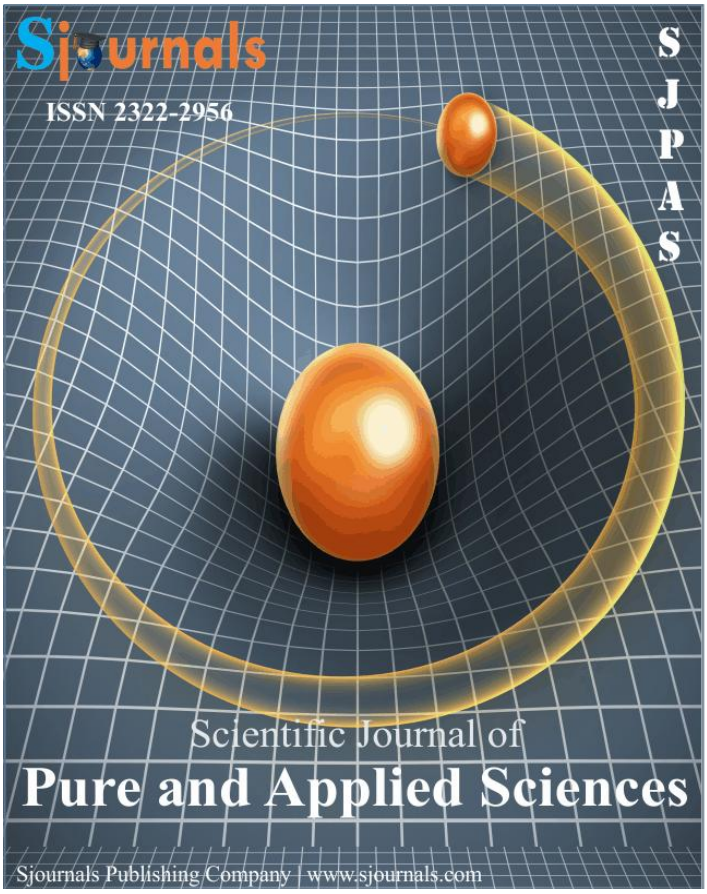

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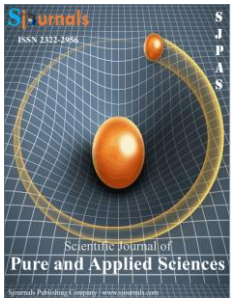

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Original article

Effect of different spacing of Napier grass (*Pennisetum purpureum*) intercropped with or without Lablab (*Lablab purpureus*) on digestibility of Napier grass

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ABSTRACT

This study was conducted with an objective of determining effect of three spacing of Napier grass intercropped with or without Lablab (Lablab purpureus) on digestibility of Napier grass in a 2 x 3 factorial arrangement in RCBD with 4 blocks. Spacing was 1m x 0.5m, 0.75m x 0.5m, and 0.5m x 0.5m. Intercropping decreased the electro conductivity but increased the available phosphorous content of the soil and did not affect the pH, organic carbon and total nitrogen of the soil. The *in vitro* DM (IVDMD) and OM digestibility (IVOMD) of Napier grass was increased by intercropping with lablab. However, spacing and interaction of spacing with intercropping did not affect the IVDMD and IVOMD content of Napier grass. *In sacco* degradability of DM and OM of Napier grass for many of the incubation hours including 48 hour which was relatively higher for the 1m x 0.5m spacing and for the one intercropped with lablab. The DM and OM *in sacco* degradability characteristics were almost all affected by spacing and intercropping but without an apparent consistent trend. In conclusion, intercropping with lablab had a positive influence on the IVDMD and IVOMD. Conversely, spacing failed to have significant impact on these parameters. However, 1 m x 0.5 m spacing appeared to have better effect on the *in sacco* DM and OM degradability and effective degradability. As such 1 m x 0.5m spacing and intercropping with lablab can be of a better choice based on the results of this study.

1. Introduction

List of abbreviations and acronyms

M a s l	Meters Above Sea Level
ADF	Acid Detergent Fiber
ADL	Acid Detergent Lignin
ATARC	Adami Tulu Agricultural Research Center
AOAC	Association of Official Analytical Chemists
CP	Crude Protein
DM	Dry Matter
DMD	Dry Matter Degradability
ED	Effective Degradability
GDP	Growth Domestic Product
GP	Gas Production
GLM	General Linear Model
ILRI	International Livestock Research Institute
IVOMD	In vitro Organic Matter Digestibility
LSD	Least Significant Difference
ME	Metabolizable Energy
MOARD	Ministry of Agriculture and Rural Development
NDF	Neutral Detergent Fiber
OM	Organic Matter
OMD	Organic Matter Digestibility
PD	Potential Degradability
RCBD	Randomized Complete Block Design
RDP	Rumen Degradable Protein
SAS	Statistical Analysis Systems

Livestock contribute 15 to17 percent of GDP and 35 to 49 percent of agricultural GDP, and 37 to 87 percent of the household income in Ethiopia (Sintayehu et al., 2010). Livestock have multiple uses such as income generation, cash storage, draught and pack services, milk and meat for household consumption, and manure for fuel and fertilizer. Despite the large number of livestock resources the country own, its productivity is extremely low. The major constraint to such low productivity is shortage of livestock feeds in terms of quantity and quality, especially during the dry season (Ahmed et al., 2010). Feed supply from natural pasture fluctuates following seasonal dynamics of rainfall (Solomon et al., 2008). Despite, these problems, ruminants continue to depend primarily on forages from natural pastures and crop residues. The feed problem in the country arises in two related forms: shortage; and high feed prices. Data adapted from MoARD (2008) Livestock Master Plan, indicate that nationwide, 64 million tons of feed are required annually to sustain the livestock population in Ethiopia. However, the same sources estimate that only about 37 million tons are currently available, so that the system satisfies just 58 percent of needs. Grazing as a source of livestock feed has begun to decline in recent years, as a result of increased areas of cultivation, and changing patterns of land use. An adequate supply of livestock feed is crucial to the livelihoods of millions of people across the developing world, and not just for smallholders, but also for pastoralists and the large number of landless who depend mainly on common land for grazing (Sanford and Ashly, 2008).

