Management of Napier Grass (*Pennisetum Purpureum* (L.) Schumach) for High Yield and Nutritional Quality in Ethiopia: A Review

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Abstract

Development of the livestock subsector in Ethiopia is hindered by many constraints, of which the unavailability of quality feed is a major factor. This result in low growth rates, poor fertility and high mortality rates of ruminant animals in the country. Increased livestock production can be achieved through the cultivation of high-quality forages with high yielding ability that are adapted to biotic and abiotic environmental stresses in Ethiopia. Amongst the recommended improved forage crops in Ethiopia, Napier grass can provide green forage throughout the year.With appropriate management practices it also best fits to intensive small scale farming systems. Moreover, Napier grass grows well in soil conservation areas, around homesteads and along roads under smallholder conditions in Ethiopia but it lacks proper management and utilization practices. Therefore, this paper highlights results of different management practices so far undertaken to increase the yield and quality of Napier grass, indicate gaps and possible future research and development directions that deserve attention for better utilization and management of Napier grass in Ethiopia.

Keywords: *Biomass yield; Frequency of defoliation; Feed shortage; Improved pasture; Nutritive value; Plant height at cutting*

Introduction

Livestock production is an integral part of the agricultural activities in Ethiopia. The livestock sector provides 12-16% of the total Gross Domestic Product (GDP) and 30-35% of the agricultural GDP in the country (Ayele et al., 2002). Moreover, livestock contributes about 60-70% of the livelihoods of the Ethiopian population (Ayele et al., 2002; Tessema et al., 2010a). However, the development of the livestock subsector in Ethiopia is hindered by many constraints, of which the unavailability of quality feed is a major factor (Manaye et al., 2009). The main feed resources for livestock in Ethiopia are natural pasture and crop residues, which are low in quantity and quality for sustainable animal production (Alemayehu, 2004). This results in low growth rates, poor fertility and high mortality rates of ruminant animals (Odongo et al., 2002). Farm animals

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thus rarely meet their nutritional requirements and so their productivity is low and draught power from oxen is minimal, thereby affecting food crop production under the smallholder farming systems (Seyoum et al., 1998; Tessema et al., 2010b).

Increased livestock production can be achieved through cultivation of high-quality forages with high yielding ability that are adapted to biotic and abiotic environmental stresses (Muia et al., 2001; Kahindi et al., 2007; Tessema et al., 2010a, b). Improved pasture crops have many advantages such as providing quality feed and improving soil fertility. The cost incurred for perennial pasture production is high only during the establishment year (Jϕrgensen et al., 2010) but declined thereafter and this approach could be the way forward in feed resources improvement strategies in Ethiopia at large. 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 industry (Ndikumana, 1996; Tessema, 2005) both under the smallholder farmer and intensive livestock production systems with appropriate management practices (Seyoum et al., 1998; Alemayehu, 2004).

Adaptation of napier grass

Napier grass (*Pennisetum purpureum Schumach*), also known as elephant grass, occurs naturally throughout tropical Africa (Lowe et al., 2003), particularly in east Africa (Kariuki et al., 1998; Mwendia et al., 2006), and has been introduced to all tropical and sub-tropical areas of the world (Lowe et al., 2003; Kahindi et al., 2007). Characteristically, Napier grass is vigorous and highly productive forage, which can withstand long periods of drought (Lowe et al., 2003; Tessema, 2005). Although little or no growth takes place during these drought periods, it rapidly recovers with the onset of rains (Mwendia et al., 2006; Wijitphan et al., 2009) and can survive in drought for more than five years (Woodard et al., 1991). It is a tall, stout and deep rooted perennial bunch grass well known for its high yielding capability and value as forage for livestock with good agronomic practices (Woodard et al., 1991). Moreover, Napier grass is an erect and tall perennial grass up to 5m heights with prolific tillering ability after cutting or grazing and adaptive to well-drained fertile soil. Because of the importance of Napier grass in the small-scale livestock farming enterprises, it is one of the most widely used fodder crops amongst small-scale livestock producers in Kenya (Mwendia et al., 2006; Mutegi et al., 2008), Malaysia (Hassan et al., 1990), Pakistan (Butt et al., 1993; Wijitphan et al., 2009), Tanzania (Kabuga and Darko, 1993), Thailand (Jϕrgensen et al., 2010), USA (Woodard et al., 1991), Napier grass is superior to other tropical grasses in terms of dry season growth and forage quality (Odongo et al., 2002; Wijitphan et al., 2009) and can support large tropical livestock units per hectare (Muia et al., 2001). It also performs well in low, mid and highland areas of Ethiopia (Seyoum et al., 1998; Tessema, 2005, 2008). Napier grass is popular among dairy farmers as it produces a lot of leaves, which are utilized as a cut and carry system (Kariuki et al., 1998; Nyaata et al., 2002; Mutegi et al., 2008). Therefore, with appropriate management practices, Napier grass can provide a continual supply of green forage throughout the year and best fits in intensive small scale farming systems in Ethiopia (Tessema, 2005, 2008; Tessema et al., 2010b).

Agronomic practices for establishment of napier grass

Napier grass is propagated vegetatively by using rootstock, stem cuttings or shoot tips planted at a distance of 1 m between rows and 0.50 m between plants (Tessema, 2008). Spacing could be adjusted on performance basis and in areas of moisture stress, narrower spacing both between rows and plants is recommended. Plants from root splits make more rapid early growth and give high herbage yields than from stem cuttings or shoot tips. Moreover, older and hardened stems are more reliable than young materials for easy establishment and tiller formation (Woodard et al., 1991). It can be planted during the main rains on coarse and weed free seedbed. It requires a minimum fertilizer at a rate of 100 kg ha^{-1} in the form of diammonium phosphate (DAP) for establishment and N fertilizer in the form of urea at a rate of 50 kg ha^{-1} should be applied close to the root slips once the Napier grass was well established on red soil under rain fed conditions (Tessema et al., 2002a, b) and 50 kg ha^{-1} urea should be top dressed annually for continuous growth and maintaining its quality (Tessema et al., 2003a). Moreover, manure is also another option for fertilization. Napier grass has higher productivity under irrigation although it is produced under rain fed condition in Ethiopia. Regular hoeing is important to control weed. It should be harvested any time of the year when it reaches the optimum harvesting stage depending on soil types and in areas where frost occurs, it should be harvested before the onset of frost.

Factors affecting the performance of napier grass

Varietal difference: Napier grass screening for high yield and adaptability to biotic and abiotic environmental stresses and nutritional values has been conducted in mid and highland areas of Ethiopia. There are variations in growth characteristics, dry matter (DM) yield, chemical composition and nutritive values among different Napier grass varieties (Ndikumana, 1996; Seyoum et al., 1998; Tessema, 2005). According to Ndikumana (1996) Napier grass ILRI accessions No: 16798, 16791, 16786 and 16835 were highly productive in most of the agro-ecological environments in sub-Saharan Africa, from sea level to the highlands above 2000 meter above sea level. Moreover, variations in morphological characteristics, yield, chemical composition, *in vitro* dry matter digestibility (IVDMD) and metabolizable energy (ME) values among 10 Napier accessions evaluated in the central highlands (Seyoum et al., 1998) and in north-western Ethiopia (Tessema, 2005; Table 1, 2 and 3) has been reported**.** There were also considerable variations in DM yields between years among Napier grass accessions (Seyoum et al., 1998; Tessema, 2005). This might be due to the perennial nature of Napier grass, which produces many tillers and dense vegetative growth as the pasture consolidates. In 10 Napier grass varieties, Fernandes et al. (1996) found significant differences in crude protein (CP) and IVDMD values. Short Napier grass accessions usually have high leaf to stem ratio (LSR) (Ndikumana, 1996; Tessema, 2005), which is an indicator of good quality.

