RESEARCH ARTICLE

Evaluation of Napier Grass (*Pennisetum purpureum* (L.) Schumach) Accessions for Agronomic Traits Under Different Environmental Conditions of Ethiopia.

Gezahagn Kebede[1], Fekede Feyissa[1], Getnet Assefa[2], Mengistu Alemayehu[2], Alemayehu Mengistu[3], Aemiro Kehaliew[1], Kassahun Melese[4], Solomon Mengistu[1], Estifanos Tadesse[5], Shewangizaw Wolde[6] & Mergia Abera[7].

1. Holetta Agricultural Research Center P. O. Box 31, Holetta, Ethiopia.
2. Ethiopian Institute of Agricultural Research, P.O.Box 2003, Addis Ababa, Ethiopia.
3. Forage and rangeland scientist, Urael Branch, P.O.Box 62291, Addis Ababa, Ethiopia.
4. D/zeit Agricultural Research Center P.O.Box 32, D/zeit, Ethiopia.
5. Adamitulu Agricultural Research Center P.O.Box 35, Adamitulu, Ethiopia.
6. Areka Agricultural Research Center P.O.Box 79, Areka, Ethiopia.
7. Hawassa Agricultural Research Center P.O.Box 6, Hawassa, Ethiopia.

Manuscript Info

Abstract

Corresponding Author

Gezahagn Kebede.

Ten Napier grass accessions were evaluated for their agronomic traits under diverse environmental conditions of Ethiopia. The study was conducted in randomized complete block design with three replications. Data on plant height and dry matter yield were analyzed using the general linear model procedures of SAS and least significance difference was used for mean comparisons. The combined analysis of variance indicated that the main effect differences among genotypes, environments and the interaction effects vary significantly for measured agronomic traits. The combined analysis for plant height differed significantly (P<0.05), which ranged from 103.80 to 132.03 cm with a mean of 114.93 cm. The local accession gave the highest mean plant height followed by accession 16819 and 15743 while accession 16792 gave the lowest over locations. Of the total variance of dry matter yield, environment main effect accounted for 40.6%, whereas genotype and genotype by environment interaction effects accounted for 14.8% and 38.8% respectively. The highest mean dry matter 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). The combined analysis indicated that dry matter yield varied significantly (P<0.05) among the tested accessions and the yield ranged from 7.97 to 12.57 t/ha with a mean of 11.04 t/ha. Accession 16819 and 16792 gave the highest and lowest dry matter yield respectively. Generally, Napier grass accessions respond differently across the testing environments due to differential responses of the genotypes to various edaphic, climatic and biotic factors.

Introduction:-

Napier grass (*Pennisetum purpureum* (L.) Schumach*)*, also known as elephant grass, originated from sub-Saharan tropical Africa (Clayton et al., 2013). Napier grass is a tall and deep-rooted perennial bunch grass well known for its high yielding capability and mainly used for cut-and-carry feeding systems (FAO, 2015) and fed in stalls, or it is made into silage or hay. It performs well in low, mid and highland areas of Ethiopia (Seyoum et al., 1998; Tessema, 2005). It 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 (Fekede et al., 2005). The herbage can be killed by light frosts but the underground parts remain alive unless the soil is frozen and growth resumes rapidly when

conditions become ideal (Fekede et al., 2005). It is propagated vegetatively by using stem cuttings, root splits or shoot tips which usually vary across agro-ecologies (Getnet and Gezahagn, 2012).

Napier grass can provide a continual supply of green forage throughout the year and best fits in all intensive small scale farming systems (Alemayehu, 1997). It is a fast growing and has a high annual productivity that depends on the climatic conditions, especially of temperature and rainfall and it can produce biomass yield of 20-30 t DM/ha/year with good agronomic and management practices (Farrell et al., 2002). Based on chemical composition and *in vitro* dry matter digestibility (IVDMD), Napier grass could be categorized as high quality forage (Tessema et al., 2002). All forage crops respond dramatically to good management practices, hence, higher yields, better forage quality and improved persistence result from paying attention to the basics of good forage management conditions. The cultivation of high quality forages with a high yielding ability, adaptable to biotic and abiotic environmental stresses is one of the possible options to increase livestock production under smallholder farmers conditions (Tessema, 1999). 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 are very important to identify the best-bet accessions for utilization. Accordingly, there is a need to evaluate Napier grass accessions for basic quantitative traits to address the feed demand of mixed farming systems. Therefore the objective of this study was to evaluate the agronomic performance of Napier grass accessions under different 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 represents 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.