Napier grass (*Pennisetum purpureum)* has become by far the most important species due to its wide ecological range of adaptation (from sea level to over 2,000 meters), high yield and ease of propagation and management (Orodho, 2006; ILRI, 2010a; ILRI, 2013). It is originated from central Africa and is commonly used by many farmers today because of its growth rate, drought tolerance, and most importantly, its yield. With an average crude protein content of 9% (ILRI, 2010b) and with DM of about 15 percent (ILRI, 2001), it is favorite for

many farming systems in Africa (ILRI, 2010a). It is for example continues to be the major feed for cut-and-carry dairy systems in East Africa (Basweti et al., 2009). Demand for Napier grass has been increasing rapidly in Ethiopia with over 200,000 cuttings of best Napier accessions distributed from ILRI in 2003 and 1.4 million cuttings in 2004 (Hanson and Peters, 2003) to NGOs, Ministry of Agriculture and Development workers for development purposes. The principal use of Napier grass is as forage for dairy animals and studies to assess the yield and nutritional values from a range of maturity types, management regimes and environments have been carried out (Tessema et al., 2002a, 2002b, 2003). The yields and quality of tropical grasses depend on many factors; most importantly, soil fertility and environmental conditions (ILRI, 2010a). Like other tropical grasses, Napier grass is considered high in structural cell wall carbohydrates that increase rapidly with advance in maturity, whereas the reverse is true with its digestibility (Van Soest, 1994). This implies the need for production strategies that can help improve the digestibility of Napier grass. The conventional methods of improving Napier grass quality through fertilization or use of concentrates to supplement Napier grass diets is limited because most farmers cannot afford these inputs. This has led to poor animal performance mostly attributed to the low protein content and low digestibility in Napier grass.

One such approach is to establish it in association with legume species to make use of the yield advantage of Napier grass and the high CP content of legume species. Legume forages are cultivated to maintain soil fertility and supplement ruminant diets because the majority of the smallholder farmers cannot afford commercial concentrates. To this effect, the use of tropical legumes like Lablab (*Lablab purpureus*) which are annual or short term perennial species in association with productive, but high cell wall fiber containing grass species such as Napier grass could be an advantage in improving the supply of nutrients to livestock (Taye et al., 2007). The optimization of productivity and nutritive value of grass/legume associations can be achieved by forage management tools such as date of harvesting (Taye et al., 2007), height of harvesting at cutting (Tessema et al., 2002a) and plant spacing (Sumran et al., 2009). Ninety days of harvesting (Taye et al., 2007) and 1m length at harvest (Tessema et al., 2002a) is recommended to get best biomass and Nutritive value of Napier grass. Lablab can be well associated with Napier grass but the association effect of the two plant species on the digestibility of Napier grass is poorly documented. Hence, there is no enough data available in Ethiopia about effect of intercropping *lablab purpureus* on the digestibility of Napier grass. It was necessary to conduct the present experiment in order to generate data on digestibility of *Pennisetum purpureum* planted at different spacing as intercropping with *Lablab purpureus* or as a sole stand. Therefore, this study was conducted with the objective of determining effects of different spacing of Napier grass intercropped with or without Lablab (*Lablab purpureus*) on digestibility of Napier grass.

2. Materials and methods

2.1. Description of the experimental area

The experiment was conducted at Adami Tulu Agricultural Research Center (ATARC), which is located in the mid rift valley, 167 km south of Addis Ababa on Awassa road. It lies at latitude of 7^{O} 9' N and 38^{O} 7' E longitude. Its altitude is about 1650 meters above sea level (m.a.s.l). It has an average annual rainfall of 760 mm. It has a bimodal rainfall from March to April (short rain) and July to September (long rains) with a dry period in May to June, which separates short rains from long rains (Teshome et al., 2012). The average annual minimum and maximum temperature of the area at the study year were 11.8 ^{O}C and 28.3 ^{O}C (metrology station of Adami Tulu Agricultural Research Center). The soil is loam with sand, silt and clay in proportion of 44%, 34% and 22%, respectively, and the pH of the soil is 7.88 (Teshome et al., 2012). The chemical properties of the soil at 0.15 and 0.5 m depth were pH 8.1 and 8.4, organic matter 2% and 1%, and nitrogen 0.13% and 0.07%, respectively. Available phosphorus was 5 ppm at both depths (Basweti et al., 2009).

2.2. Experimental layout, design and treatments

The experimental design was factorial arranged in RCBD consisting of three inter and intra row spacing of Napier grass, 1 m x 0.5 m (Tessema et al., 2002a), 0.75 m x 0.5 m (ILRI, 2010b) and 0.5 m x 0.5 m (Taye et al., 2007) without and with *Lablab purpureus* intercropping between the rows of Napier grass. There was four blocks, each containing six plots resulting to twenty-four plots in total with each plot measuring 3 m x 4 m. Distance between plot and replications (blocks) were 1 m and 1.5 m, respectively**.** Plots in each block were randomly assigned to the

six treatments. The land was ploughed and harrowed with a tractor and then by hoe. The planting material was Napier grass accession (ILRI 14984) and Lablab (*Lablab purpureus*), which are adapted in Adami Tulu Agricultural Research Center. The material was planted on July 18, 2013. Napier grass was root splited with each material for planting need to contain three shoots and the material was planted 15cm deep inclined at 45^{O} angle (ILRI, 2010b) and the seed of *Lablab purpureus* was drilled in between the rows of Napier grass in a seeding rate of 15 kg/ha in 7cm depth (Antony, 2006; ILRI, 2010b). Weeding was done early and then two times to eliminate re-growth of undesirable plants and removal of the dry root bound Napier in order to promote fodder re-growth by increasing soil aeration. The plots were kept weed free throughout growth period (Orodho, 2006). The Forage was harvested on October 18, 2013.