Table 1**.** Morphological characteristics of Napier grass accessions harvested when the grass reached at one meter height grown on red soil condition in north-western Ethiopia, from 1998-2000 growing seasons

Accession	ILPP	LSR	NTPP	Survival (%)	Vigour	Plant height (cm)
14983	16.1^{a}	4.0^{b}	169.7^{a}	90.5^{abc}	4.0^{ab}	149.7^{ab}
14984	12.5^{b}	3.2^{bc}	88.3^{b}	88.1^{bc}	4.0^{ab}	154.9^{ab}
15743	8.0^{c}	8.7^{a}	77.0^{b}	85.7^{bc}	3.0^{bc}	78.0^{c}
16834	15.7^{a}	2.3^{cd}	69.7^{bc}	92.9^{ab}	3.0^{bc}	146.9^{ab}
16835	11.7^{b}	2.8^{bcd}	54.6^{c}	81.4^{c}	4.0^{ab}	147.3^{ab}
16786	10.8^{bc}	3.4^{bc}	67.8^{bc}	87.9^{bc}	3.3^{bc}	151.4^{ab}
16791	12.7^{b}	1.2d^{e}	73.3^{bc}	94.0^{ab}	3.3^{bc}	162.6^{a}
16798	7.5^{c}	3.2^{bc}	48.0^{c}	79.8^{c}	5.0^{a}	160.6^{a}
16836	8.3^{c}	0.8^{e}	63.0^{bc}	100.0^{a}	2.0^{c}	144.4^{ab}
Local	16.6^{a}	4.0^{b}	82.3^{b}	95.2^{ab}	4.0a^{b}	136.53^{b}
SE (±)	0.58	0.54	8.7	3.6	0.41	6.58
CV (%)	8.27	27.43	17.87	6.84	20.08	8.05

Source (Tessema, 2005); ILPP = internode length per plant (cm); LL = leaf length (cm); LSR = leaf: stem ratio; NLPP = number of tillers per plant

Table 2. Least square means of dry matter yield (t ha^{-1}) of Napier grass accessions harvested when the grass reached at one meter height grown on red soil condition in north-western Ethiopia, from 1998- 2000 growing seasons

ILRI accession	Year				Nutrient yield (t ha-1)			ranking
	1998	1999	2000	Mean	CPY	DDMY	DOM	
14983	5.85^{bc}	29.67^{ab}	26.10^{a}	20.54^{a}	2.25	14.5	65.2	1
14984	7.23^{ab}	27.00^{ab}	18.13^{bc}	17.46^{ab}	2.16	12.24	64.7	4
15743	3.40^{cd}	13.08^{cd}	6.57^{ef}	7.68^{ef}	0.84	5.33	64.0	9
16834	7.49^{ab}	15.83^{cd}	6.77^{ef}	10.03^{de}	1.17	6.57	60.3	8
16835	7.76^{ab}	13.70^{cd}	8.50^{def}	9.99^{de}	1.39	7.93	64.9	7
16786	5.19^{bc}	26.23^{ab}	14.43^{cd}	15.29^{bc}	1.74	10.30	62.1	5
16791	5.15^{bcd}	32.13^{a}	24.03^{ab}	20.44^{a}	3.20	14.29	64.5	2
16798	9.51^{a}	34.57^{a}	16.87^{c}	20.31^{a}	2.29	14.29	64.9	2
16836	2.04^{d}	9.43^{d}	2.43^{f}	4.64^{f}	0.35	3.09	61.4	10
Local	6.45^{abc}	20.90^{ab}	12.27^{cde}	13.21^{cd}	1.74	8.26	57.5	6
SE (±)	0.58	1.62	1.24	1.29	1.67	9.37	63.0	

Source (Tessema, 2005); Columns with different letters are significantly different at P<0.05; CPY = crude protein yield, DDMY= digestible dry matter yield and DOM= digestible organic matter

A minimum CP of 15% is required for lactation and growth of cattle (Van Soest, 1994). However, Napier grass accession (ILRI 16791) harvested at 1.0 m height had a CP content of 15.7% which is higher than the recommended value (Tessema, 2005; Table

3). The neutral detergent fiber (NDF) values of the ten Napier grass accessions tested in the northwestern parts of Ethiopia were ranged from 53-65% (Table 3), which is below the average value for tropical grasses (66%)) and below the threshold level of NDF for tropical grasses and beyond which DM intake of cattle is negatively affected (Van Soest, 1994). The Ca values of most of the Napier accessions were above the recommended level of 0.43% of DM for cattle and the P contents were also above the minimum requirement of 0.17% in DM for grazing ruminants (McDowell, 1985). Of the 10 Napier grass accessions from the International Livestock Research Institute; 4 accessions could be categorized as high quality while two accessions and a local type as medium quality forage, which could satisfy ruminant animal production (Tessema, 2005; Table 3). Most of the Napier grass accessions could supply CP, ME and Ca above the production requirements of a 12 weeks lactating Holstein Friesian dairy cow weighing 500 kg (Kearl, 1982; Table 4). Accordingly Napier grass ILRI accessions 14983, 16791, 16798 and 14984 could be recommended under rain fed conditions in smallholder ruminant production systems in mid and highland areas of Ethiopia.

Table 3**.** Chemical compositions, *in vitro* dry matter digestibility and metabolizable energy (MJ kg^{-1} DM) of Napier accessions harvested when the grass reached at one meter height grown on red soil condition in north-western Ethiopia, from 1998-2000 growing seasons

