Effect of Fertilizer Application and Variety on Yield of Napier Grass (*Pennisetum purpureum*) at Melokoza and Basketo Special Districts, Southern Ethiopia

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Abstract: *In tropical countries, the demand for meat and milk production has been increasing at an alarming rate, which the production, in turn, is requiring sufficient energy and protein feed supply. Four Napier grass varieties (ILRI_16815, ILRI_16902, ILRI_16913, ILRI_15743) and four nitrogen, phosphorus and sulfur (NPS) fertilizer (0, 12.5, 25, 50 kg ha^{-1} N:P:S with a rate of 19% N:37% P_2O_5:7% S) level were laid out in split-plot design at Basketo and Melokoza districts during 2018-2019 cropping seasons to evaluate agronomic and forage biomass yield performance. Data were collected for three consecutive harvestings each year to evaluate yield and agronomic parameters. NPS fertilizer application had no significant variation on growth and yield of Napier grass. In terms of plant height, ILRI_15743 is found to be a shorter variety that had a wider circumference covering the ground, better leaf to stem ratio and a higher number of tillers per plant. The plant height was varied for NPS fertilizer application and the higher plant was at 12.5 kg ha^{-1}(72.2 cm) level. ILRI_16815 demonstrated as the longest 84.6 cm variety among others in the test which encompass higher dry matter yield. Dry matter yields highly correlated ($P<0.001$) with leaf length, leaf number per plant and green forage yield which have less association with circumference, leaf width and leaf to stem ratio. There was better yield recorded at Melokoza than Basketo and applying 12.5 kg ha^{-1} NPS fertilizer is economical in Napier grass production. Therefore, ILRI_16815 could be recommended with 12.5 kg ha^{-1} NPS fertilizer at Melokoza, Basketo and similar agro-ecology to have economical Napier grass yield.*

Keywords: Basketo, Feed, Melokoza, Napier Grass, NPS

1. Introduction

The demand for meat and milk production in Ethiopia has been increasing (Shapiro *et al*., 2015). Energy and protein source feeds are the two major requirements in dairy production to demand 250 days of milk and calf every year (Mhere *et al*., 2002). The high cost and low availability of good quality animal feed is a critical constraint to increasing productivity of livestock in dairy farms and feedlots, improved family and specialized poultry, and smallholder mixed crop-livestock and extensive livestock production systems (Shapiro *et al*., 2015). To use as a mitigation option of the prevailing livestock production mainly the feed nutritional constraints to livestock productivity, the use of adapted, high yielding, and drought-tolerant improved forages of high quality are recommended (Mengistu *et al*., 2016).

Napier grass (*Pennisetum purpureum* Schumach.) is a fast-growing perennial grass native to Sub-Saharan Africa that is widely grown across the tropical and subtropical regions of the world (Negawo *et al*., 2017). Napier grass, also known as elephant grass, is deep-rooted tropical bunch grass and the most popular perennial forage crop recommended for crop-livestock farming system (Nyambati *et al*., 2010). It is widely used in cut and carries feeding systems (Farrell *et al*., 2002) and is of growing importance in other agricultural systems (Negawo *et al.*, 2017). Napier grass possesses a high yield per unit area; tolerate intermittent drought and high water use efficiency (Kabirizi *et al*., 2015). It has the ability to withstand repeated cutting and will rapidly regenerate, producing palatable leafy shoots (Lowe *et al.*, 2003). The preservation of Napier grass is to ensure continuous feed supply for the animals during a shortage of forages as well as preserving the quality of the grasses (Zailan *et al*., 2018). The yield of Napier grass mainly depends on the type of cultivar used, the environment and management practices employed (Negawo *et al*., 2017).

Production and utilization of improved forages are getting low in the study area due to the limited access of forage seed, shortage of production land and less awareness of the farmers (Community level participatory planning (CLPP) document of AGP-II @ArbaMinch Research Center). Forage production was taken as an option to improve feed requirement of the study area which has been depending on the natural pasture and crop residues. Therefore, this study was designed mainly to investigate the optimum level of NPS fertilizers for Napier grass yield, to identify the response of Napier varieties to NPS fertilizer and to estimate the economic response of Napier grass variety to each unit of fertilizer application at Melokoza and Basketo areas (AGP-II sites).