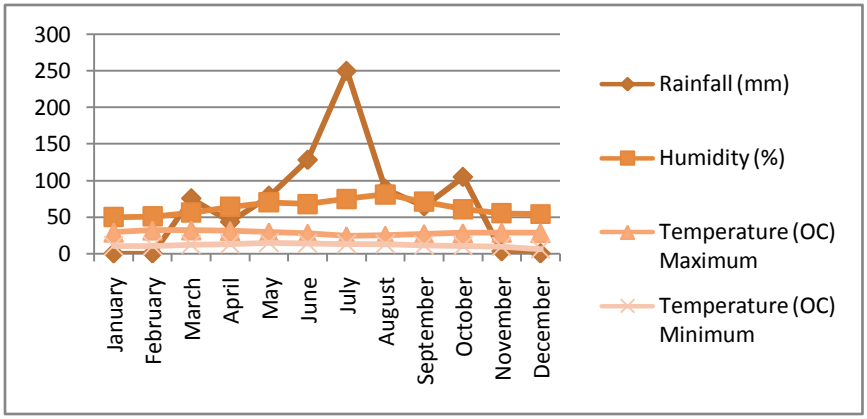

Fig. 1. Rainfall, humidity and maximum and minimum temperature of the study area during the experiment year (2013).

Table 1
Row and plant spacing of Napier grass when intercropped with or without lablab.

Row spacing	Plant spacing	No of plants / ha	Intercropping
1m	0.5m	30000	w
0.75m	0.5m	37500	w
0.5m	0.5m	52500	w
1m	0.5m	30000	w/o
0.75m	0.5m	37500	w/o
0.5m	0.5m	52500	w/o

m = meter; w = with *Lablab purpureus* and w/o = without *Lablab purpureous*.

2.3. Soil sampling and analysis

Three composite soil samples (more than one composite will give an estimate of soil variability) representing nine surface soils, in practice, it is common to collect cores following a zigzag path where a conscious effort is made to force the path into corners and along edges as well as the central parts of the site being sampled (Deb et al., 1995) before planting and from each plot representing five surface soil samples (in each corner and center of plots) of the experimental field after forage harvesting was taken diagonally at a depth of 30 cm in order to make the sample representative. The collected soil samples was dried in open air (so as not to lose the organic carbon and total nitrogen content of the soil), ground, sieved and analyzed for its nitrogen, soil pH, organic carbon and available phosphorus. Soil samples were analyzed at Ziway Soil Research Laboratory. EC was determined by using hydrometer. Total nitrogen was determined following Kjeldahl procedure as described by Cottenie (1980); the soil pH was measured with digital pH meter potential metrically in the supernatant suspension of 1: 2.5 soils to distilled water ratio (Van Reeujik, 1992). Organic carbon was determined following wet digestion method as described by Walkley and Black (1934), and the available phosphorus was measured using Olsen II methods (Olsen et al., 1954).

2.4. *In vitro* digestibility

All samples used for chemical analysis was used for *in vitro* dry matter digestibility (IVDMD). The IVDMD was analyzed at Holeta Agricultural Research Center The two-stage rumen inoculums pepsin method of Tilley and Terry (1963) was used to determine IVDMD. Rumen liquor was collected from three ruminally fistulated steers and transported to the laboratory using thermos flask that have been pre-warmed to 39 ^{O}C. Rumen liquor was taken in the morning before animals were offered feed. A duplicate sample 0.5 g each was incubated with 30 ml of rumen liquor in 100 ml test tube in water bath at 39 ^{O}C for a period of 48 hour for microbial digestion followed by another 48 hour for enzyme digestion with acid pepsin solution. Blank samples containing buffered rumen fluid only was incubated in duplicates for adjustment. Drying of samples residues was done at 105 ^{O}C for 24 hours. IVDMD was calculated (Jeans and Yolande, 2007) as:

$$\frac{\text{Dry sample weight- (residue- blank) x 100}}{\text{Dry sample weight}}$$

The sample was then ashed to estimate *In vitro* OM digestibility as:

$$\frac{\text{OM in the feed- (OM in residue – blank) x 100}}{\text{OM in the feed}}$$

Where OM = DM- Ash (measured after incineration of feed or residue). The ME content was estimated using the equation: ME (MJ kgDM) = 0.15*IVOMD (Pikrton, 2005).

2.5. *In sacco* degradability

In sacco degradability were analyzed at Holeta Agricultural Research Center. A composite sample of Napier grass for each treatment and one composite sample of Lablab was taken and dried in a forced draft oven at 60 ^{O}C for 72 hours. Samples were ground using Wiley mill to pass through a 2 mm sieve screens for *in sacco* degradability. The ruminal *in sacco* DM and OM degradability was determined by incubating 3 g of dried forage samples in nylon bags (41µm pore size and 6.5 x 14 cm dimension) in three rumen fistulated steers for 0, 6, 12, 24, 48, 72 and 96 hours. Upon the removal of nylon bags at the end of each incubation hours, all bags incubated including the zero hour was washed manually under a running tap water until the water was clean, gently squeezed to remove excess water, and dried at 100 ^{O}C for 24 hours in a forced draft oven. The dried bags were then taken out of the oven and allowed to cool down in desiccators and weighed immediately. DM and OM contents were determined in the original samples as well as in the residues according to standard procedure (AOAC, 1990).