Chemical composition										Nutrient yield (t/ha)			
	Ash	CP	NDF	ADF	ADL	Ca	P	IVD-MD	ME	DMY	CPY	DDMY	DOMY
14983	20.2^{b}	12.2^{d}	53.5^{f}	29.3^{efg}	3.46	0.73^{b}	0.43^{ab}	70.7^{a}	9.77^{a}	20.5	2.3	14.5	65..2
14984	19.7^{c}	12.4^{d}	54.7^{e}	29.6^{ef}	4.61	0.7^{bc}	0.28^{de}	70.1^{ab}	9.69^{ab}	17.6	2.2	12.2	64.7
15743	20.8^{a}	10.9^{g}	52.7^{g}	28.8^{g}	3.12	0.71^{b}	0.41^{b}	69.4^{ab}	9.59^{ab}	7.7	0.8	5.3	64.0
16834	18.6^{e}	11.7^{e}	57.9^{c}	30.3^{cd}	3.16	0.8^{a}	0.31^{cd}	65.5^{bc}	9.04^{bc}	10.3	1.2	6.6	60.3
16835	17.5^{f}	13.9^{b}	60.2^{b}	29.7^{def}	3.20	0.64^{c}	0.47^{a}	70.4^{a}	9.73^{a}	10.1	1.4	7.9	64.9
16786	19.4^{cd}	11.4^{ef}	56.5^{d}	32.0^{b}	3.70	0.4^{e}	0.27^{de}	67.4^{ab}	9.30^{ab}	15.3	1.7	10.3	62.1
16791	19.0^{de}	15.7^{a}	54.5^{e}	29.2^{fg}	3.82	0.65^{c}	0.24^{e}	69.9^{ab}	9.67^{ab}	20.4	3.2	14.3	64.5
16798	19.6^{c}	11.3^{f}	56.4^{d}	30.6^{c}	3.80	0.5^{d}	0.26^{de}	70.4^{a}	9.73^{a}	20.3	2.3	14.3	64.9
16836	11.3^{g}	7.5^{h}	64.6^{a}	36.6^{a}	4.09	0.3^{f}	0.25^{e}	66.7^{abc}	9.21^{abc}	4.6	0.4	3.1	61.4
Local	20.2^{b}	13.2^{c}	58.2^{c}	29.9^{de}	3.34	0.5^{d}	0.35^{c}	62.6^{c}	8.61^{c}	13.2	1.7	8.3	57.5
SE ±)	0.14	0.09	0.13	0.20	0.37	0.008	0.003	7.33	0.23	-	-	-	-

Source (Tessema, 2005); CP = crude protein; NDF = neutral detergent fiber; ADF = Acid detergent fiber; ADL = Acid detergent lignin; Ca = calcium; P = phosphorus; IVDMD = in vitro dry matter digestibility; ME = metabolizable energy; DMY = dry matter yield; CPY = crude protein yield; DDMY digestible dry matter yield.

Table 4. Potential of Napier grass accession to support livestock production based on nutrient requirements

Weight and production status of Animal	DOM (%)	CP (g day-1)	ME (MJ day-1)	Ca (g day-1)	P (g day-1)
Nutrient requirement	55	821	85.5	28	27
Potential of Napier grass					
14983	65.2	102.58	76.7	76.65	45.15
14984	64.7	101.745	73.5	73.5	29.4
15743	64.0	100.69	74.7	74.55	43.05
16834	60.3	94.92	84.0	84	32.55
46835	64.9	102.16	67.2	67.2	49.35
16786	62.1	97.65	42,0	42	28.35
16791	64.5	101.54	68.2	68.25	25.2
16798	64.9	102.16	52.5	52.5	27.3
16836	67.4	96.7	31.5	31.5	26.25
Local	57.5	90.4	52.5	52.5	36.75

Source (Tessema, 2005)

Effect of plant height at cutting under rain fed conditions

Growth characteristics: The number of internodes per tiller, number of leaves per tiller and per plant increased with increased cutting heights while leaf: stem ratio and leaf length were greater with the shorter plant height at cutting (Tessema et al., 2003; Table 5). This value might be due to undisturbed growth for the highest plant height at cutting. Butt et al. (1993) found that the overall stem fraction increased with cutting height, due to the maturity of the plant. Tillers per plant, base circumference and internodes length per tiller were significantly affected by plant height at cutting (Tessema et al., 2003a). Kamel et al. (1983) in Egypt found that the number of tillers per plant of Napier grass increased with plant height at cutting. In a cut-and-carry system, height at cutting is reported to affect the growth characteristics and productivity of Napier grass (Mureithi and Thorpe, 1996).

Table 5. Growth characteristics of Napier grass as influenced by height at cutting under rain fed conditions

Growth characteristics	Plant height at cutting (m)			
	0.5	1	1.5	SE (±)
Internode number per tiller	5.6^{c}	7.7^{b}	9.0^{a}	0.19
Internode length per tiller (cm)	12.8^{c}	15.0^{b}	17.4^{a}	0.41
Number of leaves per tiller	20.5^{c}	25.6^{b}	33.8^{a}	1.58
Total leaves per tiller	438.7^{c}	728.9^{b}	1036.5^{a}	53.2
Leaf length (cm)	53.3^{a}	48.5^{b}	48.6^{b}	1.47
Leaf: stem ration	3.04^{a}	1.33^{b}	1.17^{b}	0.16
Number of tiller per plant	21.3^{b}	28.2^{a}	30.3^{a}	1.23
Basal circumference per plant (cm)	60.3^{b}	63.1^{b}	73.7^{a}	1.94

Source (Tessema et al., 2003a)

Biomass production: The DM yield of Napier grass has been significantly affected by plant height at cutting **(**Tessema et al., 2002a; 2003b; Table 6). The highest value of 9.5 t ha^{-1} is reported from cutting at 1.0 m height during the establishment year in north-western part of Ethiopia. Several other studies have reported similar results in different parts of the world (Liang, 1982; Kamel et al., 1983; Hassan et al., 1990, Muinga et al., 1992; Mureithi and Thorpe, 1996). More than 25 t ha^{-1} DM yield per annum of was obtained from well-managed Napier grass harvested at 1.0 m height on red soil under rain fed condition in the north-western part of Ethiopia (Tessema, 2005) but the average total forage yield varies from 10-15 DM t ha^{-1} year^{-1} under rain fed condition in the central highlands of Ethiopia harvested at a similar height (Seyoum et al., 1998). This difference might be due to the variation in altitude where both studies have been conducted since the central highland has a higher elevation than northwestern Ethiopia. Plant height at cutting had a significant effect on annual DM yields of Napier grass in the central highlands of Ethiopia and cutting at 1.0 m height produced a higher yield than cutting at 0.5 and 1.5 m (Seyoum et al., 1998). Generally, the productivity of Napier grass per annum can be rapidly and substantially altered by variation in defoliation or cutting management (Tessema et al., 2002a, b; 2003).

Table 6**. L**east square means of dry matter yield (t ha^{-1} year^{-1} of Napier grass as influenced by plant height at cutting and fertilizer application under rain fed conditions

Plant height at cutting (m)	Fertilizer application					
	0^{xy}	46^{x}	92^{x}	1^{y}	2^{y}	Mean
0.5	6.99^{defg}	6.95^{defg}	5.51^{fg}	5.88^{efg}	4.18^{g}	5.90
1.0	6.58^{efg}	10.67^{abc}	12.34^{a}	7.84^{cdef}	8.58^{bcdef}	9.18
1.5	8.45^{bcdef}	9.05^{abcde}	10.28^{abcd}	8.16^{cdef}	11.72^{ab}	9.53
Mean	7.31	8.89	7.29	7.29	8.16	8.21

Source (Tessema et al., 2002b); ^{X} = N fertilizer (kg ha^{-1}); ^{Y} = ^{c}attle manure (t ha^{-1}); ^{abcdef} numbers with similar superscript do not significantly differ (P<0.05)