2. Materials and Methods

2.1. Description of the study area

The study was conducted at ***Zaba*** village (N= 6.16’59’’ E=36.36’55’’) of ***Basketo*** special district and at ***Phircha*** village (N=6.25'12" E=36.37'33')' of ***Melokoza*** district southwestern Ethiopia during 2018-2019 cropping season. The annual rainfalls of ***Zaba*** village and that of ***Phircha village*** were 1060.5 mm and 1820.48 mm, respectively. The altitude of the study areas in the same order were 1910 and 1462 meter above sea level. The maximum average temperature of ***Zaba*** village was 30.79 and that of ***Phircha village was*** 27.22ºC while the minimum average temperatures were 20.03 and 16.84ºC, respectively (Figure 1).

Soil chemical-physical properties of the experimental sites with its description for soil depth of 0-20 cm are presented in Table 1.

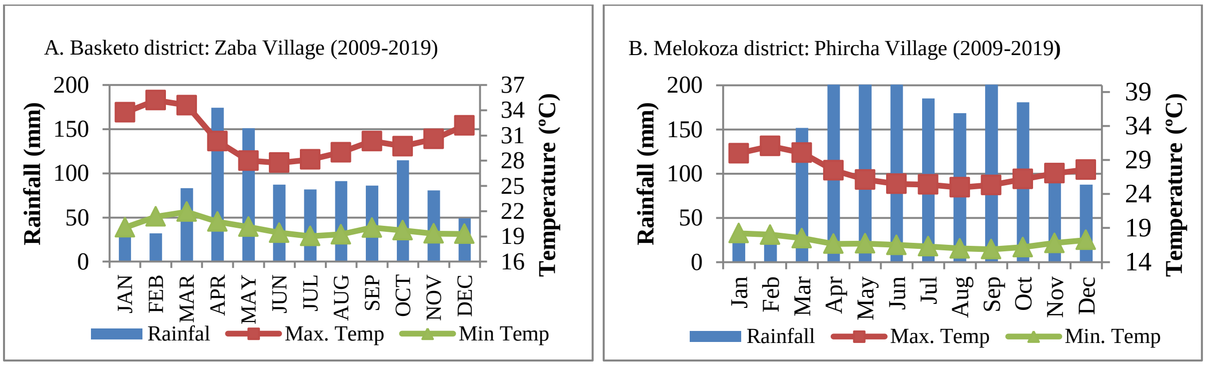

Figure 1: Environmental conditions of the experimental sites

Table 1: Soil laboratory analysis result of experimental soil sampled from the top soil of 0-20 cm depth

Description		Basketo	Melokoza	Status
pH		5.13	5.15	Strongly acidic
Total Nitrogen (TN %)		0.1364	0.14	Low
Organic carbon (OC %)		1.583	1.612	Moderate
Organic matter (OM %)		2.729	2.812	Moderate
Available phosphorus (P ppm)		13.124	13.213	Medium
Exchangeable potassium (K ppm)		153.34	154.32	
Textural class		Clay loam	Clay loam	
	Sand%	40	39	
	Clay%	34	36	
	Silt%	26	25	

2.2. Treatment and experimental design

Four varieties of Napier grass (ILRI_16815, ILRI_16902, ILRI_16913, ILRI_15743) with four levels of NPS fertilizer (0, 12.5, 25, 50 kg ha^{-1}) laid out in split-plot design with three replications in which varieties arranged in main plots and fertilizer rates in subplots. The forage was planted in four rows with 75 cm spacing between rows and 50 cm within rows. All other treatments of the experimental plots including regular weeding, Urea application and others were applied in an equal manner to all plots based on the agronomic recommendation of the International Livestock Research Institute (ILRI) for the grass.

2.3. Data collection

Data was collected from net plot area(4.5 m^2) to compute the circumference of each hole, tiller number per plant, leaf width, leaf length, leaf to stem ratio, leaf number per plant, plant height, green forage yield and dry matter yield. Upon the establishment of the forage, the data for all parameters were collected every 60 days after the first cutting (Zailan *et al*, 2018). Circumference was measured by a tape meter at the base of the plant. Tiller number counted for five randomly selected plants from the plot. Leaf width and length measured for the central leaf at centre of the leaf for selected plants. Leaf to stem ratio was the ratio of leaf dry matter to stem dry matter. Leaf number also counted for randomly selected five plants to identify better leafier plant among the experimental units. Plant height was measured from ground to top of the stem at forage harvesting for randomly selected holes. Green forage yield of a plot was weighed at the field using spring balance and converted to hectare base for fresh yield analysis and dry matter yield was computed by collecting 300-gram fresh sample leaf and stem part of the forage to be dried at 60^0C for 48 hours (Ritz *et al*., 2020) to constant weight and calculate dry matter percent, then dry matter yield was calculated by multiplying fresh matter yield by dry matter percent.