The degradability of DM (DMD) and OM (OMD) of each incubation time was determined as DMD and OMD (%) = (weight of DM / OM incubated - weight of DM / OM residue) x 100 / weight of DM / OM incubated. The DMD and OMD values at various times of incubation was fitted to the exponential equation; $p = a + b\ (1 – e^{-ct})$ where; a= washing loss (rapidly soluble fraction); b= slowly degradable fraction and c= the rate of degradation, e = the natural logarithm, p = the potential disappearance of DM / OM at time t and t = time as described by Ørskov and McDonald (1981) using the Neway Excel programme. The potential degradability (PD) was estimated as (a + b) while the effective degradability of DM and OM (ED) was calculated using Ørskov and McDonald (1979) formula: ED = a + [(b*c)/(c + k)] at 0.03/hour rumen out flow rate (k). Where a, b and c are as described above and k = passage rate.

2.6. Statistical analysis

Data on soil parameters and *in vitro* digestibility was analyzed using ANOVA by the general linear model procedure of SAS (SAS, 2000). Means were separated using Least Significant Difference (LSD) at 5% significant level. The model was $Y_{ijk} = \mu + Si + Ij + SIij + B_K + eijk$ Where:

Yijk = individual observation
µ= overall mean
$S_i = i^{th}$ spacing effect
$Ij = j^{th}$ intercropping effect
$SIij = ij^{th}$ spacing x intercropping interaction effect

B_k = k^{th} block effect
e_{ijk} = residual error

Since fistulated animals were used as a replication, the analysis of variance model for the *in sacco* degradability parameters was:

$$Yij = \mu + Si + Ij + SIij + Ak + eijk$$

Where:

Yij = individual observation
μ = overall mean
Si = i^{th} spacing effect
Ij = j^{th} intercropping effect
Ak = Animal effect
SIij = ij^{th} spacing x intercropping interaction effect
eijk = residual error

3. Results

3.1. Characterization of the soil of the study area

3.1.1. Chemical properties of the soil

The value of chemical properties of soil before sowing indicates that 0.19 Electro Conductivity (EC), 7.66 PH, 6.2 Available Phosphorous (AP), 4.09 organic carbon and 0.19 total nitrogen (Table 2). The soil of the study area is loam with sand, silt and clay in proportion of 34.97%, 45.65% and 19.38%, respectively.

3.1.2. Effect of spacing and intercropping on soil fertility

Spacing and interaction of spacing with intercropping did not have a significant impact on EC ($P>0.05$). However, intercropping of lablab with Napier grass reduced the EC of the soil. The pH of the soil analyzed after harvesting showed no significant difference for spacing, intercropping and their interaction. The AP content of the soil after harvest was only significantly affected by intercropping of Napier grass with lablab, and values was higher ($P<0.05$) for the intercropped group. Effect of spacing, intercropping and their interaction on soil carbon content was not significant ($P>0.05$). Generally total nitrogen content after harvest was unaffected by intercropping ($P>0.05$), but was significantly affected by spacing ($P<0.05$). As such values for the 1m x 0.5m were higher than the value for 0.5m x 0.5m.

3.2. *In vitro* digestibility

Spacing and interaction of intercropping with spacing has no significant effect ($P>0.05$) on the *in vitro* dry matter digestibility (IVDMD), *in vitro* organic matter digestibility (IVOMD) and metabolizable energy (ME) of the Napier grass (Table 3). Intercropping has significant effect on IVDMD and IVOMD ($P<0.05$) but not on ME ($P>0.05$).

3.3. *In sacco* degradability

3.3.1. *In sacco* dry matter degradability

There is a significant effect ($P<0.05$) of spacing on the DM degradability of Napier grass at 0, 12, 24, 48 and 72 hours of incubation time (Table 4). Interaction of intercropping and spacing has a significant effect on DM degradability at 0, 12, 24, 48 and 72 hours of incubation times ($P<0.05$). Rumen DM degradability characteristics was significantly affected by spacing ($P<0.05$). Interaction of intercropping with spacing on the rumen DM degradability characteristics was significant ($P<0.05$) for all parameters except for the rate of degradation.

Table 2
Soil fertility as influenced by different spacing of Napier grass and intercropping with lablab.

	Soil parameter				
Treatments	**EC (mmhos/cm)**	**pH**	**AP (ppm)**	**OC (%)**	**TN (%)**
Before sowing	0.19	7.66	6.20	4.06	0.19
After sowing					
Spacing					
1m × 0.5m	0.20	7. 90	3.69	3.44	0.22[a]
0.75m × 0.5m	0.19	7.94	3.95	3.09	0.174[b]
0.5m × 0.5m	0.20	8.02	3.62	3.34	0.209[ab]
SEM	0.017	0.049	0.345	0.117	0.011
Intercropping					
With Lablab	0.17[b]	7.99	4.28[a]	3.40	0.21
Without Lablab	0.23[a]	7.92	3.40[b]	3.18	0.20
SEM	0.011	0.042	0.251	0.099	0.011
Interaction effect					
1m × 0.5m * w	0.15	7.92	4.12	3.47	0.21
0.75m × 0.5m * w	0.16	7.98	4.54	3.33	0.19
0.5m × 0.5m * w	0.19	8.07	4.19	3.39	0.21
1m × 0.5m * w/o	0.25	7.88	3.80	3.41	0.24
75m × 0.5m * w/o	0.23	7.907	3.36	2.85	0.16
0.5m × 0.5m * w/o	0.21	7.97	3.05	3.29	0.20
SEM	0.018	0.069	0.158	0.412	0.016

[a, b] Means in a column within the same category having different superscripts differ at (P<0.05); AP = Available Phosphorous; EC = Electro Conductivity; m = meter; mmhos= mili mhos; OC = Organic Carbon; pH = power of Hydrogen; ppm = parts per million; SEM = Standard Error of Means; Level; TN = Total Nitrogen; w = with lablab and w/o = without lablab.