Chemical composition: An increase in plant height at cutting in Napier grass resulted in a reduction in CP, ME, IVDMD in north-western Ethiopia (Tessema et al., 2002b; Table 7). Similarly, plant height at cutting height had a remarkable effect on CP content and IVDMD than DM, Ash and fibre contents of Napier accessions in the central highlands of Ethiopia (Seyoum et al., 1998). The mean CP content of Napier grass accessions at 0.5, 1.0 and 1.5 m height at cutting were 20.2, 14.3 and 12.3%, respectively while the respective IVDMD of the three cuts were 74, 72 and 62%. Napier grass harvested at 0.5 m height (younger stage) contains satisfactory levels of CP, Ca and P that can sustain acceptable growth rates in dairy heifers (Kariuki et al., 1998). Moreover, the young Napier grass (0.5 m) showed better quality and performance than the recommended cutting height (1.0 m), which is frequently used by farmers, in Kenya (Kariurki et al., 1999). The observed mean CP content harvested at 0.5 m height were considered to be adequate to meet higher requirements and allow modest average daily gains(Kariuki et al., 1998; Seyoum et al., 1998; Tessema et al., 2002b). Generally, based on CP and digestible DM yield, 1.0 m height at cutting is appropriate to obtain better yield and quality forage of Napier grass under rain fed conditions in the mid and highland areas of Ethiopia (Seyoum et al., 1998; Tessema et al., 2002a, b; Table 8).

Table 7. Chemical composition and in vitro dry matter digestibility (% DM basis) of Napier as influenced by plant height at cutting under rain fed conditions in north-western Ethiopia

Plant height at cutting (m)				
Parameters	0.5	1.0	1.5	SE (±)
Dry matter (%)	20.0[b]	18.2[b]	24.0[a]	0.77
Ash	16.8[a]	16.6[a]	15.2[b]	0.32
Crude protein	20.0[a]	11.5[a]	9.6[c]	0.31
Neutral detergent fiber	58.3[c]	61.6[b]	63.5[a]	0.55
Acid detergent fiber	30.3[c]	35.5[b]	37.4[a]	0.47
Acid detergent lignin	3.0[c]	3.7[b]	4.2[a]	0.12
ADF-ash	5.7[b]	7.9[a]	7.4	0.30
Cellulose	21.6[c]	23.9[b]	25.8[a]	0.61
Hemicellulose	228.0[a]	26.1[b]	26.1[a]	0.20
Calcium	0.80[a]	0.60[b]	0.5[b]	0.03
Phosphorus	0.21[a]	0.2[a]	0.1[b]	0.004
In vitro dry matter digestibility	71.7[a]	65.5[b]	61.03[c]	0.43
Metabolizable energy (MJ.kg-1 DM)	9.9[a]	9.0[b]	8.39[c]	0.61

Source (Tessema et al., 2002b)

Table 8. Total nutrient yield (t ha-1) of Napier grass as influenced by plant height at cutting under rain fed condition

Plant height at cutting:	DM yield (t ha-1)	CP (%)	CP yield		IVDMD (%)	Digestible DM yield	
			Cut -1	Day-1		Cut -1	Day-1
0.5 (68 days)	5.90[b]	20.0[a]	1.18[a]	0.0174[a]	71.74[a]	4.23[b]	0.0622[a]
1.0 (93 days)	9.18[a]	11.5[b]	1.06[b]	0.0114[b]	65.50[b]	6.01[a]	0.0647[a]
1.5 (114 days)	9.53[a]	9.6[c]	0.91[c]	0.0080[c]	61.03[c]	5.82[a]	0.0510[b]

Source (Tessema et al., 2002b); DM = dry matter; CP = crude protein; IVDMD = in vitro dry matter digestibility

***In vitro* DM digestibility:** Plant height at cutting is reported to have a significant effect on IVDMD contents. As height at cutting increased from 0.5 to 1.5 m, there has been a decline in IVDMD content from 72-61% (Tessema et al., 2002a, b; Table 7). This finding is in agreement with Taliafero et al. (1975), who reported that grasses harvested at a relatively advanced stage of development had depressed IVDMD values.

In *sacco* rumen degradability

Dry matter degradability- Studies conducted in Ethiopia showed that plant height at cutting had a significant effect on rumen in *sacco* dry matter degradability (DMD) percent and their degradability characteristics incubated up to 120 h (Tessema et al., 2002b; Tessema and Baars, 2004; Table 9). There was a reduction in DMD and its degradability characteristics of Napier grass at increased plant height at cutting due to increased lignifications, thereby reducing its digestibility. Potential (PD) and effective (ED) degradabilities at rumen outflow rate of 0.03 h^{-1} were higher for Napier grass cut at 0.5m height than at 1.0 and 1.5 m height. This might be explained by the higher LSR of the grass at 0.5 m height (3.04 LSR) than at 1.5m height (1.33 LSR) (Seyoum et al., 1998; Tessema et al., 2002b). Similarly, Kabuga and Darko (1993) reported that DMD linearly decline with increasing age of growth of grass species in the tropics, which is generally attributed to the increase in structural components (cell walls), a decline in the leave to stem ratio, and an increase in the proportion of senescent plants. Digestibility decrease as plants mature and differences in digestibility of grasses were influenced by leaf to stem ratio (Tessema et al., 2003a). In very young grass, the stem is more digestible than the leaf, whereas with advancing maturity, the digestibility of the leaf fraction decreases slowly and that of the stem fraction falls rapidly (Minson, 1990). Minson (1990) also indicated that organic matter digestibility varies with the proportion of cell contents and cell wall constituents.

Table 9. In sacco rumen dry matter degradability characteristics of Napier grass as influenced by height of plant at cutting

Rumen DMD characteristics	Height at cutting (m)			
	0.5	1.0	1.5	SE (±)
Washing loss/readily fermentable fraction (A), %	20.0[a]	16.0[b]	13.8[c]	0.69
Insoluble but fermentable fractions (B), %	63.9[a]	60.7[b]	60.1[b]	0.51
Rate of degradability (A+B), %	83.9[a]	76.7[b]	73.9[c]	0.50
Rate of degradation of B (c), h	0.0532	0.0531	0.0434	0.003
Lag phase (L), h	1.40[a]	1.77[a]	2.75[b]	0.38
Effective degradability (ED), %	61.8[a]	55.9[b]	51.7[c]	0.66

Source (Tessema et al., 2002a)

The potential degradable and undegradable fractions and the duration of the lag time are affected by plant height at cutting in Napier grass (Tessema et al., 2002a). According to Van Soest (1994) the lag time in the degradation of fibrous feeds is caused by the substrate and a long lag time is one of the factors limiting intake and utilization of fibrous feeds. The relatively long lag time at 1.5 m cutting height could be a reflection of its probable higher lignocellulose content compared with 0.5 and 1 m cuttings.

Effect of defoliation frequency on performance of Napier grass

Amongst the major agronomic practices required for high production and quality of Napier grass are harvesting at appropriate cutting (stubble) heights above ground level and defoliation frequencies (days between cutting) (Butt et al., 1993; Tessema et al., 2003a; Jϕrgensen et al., 2010). Maintaining a minimum cutting height above ground level is considered as an important and easy pasture management practice (Tessema et al., 2010b) because it helps to maintain plant vigor, facilitates re-growth of the plant following cutting and maintains sufficient forage as well as stabilizing the plant within the soil (Wijitphan et al., 2009; Jϕrgensen et al., 2010). However, very frequent defoliation of the plant either by grazing or cutting, affects the growth and development of the pasture, whereas delayed defoliation frequency may enhance the growth and development of the pasture (Nyaata et al., 2002; Tekletsadik et al., 2004). Cutting of Napier grass close to ground level may negatively affect the re-growth ability by reducing tiller development. In contrast, a higher cutting height of Napier grass may result in underutilization, and the quality of the plant as forage is reduced by a higher cutting height (Butt et al., 1993; Tessema et al., 2003a).

