositions and *in-vitro* organic matter digestibility

Ash

The ash content of Napier grass showed difference at both locations (Table 8). The highest ash content was recorded from accession 16783 followed by local and 16791 whereas the lowest was recorded from accession 16815 at Holetta. At Areka, the highest ash content was obtained from accession 16815 followed by 16813 and 16819 while the local accession gave the lowest ash content. The high ash content in forage could be an

Table 8. 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 grown at Holetta and Areka agricultural research center.

Location	SN	Accessions	Nutritional qualities (g/kg DM)				
			Ash	CP	IVOMD	CPY	DY
Holetta Research Center	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	Local check	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	
	Prob.	0.1388	0.7462	0.0074	0.0425	0.0161	
Areka Research Center	1	15743	98.8 ^{bc}	56.3	387.5	0.7 ^{bc}	4.8 ^{bc}
	2	16783	97.6 ^{bc}	45.7	404.6	0.5 ^{bcd}	4.4 ^c
	3	16791	99.9 ^{bc}	53.0	396.5	0.6 ^{bcd}	6.6 ^{ab}
	4	16792	101.8 ^{bc}	66.6	401.1	0.7 ^{bc}	3.9 ^d
	5	16794	99.2 ^{bc}	42.3	358.8	0.3 ^d	4.3 ^{cd}
	6	16813	111.1 ^{ab}	64.6	430.8	0.9 ^{ab}	5.1 ^b
	7	16815	122.2 ^a	63.6	406.7	1.1 ^a	4.6 ^{bc}
	8	16817	98.6 ^{bc}	56.2	417.3	0.8 ^{abc}	5.2 ^{ab}
	9	16819	110.9 ^{ab}	44.5	414.4	0.4 ^{cd}	7.6 ^a
	10	Local check	91.5 ^c	48.6	386.2	0.8 ^{abc}	5.8 ^{ab}
	Mean	103.2	54.1	400.4	0.7	5.2	
	SEM	0.18	0.21	0.42	0.09	0.23	
	Prob.	0.0471	0.2411	0.8981	0.0144	0.0474	

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

indication of high mineral concentration. The results suggest that the mineral (ash) 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). 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).

Crude protein

The CP content of Napier grass did not show significant

($P > 0.05$) difference at both locations, though the content varied among the accessions in both testing locations (Table 8). The highest CP content was observed for accession 16783 followed by local and 16813 while it remained low for accession 16815 at Holetta. At Areka, the highest CP content was recorded from accession 16792 followed by 16813 and 16815 while accession 16794 gave the lowest CP content. 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). The CP content of about 60 to 70 g/kg DM (Leng, 1990; Smith, 1993) are required for maintenance of ruminants. The CP content of 80 to 130 g/kg DM (ARC, 1984; Humphreys, 1991) are required for moderate milk production (10 to 15 kg/cow/day) by dairy cows. For high milk production (>15 kg/cow/day), the CP content of about 150 g/kg DM (ARC, 1984) are required. The CP level of 60 to 70 g/kg DM below which voluntary

intake would decline (ARC, 1984; Minson, 1990). 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).

In-vitro organic matter digestibility

The IVOMD content showed significant ($P < 0.05$) variation only at Holetta (Table 8). Accession 16783 had the highest IVOMD followed by 16794 and 16792 while the lowest was recorded from accession 16815 at Holetta. At Areka, the highest and the lowest IVOMD was recorded from accession 16813 and 16794, respectively. It is important to bear in mind that climate, soil fertility, cutting interval and other management practices have very 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 OMD (organic matter digestibility) of about 550 g/kg DM (Smith, 1993) are required for maintenance of ruminants. The OMD of 600 to 700 g/kg DM (ARC, 1984) are required for moderate milk production (10 to 15 kg/cow/day) by dairy cows. For high milk production (>15 kg/cow/day), the OMD above 700 g/kg DM (ARC, 1984) are required. 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.

