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The Effect of Intercropping of Lablab (*Lablab purpureus* L.) and Cowpea (*Vigna unguiculata* L.) at Different Planting Densities on *in vitro* and *in sacco* Dry Matter Digestibility of Napier Grass (*Pennisetum purpureum*)

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ABSTRACT

Background: The advantage of intercropping is the more efficient utilization of the all available resources and the increased productivity compared with each sole crop of the mixture. If cowpea and Lablab intercropping with Napier grass its nutritional values was improved.

Methods: The experimental design was factorial combination arrangement in randomized complete block design with three inter and intra spaces (1 m × 0.5 m, 0.75 m × 0.5 m, 0.5 m × 0.5 m) and intercropping with two tropical legumes. Treatments were T1= Pure Napier grass at 1 m row spacing, T2= Napier grass intercropped with lablab at 0.75 m row spacing, T3= Napier grass intercropped with cowpea at 0.5 m row spacing, T4= Napier grass intercropped with cowpea at 1 m row spacing, T5= Napier grass intercropped with lablab at 0.5 m row spacing, T6= Pure Napier grass at 0.75 m row spacing, T7= Napier grass intercropped with lablab at 1 m row spacing, T8= Napier grass intercropped with cowpea at 0.75 m row spacing, T9= Pure Napier grass at 0.5 m row spacing and totally nine treatments were used. Soil samples were collected before and after forage harvested.

Result: Napier grass intercropped with lablab and cowpea at different planting densities had significant effect (P<0.05) on the *in vitro* dry and organic matter digestibility (IVDMD, IVOMD) and increased digestibility. The OM degradation constant was significantly different (P<0.05) but 'ED' was not and for DM degradation 'c' and 'b' were non-significant (P>0.05) for Napier grass intercropped with lablab and cowpea at different planting densities. In conclusion, Napier grass intercropped with lablab and cowpea at a planting density of 24 plants m^{-2} was better choice for high yield and forage quality.

Key words: Cowpea, Lablab, Intercropping, Napier grass, Nutritive qualities, Dry matter and organic matter digestibility, *In vitro, In saco.*

INTRODUCTION

The principal advantage of intercropping is the more efficient utilization of the all available resources and the increased productivity compared with each sole crop of the mixture (Willey, 1979; Mucheru-Muna *et al.,* 2010). Yield advantage occurs because growth resources such as light, water and nutrients are more efficiently absorbed and converted into crop biomass by the intercropping over time and space as a result of differences in competitive ability for growth resources between the component crops which exploit the variation of the mixed crops in characteristics such as rates of canopy development final canopy size (width and height) photosynthetic adaptation of canopies to irradiate conditions and rooting depth (Tsubo *et al.*, 2001; Midmore, 1993).

Integration of legumes into forage production systems help smallholder farmers to produce more biomass forage and increase fodder production in quality and quantity which contributes to livestock directly (Tadesse *et al.*, 2012). The reason of yield advantage of intercropping are mainly that environmental resources such as water, light and nutrients can be utilized more efficiently in intercropping than in the respective sole cropping systems (Liu *et al.,* 2006). Therefore, the use of grass-legume forage intercropping helps to increase productivity of land and livestock feedstuffs.

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Napier grass is a perennial C4 grass species that is native to Sub-Saharan Africa from where it is believed to have been distributed to other tropical and subtropical regions around to world (Harris *et al.,* 2010; Kandel *et al.*, 2016). It has been reported to be adapted a wide range of soil conditions and agro-ecologies, from sea level to 2500 meters and it can offer strong resistance to dry spells, although it grows best in areas where the annual rainfall is between 750 and 2500 mm (Singh *et al.*, 2013). It is a tall, stout and deep-rooted perennial bunch grass well known for its high yielding capability and mainly used for cut-and-carry feeding systems for livestock (Woodard and Prine, 1991; FAO, 2015).

The yield and nutritional values of Napier grass mainly depends on the type of cultivar used which in turn is influenced by both the environment and management practices employed (Oliveira *et al.,* 2014). Napier grass yield has been reported around 60 tons/ha/year (Rengsirikul *et al.,* 2013) and about 10 tons/ha/one cut cycle of DM (ILRI, 2010b). The nutritional value and other nutritional qualities of Napier grass have been reported across different studies and show significant variation in dry matter production (DM), crude protein (CP), neutral detergent fiber (NDF) and acid detergent fiber (ADF). However on average, Napier grass is considered to contain 9% CP, 20% DM, 70% NDF, 50% ADF, 9% ash and 6% lignin in samples taken from 10–15 week old plants (Islam *et al.,* 2003; Gwayumba *et al.*, 2002).

Lablab is an ancient crop and has been documented by archaeo-botanical finds in India prior to 1500 BC (Fuller, 2003). Lablab (*Lablab* purpureus), formerly Dolichos lablab, also called Hyacinth bean, Egyptian bean and Fuji mame (in Japan) is a popular legume vegetable in Southern Asia, China, Japan, West Africa and the Caribbean (Valenzuela and Smith, 2002b). Furthermore, Morris, (2009) reviewed its bio-functional properties for use as pharmaceutical or nutraceutica.