Table 1: Descriptions of the test environments 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_2o)	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

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 planting material of the accessions were collected from Bako Agricultural Research Center and brought for planting to D/zeit Agricultural Research Center. The vegetative parts in the form of root splits and stem cuttings were distributed from D/zeit research center and planted under different agro-ecological conditions to evaluate their agronomic performance. The accessions were planted in 4 m x 4 m plot using a randomized complete block design (RCBD) with three replications at the beginning of the main rainy season. Root splits at Holetta and stem cuttings at D/zeit, Adamitulu, Areka and Hawassa were planted in four rows per plot. Stem cuttings with three nodes were planted to a depth of 15-20 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 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 done uniformly to all plots as required.

Data collection and measurements:-
Measurements taken before and after harvest were plant height at forage harvesting stage and forage DM yield. Plant height was based on five culms randomly selected from 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 the two rows next to the guard rows of 5 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 oven dried for 24 hours at a temperature of $105^{o}c$ to determine dry matter yield.

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 was 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 = 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

Results and discussion:-
Environment and interaction effect on Napier grass accessions performance:-
Combined analysis of variance for measured agronomic traits of Napier grass accessions tested over environments is indicated in Table 2. The result indicated that the tested accessions varied significantly (P<0.05) for both measured agronomic traits. On the other hand, the environments displayed significant (P<0.001) variations for both measured agronomic traits. The Genotype x environment (G x E) interaction effects also reveled significant differences for plant height and DM yield. Where environmental differences are greater, it may be expected that the G x E interaction will also be greater.

The G x 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 x 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 (Basford 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 and adaptation patterns of Napier grass genotypes in multiple environments are very important for proper management and utilization.

Table 2: Combined analysis of variance for measured agronomic traits of Napier grass accessions tested over environments.

SN	Traits	Mean squares		G x E	Mean	CV
		Genotype	Environment			
1	Plant height (cm)	**	***	**	114.93	17.02
2	Dry matter yield (t/ha)	**	***	**	11.04	25.70

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

Plant height at forage harvesting stage:-
Mean plant height of Napier grass accessions were significantly (P<0.05) different across all testing environments except Areka (Table 3). The result indicated that the highest mean plant height at forage harvesting stage was recorded from Hawassa (140.53 cm) followed by Debre zeit (120.33 cm), Adamitulu (110.75 cm), Areka (106.67 cm) and Holetta (96.33 cm) testing environments during the experimental periods. The highest mean plant height was obtained from local accession at Holetta (124.77 cm) and Debre zeit (172.83 cm) while accession 16819 produced the highest plant height at Adamitulu (150.47 cm) and Hawassa (158.83 cm). On the other hand, accessions 16813,

16792, 15743 and 16817 produced the lowest plant height at Holetta (75.13 cm), Debre zeit (96.03 cm), Adamitulu (84.23 cm) and Hawassa (121.50 cm) respectively. At Areka, all accessions were harvested at the same height (100 cm) 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 environments. 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).

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[bcde]	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

Means followed by a common superscript letters within a column are not significantly different at P<0.05.

Forage dry matter yield:-
A combined analysis of variance for forage DM yield of ten Napier grass 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 x 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 superior yield across the environments. Of the total variance of DM yield, environment main effect accounted for 40.6%, whereas genotype and G x E interaction effects accounted for 14.8% and 38.8% respectively. This result shows that DM yield was significantly affected by changes in environment, followed by G x E interaction and genotypic effects. The large variance for environment indicated that the environments were diverse, with large differences among environmental conditions 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 testing environments in altitude, soil types, temperature and differences in both amount and distribution of annual rainfall and other agro-climatic factors.

In the presence of G x E interaction, a genotype does not exhibit the same phenotypic characteristics under testing environments and various genotypes respond differently to a specific environment. According to Pham and Kang (1988) study, G x 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 (Gemechu, 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 diversified environments, is the ultimate goal of plant breeders in a crop improvement program.

Table 4: Combined analysis of variance for DM yield of ten Napier grass 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

Forage DM yield showed significant (P<0.05) variation among the tested Napier grass accessions across the testing environments (Table 5). The DM yield (t/ha) ranged from 4.57 to 8.74 at Holetta; 4.34 to 14.87 at Debre zeit; 9.73 to 18.30 at Adamitulu; 6.95 to18.20 at Areka and 7.88 to 15.26 at Hawassa. 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). 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 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. 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 differences in plant height and DM yield occurred due to variations among the tested genotypes, testing environments and genotype x environment interaction effects. Herbage yield of Napier grass can be affected by the harvesting stage and plant height. 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.