Crude protein and digestible yields

The CP yield of Napier grass varies among the accessions, which generally related to the biomass yield at both testing locations (Table 8). At Holetta, accession 16791 had the highest CP yield while accession 16815 gave the lowest CP yield. Accession 16815 gave the highest CP yield followed by accession 16813 at Areka. On the other hand the lowest was recorded from accession 16794. 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. 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). However, the CPY was highest when the grass was young implying that the decline in CP with maturity was faster than the increase in DM yield. The organic matter digestible (OMD) yield of the tested accessions showed variations at both testing locations (Table 8). At Holetta, accession 16791 gave the highest digestible yield followed by accession 16819 and accession 16783. On the other

hand, the lowest digestible yield was recorded from accession 16815. At Areka, the highest digestible yield was obtained from accession 16819 followed by 16791 and local accession while accession 16792 gave the lowest digestible yield.

Neutral detergent fiber

The NDF content of Napier grass showed difference at Holetta but not at Areka, though the content varied among the accessions at both testing locations (Table 9). The highest NDF content was recorded from accession 16817 followed by accession 16819 and accession 16815 whereas the lowest was recorded from local accession at Holetta. At Areka, the highest NDF content was recorded from accession 16794 followed by accession 16783 and accession 16819 while accession 16813 gave the lowest NDF content. The fiber content of a feed is particularly important for determining quality within the parameter of digestibility. 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). Strasia and Gill (1990) have suggested that NDF should constitute at least 15% of the total DM intake for a growing heifer. The recommended minimum dietary NDF values are 250 to 290 g/kg during early lactation and 320 to 340 g/kg during mid to late lactation to allow cattle to eat more forage (NRC, 2001). 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).

Acid detergent fiber

The ADF content of Napier grass did not differ significantly ($P > 0.05$), though the accessions showed variations at both locations (Table 9). The highest ADF content was recorded from accession 16794 followed by accession 16791 and accession 15743 while the lowest was obtained from accession 16819 at Holetta. At Areka, the highest ADF content was obtained from accession 16783 followed by accession 16791 and accession 16819 whereas the lowest was obtained from local accession. 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

Table 9. Mean NDF, ADF, ADL, cellulose and hemicelluloses contents of ten Napier grass accessions grown at Holetta and Areka Agricultural Research Center.

Location	SN	Accessions	Nutritional qualities (g/kg DM)				
			NDF	ADF	ADL	Cellulose	Hemicelluloses
Holetta Research Center	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	Local check	728.5 ^b	464.0	85.1	378.9	264.5
		Mean		770.0	474.6	70.4	404.2
	SEM		0.22	0.28	0.24	0.30	0.28
	Prob.		0.0044	0.6280	0.3170	0.6413	0.1457
Areka Research Center	1	15743	798.1	415.1	80.1	335.1	382.9
	2	16783	834.1	448.4	83.7	364.8	385.7
	3	16791	809.7	445.1	82.7	362.4	364.5
	4	16792	804.1	414.5	80.9	333.5	389.7
	5	16794	836.2	435.4	80.4	355.0	400.7
	6	16813	786.4	427.6	78.3	349.3	358.8
	7	16815	789.9	414.3	78.6	335.7	375.6
	8	16817	810.4	437.8	88.0	349.8	372.6
	9	16819	819.3	439.3	83.0	356.3	380.0
	10	Local	809.7	412.1	79.7	332.4	397.6
		Mean		809.8	429.0	81.5	347.4
	SEM		0.29	0.29	0.13	0.27	0.23
	Prob.		0.2934	0.5369	0.5426	0.4909	0.0731

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

carbohydrates (Pascual *et al.*, 2000). For forage ADF, the recommended minimum is 170 to 210 g/kg, 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 fermentability of fiber source (NRC, 2001). As with NDF, higher forage ADF results in reduced digestibility dry matter as a consequence of increased lignifications of cellulose in the plants (Depeters, 1993). Forage with higher ADF, thus has lower cellulose digestibility in the rumen, thereby reducing the energy available to the lactating cow for milk production.