$$\text{DM\%} = \frac{Oven\ dry\ weight}{Fresh\ sample\ weight} x100 \quad [1]$$

Where

DM% is dry matter percent (AOAC, 1990)

$$DMY\left(\frac{t}{ha}\right) = \text{DM\% x Green forage yield } \left(\frac{\text{t}}{\text{ha}}\right) \quad [2]$$

Where

DMY (t/ha) is dry matter yield in ton per hectare (AOAC, 1990).

2.4. Economical and statistical analysis

Partial budget analysis was performed to evaluate the economic advantage of fertilization on Napier grass production (in terms of hay) by using the standard procedure (Upton, 1979). The partial budget analysis involves the calculation of the variable costs and benefits. The benefits are calculated based on the commercial market value of dry matter yield for all expenses recorded at the beginning of the study. Partial budget analysis was undertaken using fertilizer as a variable source of costs, total variable cost (TVC), and dry matter yield of the Napier grass as a source of income. Total revenue (TR) calculated by multiplying the dry matter yield in the current market price of the forage yield. Net revenue (NR) was calculated by deducting total variable cost (TVC) from total revenue (TR) as follows:

$$NR = TR - TVC \quad [3]$$

The marginal rate of return was the result of the change in net revenue divided by change total variable cost and expressed in percentage as indicated below.

$$MMR\% = \frac{\Delta NR}{\Delta TVC} * 100 \quad [4]$$

Where:

MRR (%) = marginal rate of return,

ΔNR = change in net revenue

ΔTVC = change in total variable cost

Analysis of variances for pooled data from Zaba and Phircha kebeles was carried out using SAS statistical computer package version 9.2 (SAS, 2011) and significance of means variation was compared using least significant difference (LSD) at 95% level of confidence.

3. Results and Discussion

The three-round cuts pooled mean values for circumference, tiller number per plant, leaf width and leaf to stem ratio are presented in Table 2. No interaction was observed between variety and fertilizer application for mean values presented in one-way table. NPS blended fertilizer application has no significant effect on variation (p>0.05) of circumference, tiller number per plant, leaf width and leaf to stem ratio. ILRI_15743 was found to be wider in ground covering with higher circumference value whereas ILRI_16815 with lowest circumference. This may indicate the later variety grows vertically up than the former which was covering the ground horizontally. Having a wider ground cover with higher circumference, dwarf variety like ILRI_15743 revealing a higher tiller number per plant than taller plants (Halim *et al.*, 2013). There was wider (P<0.05) leaves recorded for variety ILRI_16902 followed by ILRI_16815 indicating that it could have a broader leaf than the rest. Higher (P<0.05) leaf ratio to stem was recorded for ILRI_16902 followed by ILRI_15743. This might be due to the short internodes of dwarf varieties that might lead the plant to produce more leaves than stem compared to the taller ones. The leaf to stem ratio (LSR) is one of the criteria for evaluating the quality of the pasture grass because the higher proportion of leaves compared to stem indicate a better nutritive value (Zailan *et al.*, 2018). Thus, ILRI_16902 is leafier than the rest in the study.

Table 2: Mean values of selected vegetative growth of Napier grass as influenced by variety and NPS fertilizer at Basketo and Melokoza

NPS rate (kg/ha)	CRF (cm)	TNPP	LW (cm)	LSR
0	144.9	82.5	1.9	1.2
12.5	156.5	84.7	2.1	1.3
25	150.9	92.8	1.9	1.1
50	151.8	95.9	2.1	1
LSD (0.05)	NS	NS	NS	NS
Napier Grass variety				
ILRI-16815	131.5b	91.8	2.1ab	1.1b
ILRI-16902	131.8b	75.7	2.3 a	1.4a
ILRI-16913	150.3ab	89.45	1.9b	0.9b
ILRI_15743	190.6a	98.85	1.7b	1.2ab
LSD (0.05)	22.3	NS	0.2	0.3
CV (%)	9.2	22.7	5.1	18.01

Note: CRF = circumferences, TNPP = Tiller number per plant, LW = leaf width, LSR = leaf to stem ratio. Means in column followed by the same letter/s are not statistical different.