Table 5: Mean forage DM yield (t/ha) of ten Napier grass accessions tested across five 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

Means followed by a common superscript letters within a column are not significantly different at P<0.05.

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). 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). Generally, as grass matures, herbage yield is increased due to the rapid increase in the tissues of the plant (Minson, 1990). 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). 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).

Conclusion:-
Napier grass accessions respond differently for measured agronomic performance across the testing environments due to differential responses of the genotypes to various edaphic, climatic and biotic factors. Measured agronomic traits showed variations among the tested genotypes and the environments. The highest mean DM yield was obtained at Adamitulu, followed by Areka, Hawassa, Debre zeit and Holetta, indicating that Napier grass expressed its genetic potential under hotter than cooler environmental conditions in Ethiopia.

Acknowledgements:-

References:-
1. 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.
2. Alemayehu Mengistu. (2004): Pasture and forage resource profiles of Ethiopia. EDM printing press, Addis Ababa, Ethiopia.
3. Basford K E, and Cooper, M. (1998): Genotype x environment interactions and some considerations of their implications for wheat breeding in Australia. *Australian Journal of Agricultural Research* 4:153-174.
4. Boonman JG. (1993): East Africa's grasses and fodders: Their ecology and husbandry. Kluwer Academic Publishers, Dortrecht, Netherlands, p. 341.
5. Boonman JG. (1997): Farmers' success with tropical grasses: Crop/pastures rotation in mixed farming in East Africa. Ministry of Foreign Affairs, The Hague, Netherlands, p. 95.
6. Butt MN, Donart GB, Southward MG, Pieper RD, Mohammad N. (1993): Effect of defoliation on plant growth of Napier grass. Trop. Sci., 33: 111-120.
7. Ceccarelli S. (1997): Adaptation to low/high input cultivation. Adaptation in plant breeding, pp. 225-236, (Tigerstedt, P.M.A., ed), Kluwer Academic Publishers, The Netherlands.
8. Clayton, W. D., Govaerts, R., Harman, K. T., Williamson, H., Vorontsova, M. (2013): World checklist of Poaceae. Richmond, UK: Royal Botanic Gardens, Kew.
9. Cuomo, G.J., D.C. Blouin and J.F. Beatty. (1996): Forage potential of dwarf napier grass and a pearl millet x napiergrass hybrid. Agron. J., 88: 434-438.
10. Deitos A, E Arnhold and GV Miranda. (2006): Yield and combining ability of maize cultivars under different eco-geographic conditions. Crop Breeding and Applied Biotechnology. 6: 222-227.
11. Dixon A G O and E N Nukenine. (1997): Statistical analysis of cassava yield trials with the additive main effects and multiplicative interaction (AMMI) model. Afr. J. Root Tuber Crops, 3: 46-50.
12. 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.
13. 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.

14. FAO. (2015): Grassland Index. A searchable catalogue of grass and forage legumes. FAO, Rome, Ital.

15. Gemechu Keneni. (2012): Genetic potential and limitations of Ethiopian chickpea (*Cicer arietinumal*) germplasm for improving attributes of symbiotic nitrogen fixation, phosphorus uptake and use efficiency, and adzuki bean beetle (*Callosobruchus chinensis* L.) resistance. PhD. Thesis. Addis Ababa University faculty of life science, Ethiopia.

16. 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.

17. Humphreys L R. (1991): Tropical pasture utilization. Camb. University press. Great Britain.

18. 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.

19. Minson D J. (1990): Forage in ruminant nutrition. Academic press, Inc. San Diego.

20. 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.

21. 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.

22. Nyambati EM, Sollenberger LE, Kunkle WE. (2003): Feed intake and lactation performance of dairy cows offered Napier grass supplemented with legume hay. Liv. Prod. Sci., 83: 179-189.

23. Pham, H. N. and Kang, M.S. (1988): Interrelationships among and repeatability of several stability statistics estimated from international maize trials. Crop Science 28: 925-928.

24. 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.

25. 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.

26. Souza ARR, GV Miranda, MG Pereira and LV Souza. (2009): Predicting the genetic gain in the Brazilian white maize landrace. Ciência Rural. 39: 19-24.

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

28. Tessema Z. (1999): Napier Grass Adapts Well in North Western Ethiopia. AgriTopia. EARO, Vol.14 No. 1, 1999.

29. 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.

30. 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.

31. 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.

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

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