Growth characteristics

The number of tillers per plant, number of internodes per plant, number of leaves per tiller and per plant, leaf length per plant, and basal circumference per plant of Napier grass increased as the defoliation frequency decreased, whereas leaf to stem ratio increased as the frequency of defoliation increased, possibly due to undisturbed growth of Napier grass for a longer period (Tessema et al., 2010b; Table 10). According to previous studies (Butt et al., 1993; Tessema et al., 2003a; Wijitphan et al., 2009), the overall growth characteristics increased with increasing maturity of Napier grass. The number of leaves per tiller and per plant and basal circumstance per plant increased with increasing days between cuttings, while leaf to stem ratio and leaf length per plant decreased as the days between cutting increased (Tessema et al., 2003a; Tessema et al., 2010b). The decreasing trend observed in leaf to stem ratio as the growth period increased is in agreement with the report of Butt et al. (1993), who indicated that the reduction in leaf proportion and an increase in stem fraction of Napier grass following delayed harvest occurred due to maturity. This confirms that Napier grass harvested following delayed defoliation frequency had a greater quantity of structural components which may have contributed to the decline in leaf to stem ratio. This is also supported by Kabuga and Darko (1993) who reported that tropical grasses harvested at advanced stages of growth have increased structural components and a decline in the ratio of leaves to stems (Butt et al., 1993; Wijitphan et al., 2009). Previous studies have shown that the number of leaves per plant increased with increasing days between cuttings of Napier grass (Tessema et al., 2003a; Taye et al., 2007). The longer the vegetative growth of the plant, the greater the number of leaves produced from the newly emerging tillers (Butt et al., 1993). Nyaata et al. (2002) and Taye et al. (2007) reported that the number of tillers per plant, leaf length per plant, number of leaves per tiller and the basal circumference of the plant increased as the interval after cutting increased. This may be due to the longer physiological growth phases of the plants in the reduced cutting frequency (Butt et al., 1993; Wijitphan et al., 2009).

Table 10. Effect of defoliation frequency (DF) and cutting height (CH) on morphological characteristics of Napier grass at Haramaya University, eastern Ethiopia

Morphological characteristics							
	NTPP€	NLPT	TLPP	LLPP	NIPP	BCPP	LSR
Defoliation frequency							
60	13.7[b]	9.0b[c]	122.4[c]	69.8[c]	0.0[c]	59.6[b]	1.13[a]
90	19.9[a]	10.0[b]	199.0[b]	87.3[b]	2.3[b]	84.0[a]	0.76[b]
120	18.5[a]	12.2[a]	225.7[a]	98.6[a]	6.1[a]	89.2[a]	0.41[c]
Cutting height							
5	17.6[a]	10.3[a]	181.3[a]	88.8[a]	2.7[a]	77.2[a]	1.0[a]
10	16.1[a]	10.9[a]	175.5[a]	88.3[a]	2.5[a]	70.0[a]	0.9[a]
15	15.8[a]	10.5[a]	165.9[a]	88.8[a]	2.4[a]	80.5[a]	0.8[a]
20	17.8[a]	10.0[a]	178.0[a]	84.0[b]	2.8[a]	82.3[a]	0.7[a]
25	18.9[a]	10.2[a]	192.8[a]	76.1[c]	2.9[a]	78.0[a]	0.7[a]
Defoliation frequency							
P	0.013	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
LSD	4.12	1.22	31.07	5.25	0.85	14.26	0.08
Cutting height							
P	0.757	0.812	0.695	0.002	0.905	0.738	0.089
LSD	NS	NS	NS	6.78	NS	NS	NS
DF x CH							
P	0.556	0.941	0.715	0.544	0.977	0.984	0.032
LSD	NS	NS	NS	NS	NS	NS	NS
CV (%)	11.9	16.11	17.09	8.24	7.95	14.57	7.39

Source (Tessema et al., 2010b); [€]NTPP = number of tiller per plant; NLPT = number of leaf per tiller; TLPP = total number of leaf per plant; LLPP = leaf length per plant; NIPP = number of internodes per plant; BCPP = basal circumference per plant; LSR = leaf stem ra- tion. Numbers with the same superscript within a column and within a factor are not different (P<0.05).

Dry matter yield

The DM yield increased as frequency between cuttings increased from 60 days - 120 days (Tessema et al., 2010b; Figure 1). According to previous studies (Tessema et al., 2002b; Tessema et al., 2003a), the DM yield of Napier grass increased as defoliation interval increased. A significant increase in DM yield occurring following long regrowth period with a tendency towards maturity was reported by Kariuki et al. (1998). It has been observed that Napier grass DM yield increased 6.8 t ha-1 at 3 weeks post establishment to 13.0 t ha-1 10 weeks post establishment at a number of locations in Kenya (Kariuki et al., 1998). This indicates that a long harvest interval is necessary to achieve high herbage yields of Napier grass (Tekletsadik et al., 2004; Tessema et al., 2010b).

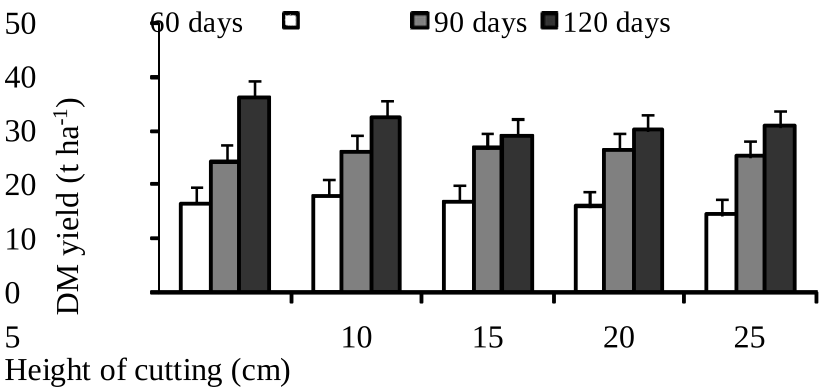

Figure 1. *Effect of defoliation frequency and cutting height on dry matter yield (t ha^{-1}) of Napier grass (Pennisteum purpureum (L.) Schumach) at Haramaya University, eastern Ethiopia*

Chemical composition and IVDMD

Total ash, CP, hemicellulose, and IVDMD contents of Napier grass decreased as defoliation interval increased from 60 to 120 days after establishment (Tessema et al., 2010b; Table 11). However, DM, ADF, ADL and cellulose contents showed an increasing trend with an increase in frequency of defoliation. It is widely reported that CP and IVDMD decrease as defoliation interval increases (Tessema et al., 2002a). In contrast, NDF, ADF, ADL, and cellulose increase with increasing days of defoliation (Kabuga and Darko, 1993).