Leaf length, leaf number and stand height presented in Table 3 shows that NPS blended fertilizer application not influenced the leaf length and leaf number while plant height varied. ILRI_16815 possessed higher (P<0.05) leaf length, leaf number per plant and plant height. Increasing the level of NPS blended fertilizer from 0 to 12.5 kg ha^{-1} increased plant height from 60.3 to 72.2 cm, the increment of fertilizer level beyond 12.5 to 50 kg ha^{-1} decreased the height. Nitrogen fertilizer application improves plant height of Napier grass (Zewudu *et al.*, 2003) and the longer leaf observed at Melokoza while a higher number of leaves at Basketo. Plant height is an important parameter contributing to yield in forage crops (Zewudu *et al.*, 2003) that taller variety gives higher cumulative dry matter yield (Halim *et al.*, 2013).

Table 3: Mean values of selected growth parameters of Napier grass as influenced by NPS fertilizer, variety and site

NPS rate (kg/ha)	LL (cm)	LNPP	PH (cm)
0	70.1	9.9	60.3b
12.5	74	10.6	72.2a
25	74.6	10.5	67.4ab
50	72.1	10.7	69.5a
LSD (0.05)	NS	NS	8.5
Napier Grass variety			
ILRI_16815	91.9a	11.8a	84.6a
ILRI_16902	61.5c	10.9ab	71.5b
ILRI_16913	55.4d	8.8c	64.4b
ILRI_15743	82.0b	10.1b	48.9c
LSD (0.05)	4.9	1.1	8.5
Study site			
Basketo	69.0b	10.86a	65.9
Melokoza	76.4a	9.99b	68.8
LSD (0.05)	3.48	0.74	NS
CV (%)	5.9	9.8	12.2

Note: LL = leaf length, LNPP = leaf number per plant, PH = plant height. Means in column followed by the same letter/s are not statistical different.

Dry matter yield of Napier grass varied among varieties in the experiment and location while not for NPS blended fertilizer application. The interaction effect was not significant for either three or two ways (variety x fertilizer x locations). As presented in Table 4, ILRI_16815 had a higher (P<0.05) dry matter yield followed by ILRI_15743. Phosphorus contribution to dry matter yield was not significant for maize forage production (Hani, *et al.*, 2006) report is in line with the present study for NPS fertilization of Napier grass. Dry matter yield variation due to varietal differences reported before and the higher dry matter yield reported 5.8 t ha^{-1}cut^{-1} for four cultivars (Zailan *et al.*, 2018); 13.5 t ha^{-1} cut^{-1} for twelve cultivars (Nyambati *et al.*, 2010); 16.5 t ha^{-1} year^{-1} for four varieties (Maleko *et al.*, 2019). Three cuttings per year mean value dry matter yield in the present study, 12.7 t ha^{-1} cut^{-1}, was in line with 4.6-20.5 t ha^{-1} year^{-1} reported before in Ethiopia (Zewdu, 2005). An increase in dry matter yield could be due to higher plant height in the present study is concurring with the previous result (Atumo, 2018).

Table 4: Dry matter and green forage yields of Napier grass as influenced by NPS fertilizer, variety and site

NPS fertilizer (kg/ha)	GFY (t/ha)	DMY (t/ha)
0	26.51	5.8
12.5	38.41	8.7
25	30.06	8.3
50	34.86	7.6
LSD (0.05)	NS	NS
Napier grass variety		
ILRI-16815	56.02a	12.7a
ILRI-16902	18.81c	4.8c
ILRI-16913	16.83c	3.9c
ILRI_15743	40.42b	9.1b
LSD (0.05)	9.43	2.28
Site		
Basketo	26.58b	6.16b
Melokoza	39.45a	9.04a
LSD (0.05)	6.67	1.61
CV%	11.5	20.9

Note: GFY = green forage yield, DMY = dry matter yield, Means in column followed by the same letter/s are not statistical different.