Table 3
In vitro digestibility of Napier grass as influenced by different spacing of Napier grass and intercropping with lablab.

Treatments	**IVDMD (%)**	**IVOMD (%)**	**ME (MJ kg^{-1} DM)**
Spacing			
1m × 0.5m	69.92	59.28	9.94
0.75m × 0.5m	68.89	56.05	8.96
0.5m × 0.5m	67.85	55.01	8.77
SEM	2.02	1.8	0.39
Intercropping effect			
With Lablab	73.48[a]	59.87[a]	9.58
Without Lablab	64.31[b]	53.72[b]	8.88
SEM	0.87	1.22	0.33
Interaction effect			
1m × 0.5m * w	74.08	62.76	10.04
0.75m × 0.5m * w	74.4	59.93	9.58
0.5m × 0.5m * w	71.94	56.92	9.11
1m × 0.5m * w/o	65.76	55.81	9.84
0.75m × 0.5m * w/o	63.39	52.17	8.35
0.5m × 0.5m * w/o	63.78	53.16	8.43
LC	57	66.3	9.12
SEM	1.54	1.88	0.45

[a, b]Means in a column within the same category having different superscripts differ (P<0.05); IVDMD = *In vitro* Dry Matter Digestibility; IVOMD = *In vitro* Organic Matter Digestibility; kg = kilo gram; LC = Lablab Composite; m = meter; ME = Metabolizable Energy; MJ = Mega Joule; SEM = Standard Error of Means; w = with lablab; w/o = without lablab.

Table 4

In sacco dry matter degradability and its rumen degradability characteristics as influenced by different spacing of Napier grass and intercropping with lablab.

	***In sacco* DMD and its rumen degradability characteristics**											
Treatments	**0hr**	**6hr**	**12hr**	**24hr**	**48hr**	**72hr**	**96hr**	**A**	**B**	**A + B (PD)**	**C**	**ED**
Spacing												
1m × 0.5m	14.87^{c}	20.82	43.05^{a}	49.22^{a}	75.17^{a}	78.97^{a}	80.13	14.87^{c}	67.65^{a}	82.52^{b}	0.048	51.47^{a}
0.75m × 0.5m	15.81^{b}	20.11	36.15^{b}	50.48^{a}	74^{b}	76.97^{b}	80.25	15.81^{b}	66.67^{b}	81.88^{b}	0.105	49.87^{a}
0.5m × 0.5m	16.45^{a}	20.17	35.94^{b}	46.85^{b}	73.22^{b}	79.93^{b}	80.58	16.45^{a}	67.55^{a}	84.00^{a}	0.036	48.05^{b}
SEM	0.47	0.53	0.62	2.13	1.41	0.87	3.34	0.47	0.63	0.87	0.024	0.944
Intercropping												
With Lablab	14.67^{b}	21.69^{a}	40.91^{a}	49.24	73.58^{b}	76.98^{a}	80.1	14.67^{b}	67.60^{a}	82.27^{b}	0.086	49.98
Without Lablab	16.75^{a}	19.02^{b}	35.85^{b}	48.47	74.69^{a}	78.27^{b}	80.55	16.75^{a}	66.57^{b}	83.33^{a}	0.041	49.61
SEM	0.36	0.49	0.53	1.89	1.38	0.55	2.63	0.36	0.54	0.85	0.022	0.81
Interaction effect												
1m × 0.5m * w	12.42^{f}	22.52	49.53^{a}	56.39^{a}	73.74^{bc}	79.16^{a}	79.66	12.42^{f}	66.63^{bc}	79.05^{c}	0.06	54.17^{a}
0.75m × 0.5m * w	15.27^{e}	21.77	36.83^{b}	49.38^{c}	74.69^{b}	76.13^{b}	80.33	15.27^{e}	66.95^{b}	82.22^{b}	0.17	49.9^{b}
0.5m × 0.5m * w	16.31^{d}	20.83	36.36^{b}	41.95^{d}	72.31^{c}	75.68^{b}	80.31	16.31^{d}	69.22^{a}	85.53^{a}	0.03	45.87^{c}
1m × 0.5m * w/o	17.32^{a}	19.22	36.56^{b}	42.07^{d}	76.59^{a}	78.79^{a}	80.61	17.32^{a}	68.68^{a}	85.97^{a}	0.034	48.77^{b}
0.75m × 0.5m * w/o	16.34^{c}	18.4	35.46^{b}	51.59^{b}	73.33^{bc}	77.81^{a}	80.17	16.34^{c}	65.19^{c}	81.53^{b}	0.045	49.83^{b}
0.5m × 0.5m * w/o	16.59^{b}	19.55	35.51^{b}	51.74^{b}	74.14^{b}	78.20^{a}	80.88	16.59^{b}	65.89^{bc}	82.48^{b}	0.043	50.23^{b}
LC	19.48	30.41	53.93	71.00	74.12	76.75	78.38	19.49	57.09	76.58	0.12	55.57
SEM	0	0.40	0.63	0.78	0.82	0.89	5.24	0	0.446	0.447	0.139	0.363

$^{a, b}$ Means in a column within the same category having different superscripts differ (P<0.05); A= washing loss (rapidly soluble fraction); B = slowly degradable fraction; C = the rate of degradation; ED = Effective Degradability; CV = Coefficient of Variation; DMD = Dry Matter Degradability; hr = hour; LC = Lablab Composite; m = meter; PD = Potential Degradability; SEM = Standard Error of Means; w = with lablab; w/o = without lablab.