Table 11. Effect of frequency of defoliation (DF) and cutting height (CH) on chemical compositions and in vitro dry matter digestibility of Napier grass at Haramaya University, eastern Ethiopia.

Chemical composition and IVDMD (% DM basis)										
		DM$^{\lambda}$	TA	CP	NDF	ADF	ADL	CELL	HC	IVDMD
Defoliation frequency										
	60	90.4^{c}	13.8^{a}	12.1^{a}	54.6^{a}	36.0^{b}	3.4^{b}	29.7^{b}	33.7^{a}	63.9^{a}
	90	91.5^{b}	13.4^{a}	10.6^{b}	54.7^{a}	39.8^{a}	3.5^{b}	33.6^{a}	29.2^{b}	62.9^{a}
	120	92.8^{a}	12.3^{b}	8.0^{c}	54.8^{a}	41.0^{b}	4.0^{a}	33.9^{a}	28.0^{c}	56.9^{b}
Cutting height										
5		91.9^{a}	13.5a	11.4^{a}	54.9^{a}	37.9^{a}	3.5^{a}	31.9^{a}	30.8^{a}	60.8^{a}
	10	92.3^{a}	13.1^{ab}	9.8^{ab}	54.4^{a}	38.9^{a}	3.8^{a}	32.1^{a}	30.1^{a}	62.9^{a}
	15	92.4^{a}	12.8^{b}	9.3^{b}	54.7^{a}	39.7^{a}	3.7^{a}	33.1^{a}	29.9^{a}	61.0^{a}
	20	93.6^{a}	12.9^{b}	9.4^{b}	54.8^{a}	39.4^{a}	3.7^{a}	32.7^{a}	30.5^{a}	60.9^{a}
	25	92.6^{a}	13.5^{a}	11.2^{a}	54.6^{a}	38.7^{a}	3.5^{a}	32.3^{a}	30.2^{a}	60.4^{a}

Chemical composition and IVDMD (% DM basis)									
	DM$^{\lambda}$	TA	CP	NDF	ADF	ADL	CELL	HC	IVDMD
Defoliation frequency									
P	0.001	0.001	0.001	0.144	0.001	0.001	0.001	0.001	0.001
LSD	0.38	0.42	1.21	NS	1.16	0,21	1.03	0.71	1.85
CH									
P	0.191	0.021	0.018	0.153	0.328	0.274	0.388	0.303	0.466
LSD	NS	0.54	1.58	NS	NS	NS	NS	NS	NS
DF x CH									
P	0.034	0.171	0.434	0.056	0.071	0.163	0.141	0.231	0.002
LSD	0.87	NS	NS	NS	NS	NS	NS	NS	4.14
CV %	0.56	4.27	5.75	1.31	3.98	7.68	4.23	3.15	4.92

Source (Tessema et al., 2010b); $^{\lambda}$ DM = dry matter; TA = total ash; CP = crude protein; NDF = Neutral detergent fiber; ADF = acid detergent fiber; ADL = acid detergent lignin; CELL = cellulose; HC = hemicellulose; IVDMD = *in vitro* dry matter digestibility; NS, not significant; Numbers with the same superscript within a column and within a factor are not different (P<0.05).

Effect of fertilizer application on performance of Napier grass

Growth characteristics: Studies showed that the number of tillers per plant, number of internodes per tiller base circumference and internodes length per tiller were significantly affected by fertilizer application with the highest values at 1.5 m in Napier grass (Tessema et al., 2003a; Table 12). Kamel et al. (1983) in Egypt found that the number of tillers per plant of Napier grass increased with N levels, although animal manure and chemical fertilizers had no effect on tillers per plant in the early stage of growth in Taiwan (Liang, 1982). Cattle manure did not have as much effect on growth as N fertilizer, perhaps because only small amounts of manure were applied in the study or because cattle manure has only a long-term effect on soil-plant interaction.

Table 12. Growth characteristics of Napier grass as influenced by fertilizer application under rain fed conditions

Growth characteristics	Fertilizer application					
	0^{d}	46^{d}	92^{d}	1e	2e	SE (±)
Internode number per tiller	8.3^{a}	6.9^{b}	7.3^{b}	7.4^{ab}	7.3^{b}	0.24
Internode lengeth per tiller (cm)	14.7^{b}	16.9^{a}	14.9^{ab}	14.3^{b}	14.3^{b}	0.54
Number of leaves per tiller	28.8	25.1	25.9	26.2	27.4	2.05
Total leaves per tiller	860.2	717.3	834.4	620.6	640.6	68.7
Leaf length (cm)	48.8	52.8	51.4	48.5	49.2	1.90
Leaf: stem ration	1.91	1.84	1.72	2.14	1.62	0.21
Number of tiller per plant	28.5^{ab}	27.9^{ab}	31.1^{a}	23.0b	22.5^{b}	1.59
Basal circumference per plant (cm)	67.3^{ab}	67.9^{ab}	71.3^{a}	58.9^{c}	62.9^{bc}	2.50

Source (Tessema et al., 2003a); ^{d} = N fertilizer (kg ha^{-1}); ^{e} = cattle manure (t ha^{-1}); Numbers within a row with similar superscript do not significantly differ (P<0.05)

Biomass production: The DM yield of Napier grass was significantly affected by fertilizer application with the highest DM yield of 8.9 t ha^{-1} by the application of 46 kg N ha^{-1}. Similarly, application of cattle manure at a rate of 2 t ha^{-1} gave a higher DM yield of Napier grass compared to 1.0 t ha^{-1} and without N and manure application (Tessema, et al., 2002b; Table 6). However, the effect of cattle manure on DM yield when compared to inorganic fertilizer application was not pronounced, which might be due to the small amount of manure applied and the slow nutrient releasing as the manure was not yet fully decomposed. For instance, a ton of cattle manure (DM basis) contains 8 and 4 kg of N and P, respectively (Tessema et al., 2002a). However, some studies reported that the DM yield of Napier grass was proportional to the amount of applied manure. The use of 30 t ha^{-1} farmyard manure increased growth and DM yield of Napier grass harvested at 1.5 m in Paraguay (Averio et al., 1991). Similarly, more than 25 t ha^{-1} DM yields per annum is obtained from well-managed and fertilized Napier grass with 92 kg ha^{-1} N on red soil under rain fed condition in the north-western Ethiopia (Tessema, 2005).

Chemical composition and IVDMD: Fertilizer application per se had no significant effect on IVDMD and ME of Napier grass. Crude protein and hemicellulose increased whereas ash, ADF-ash, and P decreased as a result of an increase in the level of N application (Tessema et al., 2002b; Table 13). According to Taliaferro et al. (1975), addition of N tended to increase IVDMD of grasses when compared with plots receiving no N. Nitrogen fertilization of grasses affects herbage digestibility only slightly and improved DMD during the earlier part of growth period but at the advanced stage of maturity the DMD of N-fertilized grass was inferior to the non-fertilized ones (Daniel, 1996). Dressings of fertilizers can markedly affect the mineral content of plants, and it is also known that the application of N fertilizer can increase the CP of herbage and influence the amide and nitrate content (Van Soest, 1994). Generally application of 92 kg ha^{-1} N in the form of urea provided the highest yield and total nutrient per ha in Napier grass under rain fed condition in mid and highland areas of Ethiopia (Table 14).