Pearson correlations of parameters presented in Table 5 showed that dry matter yield positively (P<0.05) correlated with leaf length and green forage yield. Leaf width and plant height negatively (P<0.05) correlated with circumference. A positive correlation (P<0.05) of plant height with leaf width and leaf number per plant with leaf length was observed in this study. Dry matter yield possessed a high positive correlation with leaf length (P<0.001), leaf number per plant (P<0.05) and green forage yield (p<0.001) in the present study. Thus, dry matter accumulation in the crop could be a contribution to the growth and development of agronomic parameters which in turn could be the result of leaf growth and development of Napier grass. In the present study, the varieties with longer plant height were having higher dry matter yield than shorter ones. This result was reported before for the association of plant height with dry matter yield of a given crop (Halim *et al.*, 2013).

Partial budget analysis (Upton, 1979) presented in Table 6 showed that the higher net revenue recorded at 12.5 kg/ha NPS blended fertilizer level. The marginal rate of return also showed that there was a high rate of return at 12.5 kg/ha for each unit of NPS blended fertilizer application at *Basketo* and *Melokoza*.

Table 5: Pearson Correlation of parameters

	CRF cm	TNPP	LW cm	LSR	LL cm	LNPP	PH cm	GFY t/ha
TNPP	0.622							
LW (cm)	-0.764*	-0.63						
LSR	-0.061	-0.62	0.385					
LL cm	0.167	0.501	-0.161	0.086				
LNPP	-0.387	-0.03	0.561	0.406	0.698*			
PH cm	-0.807*	-0.27	0.764*	0.003	0.231	0.667		
GFY t/ha	0.122	0.502	-0.054	0.005	0.963**	0.693*	0.355	
DMY t/ha	0.092	0.499	-0.052	0.027	0.971***	0.039*	0.385	0.979***

*= P<0.05, **= P<0.01, ***= P<0.001, CRF= circumferences, TNPP= Tiller number per plant, LW= leaf width, LSR= leaf to stem ratio, LL= leaf length, LNPP= leaf number per plant, PH= plant height, GFY= green forage yield

Table 6: Partial budget analysis of fertilizer application to Napier grass

Descriptions	ILRI-15743				ILRI-16815				ILRI-16902				ILRI-16913			
	0	12.5	25	50	0	12.5	25	50	0	12.5	25	50	0	12.5	25	50
Total Fixed costs(TFC)	2590	2590	2590	2590	2590	2590	2590	2590	2590	2590	2590	2590	2590	2590	2590	2590
Variable Costs																
Urea (14 ETB/kg)	0	1400	1400	1400	0	1400	1400	1400	0	1400	1400	1400	0	1400	1400	1400
NPS (14 ETB/kg)	0	175	350	700	0	175	350	700	0	175	350	700	0	175	350	700
Total Variable Costs (TVC)	0	1575	1750	2100	0	1575	1750	2100	0	1575	1750	2100	0	1575	1750	2100
Dry matter yield (t/ha)	7.55	12.65	10.25	7.85	6.9	13.7	8.95	9.15	4.55	4.45	6.3	6.2	5.95	4.15	7.6	5.2
Total Revenue (TR=3588ETB/t=50% WB)	27089	45388.2	36777	28165.8	24757	49155.6	32112.6	32830	16325	15966.6	22604.4	22245.6	21349	14890.2	27269	18657.6
Net Revenue	27089	43813.2	35027	26065.8	24757	47580.6	30362.6	30730	16325	14391.6	20854.4	20145.6	21349	13315.2	25519	16557.6
ΔNR		16723.8	-8786.2	-8961.2		22823.4	-17218	367.6		-1933.8	6462.8	-708.8		-8033.4	12204	-8961.2
ΔTVC		1575	175	350		1575	175	350		1575	175	350		1575	175	350
MRR (%)		10.618	-50.2	-25.60		14.491	-98.39	1.05		-1.228	36.93	-2.025		-5.101	69.7	-25.60

MRR- Marginal Rate of Return, WB-Wheat bran

4. Conclusion

Napier grass is more productive at Melokoza lowlands than Basketo midlands. Though dry matter yield variation for fertilizer application was not significant, the higher economical yield was at 12.5 kg/ha NPS application. ILRI-16815 recorded significantly higher dry matter yield among others in the test. Leaf to stem ratio was higher for ILRI-16815. Dry matter yields highly correlated ($P<0.001$) with leaf length, leaf number per plant and green forage yield which have less association with circumference, leaf width and leaf to stem ratio. There was better yield recorded at Melokoza than Basketo and economically feasible return in applying 12.5 kg ha^{-1} NPS blended fertilizer in Napier grass production. Thus, ILRI-16815 could be recommended for better dry matter yield at Melokoza, Basketo and similar agro-ecology and it is economical to use 12.5 kg/ha NPS in Napier production.