3.3.2. In sauce, organic matter degradability

Analysis of variance showed that there is a significant effect of spacing (P<0.05) on organic matter degradability (OMD) at 0, 12, 24, 48 and 72 hours of incubation time (Table 5). Intercropping had significant effect on OMD at 0, 12, 48 and 72 hours of incubation time (P<0.05). However, at 6, 24 and 96 hours of incubation time intercropping have no significant effect on OMD. Interaction of intercropping with spacing has no significant effect on the organic matter degradability at 6, 72 and 96 hours of incubation time (P>0.05). At 0, 12, 24 and 48 hours of incubation time interaction of intercropping with spacing have a significant effect on the ruminal organic matter degradability (P<0.05). Regarding the rumen OM degradability characteristics spacing has a significant effect for all parameters (P<0.05). Intercropping has also significant effect (P<0.05) on ruminal DM degradation characteristics. Lablab intercropping has no significant effect on both the rate of degradation and effective degradability of Napier grass (P>0.05). Interaction of intercropping with spacing has a significant effect on all rumen OM degradability characteristics (P<0.05). However, there was no consistent trend among the three spacing of the intercropped and non intercropped groups for the different OM degradability parameters.

Table 5

In sacco organic matter degradability and its rumen degradability characteristics as influenced by different spacing of Napier grass and intercropping with lablab.

	***In sacco* OMD and its rumen degradability characteristics**											
Treatments	**0hr**	**6hr**	**12hr**	**24hr**	**48hr**	**72hr**	**96hr**	**A**	**B**	**A + B (PD)**	**C**	**ED**
Spacing												
1m × 0.5m	10.71^{a}	12.38	37.08^{a}	43.94^{b}	72.48^{a}	76.72^{a}	78.00	10.71^{a}	69.86^{c}	80.57^{b}	0.048^{a}	46.78^{a}
0.75m × 0.5m	8.78^{b}	13.40	30.81^{b}	46.36^{a}	71.83^{a}	75.06^{b}	78.60	8.78^{b}	71.58^{b}	80.36^{b}	0.043^{ab}	45.67^{a}
0.5m x 0.5m	7.92^{c}	12.02	29.40^{b}	41.40^{c}	70.49^{b}	74.60^{b}	78.61	7.92^{c}	74.46^{a}	82.37^{a}	0.036^{b}	42.73^{b}
SEM	0.16	0.889	1.399	2.199	0.77	0.576	0.396	0.16	1.16	1.01	0.0038	0.95
Intercropping												
With Lablab	9.16^{a}	13.61	34.90^{a}	44.05	70.84^{b}	76.98^{a}	80.1	9.16^{a}	71.25^{b}	80.41^{b}	0.044	45.12
Without Lablab	9.12^{b}	15.59	29.96^{b}	43.76	72.36^{a}	78.27^{b}	80.55	9.12^{b}	72.68^{a}	81.79^{a}	0.04	45
SEM	0.41	0.644	1.387	1.99	0.633	0.492	0.33	0.41	1.13	0.97	0.0034	0.85
Interaction effect												

1m × 0.5m * w	11.28^{a}	12.67	43.11^{a}	50.84^{a}	70.4^{dc}	76.50	77.07	11.28^{a}	65.10^{d}	76.38^{c}	0.06^{a}	49.23^{a}
0.75m × 0.5m * w	8.65^{d}	15.66	31.90^{b}	45.43^{b}	72.71^{b}	74.27	78.80	8.65^{d}	72.18^{c}	80.83^{b}	0.041^{bc}	45.93^{b}
0.5m × 0.5m * w	7.54^{f}	12.51	29.69^{bc}	35.87^{c}	69.41^{d}	73.12	78.23	7.54^{f}	76.47^{a}	84.01^{a}	0.03^{d}	40.17^{c}
1m × 0.5m * w/o	10.14^{b}	12.10	31.05^{bc}	37.04^{c}	74.56^{a}	76.94	78.93	10.14^{b}	74.62^{b}	84.76^{a}	0.034^{dc}	44.30^{b}
0.75m × 0.5m * w/o	8.91^{c}	11.15	29.73^{bc}	47.29^{b}	70.96^{dc}	75.85	78.41	8.91^{c}	70.98^{c}	79.89^{b}	0.045^{b}	45.40^{b}
0.5m × 0.5m * w/o	8.29^{e}	11.54	29.10^{c}	46.94^{b}	71.56^{bc}	78.20	78.97	8.29^{e}	72.45^{c}	80.74^{b}	0.043^{bc}	45.30^{b}
LC	18.62	29.66	53.44	70.70	73.89	76.50	78.14	18.62	57.61	76.23	0.12	38.13
SEM	0	0.979	0.895	0.853	0.69	0.57	0.47	0	0.493	0.612	0.33	0.0024

[a, b] Means in a column within the same category having different superscripts differ (P<0.05); A= washing loss (rapidly soluble fraction); B = slowly degradable fraction; C = the rate of degradation; ED = Effective Degradability; hr = hour; LC = Lablab Composite; OMD = Organic Matter Degradability; m = meter; PD = Potential degradability; SEM = Standard Error of Means; w = with lablab; w/o = without lablab.

Appendix Table 6

Analysis of variance table for *in vitro* digestibility of different spacing of Napier grass influenced by intercropping with or without lablab.