Table 13. Chemical composition and in vitro dry matter digestibility (% DM basis) Napier as influenced by fertilizer application under rain fed conditions

	Fertilizer application					
Parameters	0wz	46w	92w	1z	2z	SE (±)
Dry matter	21.9	19.40	20.50	21.80	20.40	0.99
Ash	16.50[a]	15.70[b]	15.10[c]	16.50[ab]	17.10[a]	0.41
Crude protein	12.60c	14.50[ab]	15.10[a]	13.40[bc]	12.90[c]	0.40
Neutral detergent fiber	61.31	61.44	61.78	60.42	60.51	0.71
Acid detergent fiber	34.99	34.08	34.98	34.03	34.01	0.61
Acid detergent lignin	3.59	3.66	3.79	3.61	3.55	0.15
ADF-ash	7.02[a]	6.86[a]	6.05[b]	7.42[a]	7.74[a]	0.38
Cellulose	24.39	23.56	25.14	23.00	22.73	0.79

	Fertilizer application					
Parameters	0wz	46w	92w	1z	2z	SE (±)
Hemicellulose	26.32[c]	27.36[a]	27.13[ab]	26.40[bc]	26.35[c]	0.26
Calcium	0.63	0.63	0.59	0.68	0.70	0.04
Phosphorus	0.20[ab]	0.19[a]	0.17c	0.20[ab]	0.21[a]	0.01
IVDMD	65.90	66.16	65.53	66.19	66.67	0.55
ME (MJ.kg -1 DM)	9.09	9.12	9.03	9.13	9.19	0.78

Source (Tessema et al., 2002a); [w] = N fertilizer (kg ha^{-1}); [z] = cattle manure (t ha^{-1}); IVDMD = *in vitro* dry matter digestibility; Numbers within a row with similar superscript do not significantly differ (P<0.05)

Table 14. Total nutrient yield (t.ha-1) of Napier grass as influenced by fertilizer application under rain fed conditions in north-western Ethiopia

Fertilizer application	DM yield (t.ha-1)	Crude protein (%)	Crude protein yield		IVDMD (%)	Digestible DM yield	
			Cut -1	Kg N-1		Cut -1	Kg N-1
0 N kg ha-1	7.31[c]	12.6[c]	0.92[c]	-	65.90	4.82c	-
46 N kg ha-1	8.89[a]	14.5[ab]	1.29[b]	0.008[az]	66.16	5.88[ab]	0.0231[a]
92 N kg ha-1	9.38[a]	15.1[a]	1.42[a]	0.0054[b]	65.53	6.15[a]	0.0145[b]
1 t ha-1 manure	7.29[c]	13.4[bc]	0.98[c]	-	66.19	4.83[c]	-
2 t ha-1 manure	8.16[b]	12.9[c]	1.05[c]	-	66.67	5.44[b]	-

Source (Tessema et al., 2002a); DM = dry matter; IVDMD = *in vitro* dry matter digestibility

Supplementation of Napier grass with multipurpose trees

Multipurpose fodder trees (MPT) and shrubs have often considerable potential in mixed crop-livestock production systems to alleviate and compliment the low feeding value of roughage diets (Tessema and Baars, 2004; Manaye et al., 2009). They are seldom exclusively fed, mostly as a supplement to enhance the utilization of fibrous feeds. An important attribute of MPT is their positive effect on digestibility when used as a supplement to fibrous basal feeds (Solomon et al., 2003). The increased DM and/or OM digestibility of low quality feeds by supplementing MPT could be due to the retention of adequate level of rumen ammonia and the removal of amino acid deficiency at tissue level (Solomon et al., 2003). On top of these, the OM digestibility of MPT is higher than grasses due to the fact that MPT supply soluble carbohydrates and fermentable N for rumen and post rumen function (Smith, 1992).

Chemical composition and IVDMD: Studies indicated that the DM, ash, CP, and ADL contents of Napier grass increased as the proportion of Sesbania (10, 20, 30 and 40% *Sesbania sesban* in DM basis) in the nixture increased. The DM, ON and CP intake and DM, ON, CP and NDF digestibilities of Napier grass –Sesbania mixtures were higher than sole Napier grass alone (Manaye et al., 2009; Table 15 and 16). The average daily wight gain was higher in animals fed a diet containing 300 g DM^{-1} Sesbania as compared to the sole Napier grass. The CP contents of different Napier-

Sesbania mixtures were above the minimum CP level of 7.5% required for adequate rumen function in ruminants (Van Soest, 1994). The minimum CP content required for lactation and growth of cattle is 15% (Van Soest, 1994) suggesting that the 70:30 and 60:40% Napier-Sesbania mixtures were above the recommendation. The advantage of perennial legume in a mixed pasture is their higher protein value compared to grass alone (Minson, 1990; Lemma et al., 1991). The low fibre content of Sesbania might have contributed to the increasing CP and IVDMD in Napier grass. The important attributes of MPT are their positive effects on digestibility and to enhance utilisation of fibrous feeds when used as a supplement to fibrous basal feeds (Solomon et al., 2003; Tessema and Baars, 2004). The increased DMD of low quality feeds by supplementing MPT could be due to maintenance of adequate levels of rumen ammonia and removal of amino acid deficiency at the tissue level (Solomon et al., 2003). Moreover, the DMD of MPT is higher than grasses since MPT supply soluble carbohydrates and fermentable N for rumen and post rumen function (Smith, 1992). Napier-Sesbania mixtures could adequately supply CP, ME and Ca above the production requirements (Kearl, 1982) of a 12 weeks lactating dairy cow weighing 500 kg since the nutrient, digestibility and intake increases with the level of Sesbania in the Napier mixture (Table 16). It can be concluded that feeding a sole diet of young Napier grass to sheep could result in reseanably god performance and inclusion of above 300 g DM^{-1} Sesbania in the Napier diet did not have further beneficial effects. This shows that Sesbania leaves would increase the digestibility and intake of matured Napier grass and could be used as an effective supplement under smallholder conditions in Ethiopia.