Conflict of Interest

There is no conflict of interest claimed by the authors.

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References

AOAC (Association of Official Analytical Chemists). (1990). Official methods of analysis. 15thEdn. VA, USA: AOAC Inc., Arlington.

Atumo, T. T. (2018). Evaluation of forage type cow pea (Vigna unguiculata L.WALP.) accessions for dry matter yield in lowlands of Southern Ethiopia. Forage Res, 44(2), 74-80.

Farrell, G., Simons, S., & Hillocks, R. (2002). Pests, diseases and weeds of Napier grass, Pennisetum purpureum: A review. Int. J. Pest Manag, 48, 39-48.

Halim, R., Shampazuraini, S., & Idris, A. (2013). Yield and Nutritive Quality of Nine Napier Grass Varieties in Malaysia. Mal. J. Anim. Sci., 16(2), 37-44.

Hani, E. A., Muna, H. A., & Eltom, A. E. (2006). The Effect of Nitrogen and Phosphorus Fertilization on Growth, Yield and Quality of Forage Maize (Zea mays L.). Journal of Agronomy, 5, 515-518.

Kabirizi, J., Muyekho, F., Mulaa, M., Msangi, R., Pallangyo, B., Kawube, G. *et al*. (2015). Napier Grass Feed Resource: Production, Constraints and Implications For Smallholder Farmers in Eastern and Central Africa. Naivasha, Kenya: The Eastern African Agricultural Productivity Project.

Lowe, A., Thorpe, W., Teale, A., & Hanson, J. (2003). Characterisation of germplasm accessions of Napier grass (Pennisetum purpureum and P. purpureum× P. glaucum hybrids) and comparison with farm clones using RAPD. Genet. Resour. Crop Evol, 50, 121-132.

Maleko, D., Mwilawa, A., Msalya, G., Pasape, L., & Mtei, K. (2019). Forage growth, yield and nutritional characteristics of four varieties of napier grass (Pennisetum purpureum Schumach) in the west Usambara highlands, Tanzania. Scientific African, ScienceDirect, Elsevier, 6(e00214).

Mengistu, A., Kebede, G., Assefa, G., & Feyissa, F. (2016). Improved forage crops production strategies in Ethiopia: A review. Academic Research Journal of Agricultural Science and Research, 4, 285-296.

Mhere, O., Maasdorp, B., & Titterton, M. (2002). Forage Production and Conservation Manual: Growing and ensiling annual and perennial forage crops suited to marginal and semi-arid areas of Southern Africa. Zimbabwe: DFID.

Negawo, A. T., Teshome, A., Kumar, A., Hanson, J., & Jones, S. C. (2017). Opportunities for Napier Grass (Pennisetum purpureum) Improvement Using Molecular Genetics: A review. Agronomy, 7(28), 1-21.

Nyambati, E. M., Muyekho, F. N., Onginjo, E., & Lusweti, C. M. (2010). Production, characterization and nutritional quality of Napier grass [Pennisetum purpureum (Schum.)] cultivars in Western Kenya. African Journal of Plant Science, 4(12), 496-502.

Ritz, K. E., Heins, B. J., Moon, R., Sheaffer, C., & Weyers, S. L. (2020). Forage Yield and Nutritive Value of Cool-Season and Warm-

Season Forages for Grazing Organic Dairy Cattle. agronomy, 10, 1-13.

SAS. (2011). SAS/STAT® 9.2 Users guide. SAS Institute Inc., Cary, NC, USA.

Shapiro, B., Gebru, G., Desta, S., Negassa, A., Nigussie, K., Aboset, G., *et al*. (2015). Ethiopia livestock master plan. ILRI Project Report. Kenya, Nirobi: International Livestock Research Institute (ILRI).

Upton, R. M. (1979). Farm management in Africa, the principal of production and planning. Oxford University Press.

Zailan, M. Z., Yaakub, H., & Jusoh, S. (2018). "Yield and nutritive quality of Napier (Pennisetum purpureum) cultivars as fresh and ensiled fodder. Journal of Animal and Plant Sciences 28(1), 63-72.

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

Zewudu, T., Baars, R., & Alemu, Y. (2003). Effect of plant height at cutting and fertilizer on growth of Napier grass (Pennisetum purpureum). Trop. Sci. 42, 57-61.