In vitro		**IVDMD (%)**		**IVOMD (%)**		**ME (MJ kg $^{-1}$ DM)**	
digestibility	**DF**	**MS**	**Pr > F**	**MS**	**Pr > F**	**MS**	**Pr > F**
Spacing	2	8.57	0.4568	39.19	0.1299	3.16	0.1245
Intercropping	1	504.19	<.0001	227.50	0.0022	2.96	0.1542
S x I	2	5.11	0.6208	8.97	0.5955	0.55	0.6646
Error	15	10.38		16.71		1.32	
Total	23						

DF = Degree of Freedom; DM = Dry Matter; I = Intercropping; MS = Error Mean Square; IVDMD = *In vitro* Dry Matter digestibility; IVOMD = *In vitro* Organic Matter digestibility; kg = kilo gram; ME = Metabolizable energy; MJ = Mega Joule; Pr = Probability and S = Spacing.

4. Discussion

Electrical conductivity (EC) of the soil indicates the amount of salt in the soil. Pre planting soil analysis showed that the EC content was 0.19 which is salt free (Table 2) which agrees with that noted by Tekalign *et al*. (1991). The mean pH of the soil of the composite sample before planting was 7.66, which is almost similar to the pH value of 7.88 reported for Adami Tulu Agricultural Research Center (Teshome et al., 2012). The pH values noted in this study is in the range 4.5- 8.2 soil pH required by Napier grass (Center for New Crops and Plant Productivity, 2002). The available phosphorous was 6.2 which are considered as medium (Driven et al., 1973), while the organic carbon and total nitrogen content of the area before planting was 4.06 and 0.19, respectively indicating the soil to be rich in organic carbon and total nitrogen (Driven et al., 1973; Tekalign et al., 1991). However, the current result fail to agree with that reported by Teshome et al. (2012), which classifies the soil of Adami Tulu Research Center as being low in total nitrogen and organic carbon contents.

Analysis of variance for soil parameters after harvesting the forage indicates that the EC of the soil slightly increased as compared to the value obtained for the soil samples before planting.The values for EC in the current study are indicative of the soil to be salt free (Takalign et al., 1991). This is in agreement with the report of Kabirizi et al. (2007) that noted lablab intercropping increases phosphorus and calcium content of the soil as compared to mono crop. The pH of the soil after harvest was a bit higher as compared to the values before planting. This is because of environmental factor like rainfall, flood and effect of the planting material itself. The available phosphorous (AP) for soil samples after harvest was somewhat lower than the ones before planting. Such values for AP are categorized as low (Driven et al., 1973). This shows that there was more utilization of phosphorous by the grass and/or legume planted. However, the increase in AP with intercropping was lower than the amount of P extracted by the plants as the values for AP for before planting soil samples were higher than the values after harvest and with intercropping, since intercropping facilitate the utilization of phosphorous (Teshome et al., 2012). The organic carbon content of the soil was lower for soil samples taken after harvest as compared to the pre-planting soil samples. But according to the Netherlands Commissioned Ministry of Agriculture and Fisheries (1985) all soil of the study area can be classified in the high organic carbon range of availability. All soil samples are considered medium in their organic carbon content (Driven et al., 1973). Total nitrogen content of the soil increased slightly after harvest compared to pre-planting values. In terms of total nitrogen, the soil samples in this

study can be classified as rich except for the soil samples in the 0.5m x 0.5m spacing which is categorized under the medium category (Driven et al., 1973). However, according to the Netherlands commissioned by the Ministry of Agriculture and Fisheries (1985) all soil samples fall under medium category.

The result noted by Tesema (2000) for IVDMD of Napier grass planted with spacing of 1m x 0.5 and harvested at 90 days were 65.05%, which are lower than the mean result (69.9%) for the present finding. On the other hand, the IVOMD value for 0.5 m x 0.5 spacing of sole Napier and with lablab intercropping of 53.16% and 59.62%, respectively reported in this study was lower than the 62.54% and 67.96% noted by Taye et al. (2007) at ninety days of harvesting. Such variation could be associated to various environmental and edaphic factors, and the level of fertilization employed. The IVDMD value of Napier grass of the current study was higher than the digestibility of tropical grasses which lies between 50 to 60% (Own and Jaysuria, 1989). Napier grass intercropped with lablab had higher IVDMD and IVOMD (Table 3). This is in line with the finding of Njoka et al. (2006) which noted that Napier grass intercropped with Seca stylo was significantly more digestible than the sole Napier grass. This is partly because while intercropping the grass with lablab there is an increase in crude protein and decrease in ADF and ADL, which increases the IVDMD of the Napier grass (Tesema, 2000; Njoka et al., 2006). Contrary to spacing, intercropping with lablab has significant effect on the IVOMD which may be due to the influence of accumulation of cell components due intercropping. This result agrees with the finding of Taye et al. (2007) which noted that intercropping results in significantly higher values of IVOMD than sole Napier grass. The IVOMD values of all the treatments are above the critical threshold level of 50% required for feeds to be considered as having acceptable digestibility (Owen and Jayasuriya, 1989). The extent of digestion of Napier grass when intercropped with lablab was greater than for sole Napier grass and this is in line with that noted by Nijoka et al. (2006) that legumes in association with grasses positively influence digestibility of the grass probably due to increased N level from legume. The increase in digestibility also will lead to increased feed intake as digestibility and feed intake are positively correlated (Van Soest, 1982). Metabolizable energy for all spacing, intercropping and interaction of intercropping with spacing is higher than the critical threshold level of 7.5 (MJ kg^{-1} DM) for roughages and forages as noted by Owen and Jayasuriya (1989). The IVOMD of composite sample of lablab from the intercropped forages which was 66.3% in this study was higher than that of the 63.42% IVOMD value noted for sole lablab (Taye et al., 2007). Lablab composite has IVOMD which is above the minimum value of 65% to qualify forages to be of high nutritive value and was above the critical threshold level of 50% required for feeds to be considered as having acceptable digestibility Owen and Jayasuriya, (1989).