Acid detergent lignin

The ADL content of Napier grass did not show significant ($P > 0.05$) difference, though the content varied among the accessions at both locations (Table 9). The highest ADL content was recorded from accession 16794

followed by local accession and accession 16792 while the lowest was obtained from accession 16817 at Holetta. At Areka, the highest ADL content was recorded from accession 16817 followed by accession 16783 and accession 16819 while the lowest was recorded for accession 16813. Lignin is a component which attributes erectivity, strength and resistance to plant tissue thereby limiting the ability of rumen microorganisms to digest the cell wall polysaccharides, cellulose and hemicelluloses contents. 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).

Cellulose content

The cellulose content of Napier grass did not show significant ($P > 0.05$) difference, though the content varied among the accessions at both locations (Table 9). The highest cellulose content was recorded from accession 16791 followed by accession 16817 and accession 15743 whereas the lowest was recorded from local accession at Holetta. At Areka, the highest cellulose content was recorded from accession 16783 followed by accession 16791 and accession 16819 while the lowest was recorded from local 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 hemicelluloses 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.

Hemicelluloses content

The hemicelluloses content of Napier grass did not show significant ($P > 0.05$) difference, though the content varied among the accessions at both locations (Table 9). The hemicelluloses content ranged from 264.5 to 324.0 g/kg DM with a mean of 295.4 g/kg DM at Holetta. The highest hemicelluloses content was recorded from accession 16819 followed by accession 16817 and accession 16815 whereas the lowest was recorded from local accession. At Areka, the hemicelluloses content ranged from 358.8 to 400.7 g/kg DM with a mean of 380.8 g/kg DM. The highest hemicelluloses content was recorded from accession 16794 followed by local accession and accession 16792 whereas the lowest was recorded from accession 16813. The composition and content of cell walls are the key factors affecting herbage digestibility. Cell walls are predominately composed of cellulose, hemicelluloses and lignin. This experiment confirms that, among the cell wall constituents, cellulose is the dominant followed by hemicelluloses and lignin at both locations and experiments reported by Diriba (2003) and Fekede (2004) also support this result. The higher hemicelluloses 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, yield stability and nutritive values across the test environments due to differential responses of the genotypes to various edaphic, climatic and biotic factors. Measured agronomic traits such as plant survival rate, plant height, forage DM yield showed variations among the tested genotypes and the test environments. The highest mean DM yield was obtained at Adamitulu followed by Areka, Hawassa, Debre zeit and Holetta per year, indicating that Napier grass expressed its genetic potential under hotter than cooler environmental conditions. The genotypes also showed variations in DM yield stability across the test environments during the experimental period. Different stability parameters and models indicating that Napier grass accessions such as 16817, 16783 and local were considered as the most desirable and stable ones among the ten genotypes evaluated in this study. On the other hand, accessions such as 16791 and 16815 were considered as the most unstable genotypes across the test environments. The chemical compositions and *in-vitro* organic matter digestibility indicated that the mean ash, CP, IVOMD, ADF, and cellulose contents were comparatively higher at Holetta than Areka conditions. On the other hand, the mean CP yield, digestible yield, NDF, ADL and hemicelluloses contents were higher at Areka than Holetta. The CP and IVOMD were higher in the highlands while CP yield, digestible yield and most fiber components were relatively higher in the mid altitude areas indicating that temperature and amount of rainfall and its distribution had an adverse effect on the feed quality of Napier grass. From this study, accession 16791 is specifically recommended for Holetta and Debre zeit environment. Similarly, accessions such as 16819, 16815 and 16794 are specifically recommended for Adamitulu, Areka and Hawassa environmental conditions. Generally, Napier grass accessions such as 16817, 16783 and local are recommended for wider cultivation due to better DM yield stability performance across the test environments.

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