Table 15. Chemical composition (g kg-1 DM) and digestibility (%) of Napier grass (N) mixed with differ- ent proportions of Sesbania (S)

Feeds	Chemical composition					Digestibility (%)				
	OM	CP	NDF	ADF	ADL	DM	OM	CP	NDF	ADF
SSesbania alone	757	248	399	299	80	-	-	-	-	-
Napier alone	854	120	715	406	65	65.8^{b}	71.8^{b}	69.8^{b}	69.0^{b}	51.5^{a}
N + 100 g kg-1 S	841	133	684	395	66	74.4^{ab}	80.4^{ab}	82.0^{a}	75.7^{ab}	42.6^{b}
N + 200 g kg-1 S	834	146	652	384	68	77.1^{a}	81.8^{a}	83.4^{a}	77.3^{ab}	29.0^{c}
N + 300 g kg-1 S	825	159	621	374	70	82.0^{a}	85.8^{a}	87.8^{a}	81.2^{ab}	11.8^{d}
N + 400 g kg-1 S	815	171	589	363	71	84.1^{a}	85.3^{a}	88.5^{a}	82.6^{a}	4.8^{e}

Source (Manaye et al., 2009); Means with different superscripts in a column are significantly different at P<0.05

Table 16. Mean daily dry matter and other nutrient intake and average daily weight gain () of local sheep fed Napier grass mixed with different levels of Sesbania sesban

Daily DM and nutrient intakes (g kg $W^{-0.75}$ day^{-1})								ADWG
Feeds	DM	OM	CP	NDF	ADF	ADL	Ash	(g day-1)
Napier alone	57.9^{b}	47.5^{b}	7.0^{d}	41.4^{ab}	23.5^{a}	3.8^{b}	8.5^{d}	75.6^{b}
N + 100 g kg^{-1} S	63.1^{a}	51.1^{ab}	8.4^{c}	43.2^{a}	25.0^{a}	4.2^{b}	9.8^{c}	87.0^{ab}
N + 200 g kg^{-1} S	63.7^{a}	51.0^{ab}	9.3^{b}	41.6^{ab}	24.5^{a}	4.3^{b}	10.6^{bc}	86.2^{ab}
N + 300 g kg^{-1} S	63.6^{a}	50.2^{ab}	10.1^{b}	39.4^{b}	23.8^{a}	4.4^{b}	11.1^{ab}	103.0^{a}
N + 400 g kg^{-1} S	67.9^{a}	52.9^{a}	11.6^{a}	40.0^{b}	24.8^{a}	4.8^{a}	12.5^{a}	93.3^{ab}
SEM	0.002	0.001	0.000	0.001	0.001	0.000	0.000	7.5

Source (Manaye et al., 2009); SEM = standard error of the mean; Means with different superscripts in a column are significantly different at P<0.05

In sacco rumen degradability

Dry matter degradability-The proportions of Sesbania leaves mixed with Napier grass had a linear (P<0.05) effect on rumen DMD contents (Tessema and Baars, 2004; Table 17). There were no differences in DMD for the insoluble but gradually degradable fractions (B), and the lag phase (L), but other DMD characteristics had increasing linear (L: P<0.01) effects as the proportions of Sesbania increased in the mixture. However, the DMD lag time had quadratic (P<0.01) and cubic (P<0.01) effects. The PD, ED, and the rate of degradability of the B fraction (c) showed an increasing linear (P<0.01) effect as the proportion of Sesbania increased in the diet. Sesbania supplementation increased the rate of degradation and potential degradability (PD) for sheep fed a low quality basal diet (Nsahlai and Umunna, 1996). Incubation of Sesbania in the rumen of sheep affected the extent of DMD, the intercept (a), the slowly degradable component (b), rate of degradation (c), PD and lag time (Nsahlai and Umunna, 1996; Bonsi et al., 1995). Supplementation of Sesbania improved the fractional rumen out flow rate and out flow rate of liquids for sheep fed fibrous basal feeds (Bonsi et al., 1995). The faster degradation of Sesbania leaves released greater amounts of rumen metabolities, which probably enhanced rumen microbial function and proliferation (Bonsi et al., 1994; Bonsi et al., 1995) that might have improved feed digestibility. Compared with the foliages of other MPT, Sesbania has lower fibre levels that degraded faster in the rumen of animals fed a low quality basal diet, and it will tend to exhaust within a short time. Feeding fast degrading foliages, such as Sesbania, improved rumen ecology (i.e., N, minerals and isoacids), and they might further enhance forage intake since they move out the rumen faster and thus reduce rumen fill (Bonsi et al., 1994; Bonsi et al., 1995). This might have contributed to increase DMD as the proportion of Sesbania in Napier mixture increased.

Table 17. In sacco rumen dry matter degradability characteristics of Napier grass as influenced by different proportions of Sesbania in the mixture (g kg-1 DM)

Proportion of Sesbania in the mixture							Probability [a]		
Parameters	0	100	150	200	250	SE (±)	L	Q	C
The readily fermentable fraction, g kg^{-1} DM	191	186	206	273	338	30	**	NS	NS
The insoluble but fermentable fraction, g kg^{-1} DM	559	586	593	527	477	24	NS	NS	NS
Potential degradability, g kg-1 DM	750	772	799	800	816	8	**	NS	NS
Rate of degradation of insoluble fraction, /h	0.04	0.05	0.05	0.07	0.07	0.02	**	NS	NS
Lag (L), h	5.6	4.3	4.5	5.0	6.1	0.8	NS	NS	NS
Effective degradability, g/kg	510	533	578	602	638	7	**	NS	NS

Source (Tessema and Baars, 2004); [a]Probability for linear (L), quadratic (Q), and cubic (C) trends; * $P < 0.05$; ** $P < 0.01$; NS = not significant

Intercropping Napier grass with herbaceous legumes

Intercropping Napier grass with *L. purpureus* and *D. intortum* significantly (P<0.01) out yielded the sole Napier grass and Napier grass associated with *L. purpureus* found to be better than either sole Napier or Napier grass + *D. intortum*. Intercropping Napier grass with *L. Purpureus* and *D. interterm* have resulted a significant difference on CP, CPY, fiber fractions (NDF, ADF, ADL, Cellulose and hemicellulose) and IVOMD (Taye et al., 2007). Moreover, Napier grass intercropped with Stylosanthes cv. Seca was more degradable than sole Napier grass. It can be concluded that *Lablab, Desmodium*, and *Stylosanthes* could form a better association with Napier grass and are recommended for intercropping in mid and semi-arid agro-ecologies of Ethiopia.

Summary and conclusion

Large productions of Napier grass are available in soil conservation areas, homestead plots, around road sides and other areas in Ethiopia, which indicated that Napier grass has no competition for land for food crop cultivations. Therefore, Napier grass could be easily established using rootstock and/or stem cuttings at a spacing of 1 m between rows and 0.50 m between plants under smallholder conditions for ruminant feeding. Spacing could be adjusted on performance basis and in areas of moisture stress, narrower spacing both between rows and plants is recommended. Plants from root splits make more rapid early growth and give high herbage yields than from stem cuttings under rain fed conditions in Ethiopia. However, older and hardened stems are more reliable than young materials for easy establishment and tiller formation if Napier grass is established by stem cuttings. Studies conducted in Ethiopia have shown that Napier grass has fast regrowth ability, high DM yield and nutritive values compared to other improved pasture species if harvested at an appropriate stage under rain fed conditions in mid and highland areas of Ethiopia. Therefore, the available management practices such as harvesting Napier grass when the plant reaches 1m height, or harvesting at 90 days interval, or mixing Napier grass with Sesbania up to 25%, or growing Napier grass with *Lablab purpureus* or *Desmodium intortum/unicinatum or Stylosanthes* or with forage vetch or with other multipurpose browse species or applying 92 kg ha^{-1} N or 2 t ha^{-1} cattle manure (DM basis) per annum could be practiced and followed by the livestock development and extension systems in Ethiopia. Further studies on intake and animal performances related to these management practices are suggested to develop Napier-based diets for smallholders' in different agro-ecological parts of Ethiopia.

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