Most of the time 48 hours of incubation time is considered as perfect measurement of *in sacco* DM degradability since most feeds are staying in the animal digestive system for this hour. In this case 1m x 0.5m spacing had higher *in sacco* DM degradability at 48 hour of incubation time. But the general trend appears that DM degradability increases with increasing spacing. Dry matter degradability at 6, 12 and 72 hours were higher for lablab intercropping, while the reverse happened 48 hours incubation time and its washing loss. The DM degradability due to intercropping observed in this study is in line with that noted by Njoka et al. (2006) that legumes had significant effect on degradability of Napier grass. The higher degradability may be linked to the greater CP content due to intercropping which provides more N for microbial utilization. The 1m x 0.5m with lablab intercropping has the highest DM degradability at 12, 24 and 72 hours of incubation. The lowest degradability for 24h was for 0.5m x 0.5m with lablab intercropping. The lower dry matter degradability could be attributed to increased fiber content which contributes to a decrease of degradability of cell wall constituents (Tesema, 2000). Spacing 0.5m x 0.5m has significantly higher washing loss; slowly degradable fraction and potential degradability. The rate of degradation was similar among spacing, while effective degradability was lower for 0.5 m x 0.5m as compared to the other spacing. Intercropping has also significant effect ($P<0.05$) on ruminal DM degradation characteristics. Washing loss and potential degradability was lower and the slowly degradable fraction was higher for the Napier grass intercropped with lablab as compared to the one not intercropped with lablab. Intercropping has no significant effect on rate of degradation and effective degradability. This disagrees with Nijoka et al. (2006), which noted that effective degradability was significantly higher in the intercropped Napier grass than the sole Napier grass, and differences between treatments for potential degradability and rate of degradation were small.

The 1m x 0.5m without lablab intercropping has the highest washing loss, the reason of which is not apparent, slowly degradable fraction and potential degradability. However, 1m x 0.5m with lablab intercropping has the lowest value for washing loss, slowly degradable fraction and potential degradability. The slowly degradable fraction (B) and potential degradability of Napier grass harvested at 0.5m x 0.5m of this finding was higher and the effective degradability value was lower than that noted by Kariuki (1998) and Tesema et al. (2002b).

The variation might be due to species of animal used for incubation, ration fed to the fistulated animals, and the change in environmental factors during the growth of Napier grass. The DMD degradability of lablab composite was higher than all the treatments at 0, 12, 24, 48, and 72 and 96 hours which indirectly increases the degradability of the grasses which are intercropped with it due to the possible additive effect of intercropping on the degradability of the forage.

In most incubation hours as spacing increases degradability also increases. Similar trend has been observed as *in sacco* DMD at 48 hours of incubation which 1m x 0.5m spacing has highly significant for *in sacco* OMD. The intercropped one being higher in OM degradability at 12 and 72 hours, while the non intercropped one has higher degradability at 48 hours of incubation time. This disagrees with Nijoka et al. (2006) which noted that OMD at 48 hours of incubation was significantly higher for intercropped Napier grass than sole Napier grass. At 12 and 24 hours of incubation time 1m x 0.5m with or without lablab intercropping have the highest value. At 12 hours 0.5m x 0.5m without lablab intercropping has lowest degradability. Generally this is in line with the suggestion that organic matter degradability varies with the proportion of cell contents and cell wall constituents (Minson, 1990).

The 0.5m x 0.5m has the lowest washing loss (rapidly soluble fraction), rate of degradation and effective degradability, but has the highest slowly degradable fraction and potential degradability. Washing loss for the intercropped Napier grass was higher but slowly degradable fraction and potential degradability were lower for intercropped Napier grass. Lablab composite has higher OMD than all the treatments at 12, 24, 48, and 72 and 96 hours which can have a positive effect in increasing the degradability of the grasses which are intercropped with them. This is supported by the finding of Nijoka et al. (2006) that reported that Napier grass intercropped with legumes is more degradable than sole Napier grass. Generally the feeding value of the forages and extent of forage degradation is constrained by amount of fiber content (NDF) (Van Soast, 1994).

5. Conclusion

All of the soil parameters were not affected (P>0.05) by plant spacing and interaction of intercropping with spacing except TN which is significant for spacing. Intercropping decreased the EC but increases the AP content of the soil. The AP and OC content of the soil after harvest were lower than the original soil sample taken before planting. The IVDMD and IVOMD of Napier grass was increased by intercropping it with lablab. However, spacing and interaction of spacing with intercropping did not significantly affect the IVDMD and IVOMD content of Napier grass. *In sacco* degradability of DM of Napier grass for many of the incubation hours including 48 hours was relatively higher for the 1m x 0.5m spacing and for the one intercropped with lablab. Similar trend appears to be apparent for the *in sacco* degradability of OM of Napier grass. The DM and OM *in sacco* degradability characteristics were almost all affected by spacing and intercropping but without an apparent consistent trend. Generally, intercropping with lablab had a positive influence on the soil fertility, the nutritive value of Napier grass through enhancing IVDMD and IVOMD. Conversely, spacing failed to have significant impact on forage yield, chemical composition and IVDMD and IVOMD of Napier grass. However, 1m x 0.5m spacing appeared to have better effect on the *in sacco* degradability of DM and OM. As such this spacing and intercropping can be of a better choice based on the results of this study.

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