Lablab is drought hardy and has been grown in arid, semi-arid and humid regions with rainfalls between 200 and 2500 mm (Hendricksen and Minson, 1985). It needs rainfall or irrigation (minimum of 10 to 20 mm) during germination and early establishment, although once established it is extremely resistant to drought (Mayer *et al*., 1986). Being a hardy plant, lablab can be found throughout the tropics and subtropics; ranging from 30° south to 30° North Latitude. It is normally grown from sea level up to elevations ranging between 1800 and 2100 meters (Hendricksen and Minson, 1985; Mayer *et al*., 1986).

Similarly, cow pea plays an important nutritional role in the sub-Saharan areas because of high protein content in its grains and leaves (Pasquet and Fotso, 1994). Because of its superior nutritional attributes, versatility, adaptability and productivity cowpea was chosen by the United State National Aeronautical and Space Administration (NASA) as one of few crops worthy of study for cultivation in space stations (Ehlers and Hall, 1997). Grasses-legumes intercropping of Napier grass with legumes species improve the nutritive value of Napier grass (Mohammeda *et al*., 2016). However, there is a controversial idea about the planting densities on the biomass yield and nutritional value of Napier grass in different parts of the country.

Benefits of growing grass and legumes as mixed fodder crop are to maximize yield and quality in forage production (Yisehak, 2008). Mixed cropping especially with legumes can improve both forage quality and yield because legumes are good source of protein (Zhu *et al*., 2001). Furthermore, intercropping legumes with grasses significantly reduced neutral detergent fiber and acid detergent fiber content and increase digestibility of the forage.

Legumes have higher protein content than grasses and as a result the protein requirements of growing animals can be met to a large degree by adequate legumes in the forage mix. Legesse *et al.,* 2012 found that alfalfa mixture with grass pasture contained more crude protein, compared to grass pasture. The DM yields of both the binary and ternary legume-grass mixtures were greater than the yield of any grass under mono-culture (Albayrak and Türk, 2013).

Significant effects of Napier Grass/ Lablab associations and their interactions were observed on crude protein yield (CPY), *in vitro* organic matter digestibility (IVOMD), content of CP, neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), ash and hemicelluloses (Bayble *et al.,* 2007). Association of Napier grass with Lablab species generally improved the nutritive value of Napier grass (Bayble *et al.,* 2007). Therefore, to this effect Napier grass may get additional nutritive value from intercropping with Lablab. These indicated the possibility of improving the feeding of animals in tropical regions by planting Napier grass which is reputed for its high biomass yield along with lablab, thus enhancing the quality of nutrients supplied to animals (Bayble *et al.,* 2007).

Intercropping of Napier grass with legumes species generally improve the nutritive value of Napier grass (Bayble *et al*., 2007). These indicated the possibility of improving the feeding of animals in tropical regions by planting Napier grass, which is reputed for its high biomass yield along with legumes such as cowpea and lablab, thus enhancing the quality of nutrients supplied to animals (Bayble *et al.,* 2007). Plant densities or pattern intercropping has significant effect on dry matter production of the Napier grass.

Considering the above merits of Napier grass, lablab and cow pea intercropping evaluating the effect of these two forage legumes on the nutritive value of Napier grass will be of great importance. Information on the management practices and cropping system that influence yield quantity and nutritive quality of Napier grass when intercropped with lablab and cowpea at different planting densities was not well practiced in Ethiopia country (Mohammeda *et al*, 2016). Therefore the current study was being carried out with the objectives to determine the effect of inter-cropping lablab and cow pea on the nutritional qualities of Napier grass.

MATERIALS AND METHODS

Description of the study area

The study was conducted at Haro Sabu Agricultural Research Center during the main cropping season (Fig 1). The center is located in western Ethiopia at 550 km from Addis Ababa. It lies at latitude of 8°52′51″ N and longitude 35°13′18″ E and altitude of 1515 m.a.s.l. It has a warm humid climate with average minimum and maximum temperature of 14 and 30°C respectively (HSARC, 2012). The area receives average annual rainfall of 1000 mm and its distribution pattern is uni-modal (HSARC, 2012) Table 1. The main rainy season covers from April to October. The soil type of the experimental site was vertisol with sandy loam in texture(Abebe, 2007). The area is characterized by coffee based farming and crop-livestock mixed farming system (HSARC, 2012).

Experimental layout, design and treatments

The experimental design was factorial combination arrangement in RCBD with three blocks consisting of three levels of inter and intra row spacing of Napier grass (ILRI 16840 accession) *i.e.* 0.5 m × 0.5 m, 0.75 m × 0.5 m and 1 m × 0.5 m intercropping with two tropical forage legumes of cowpea (*Vigna unguiculata* L.) Bole variety and Lablab (*Lablab purpureus* L.) 14455 accession between the rows of Napier grass and totally nine treatments were used (Table 2).

Total area of land 525 m^2 (35 m × 15 m) was selected and thoroughly prepared for sowing. The land was ploughed and harrowed with a tractor and then hoe to make the soil fine. The land was divided in to three blocks and each of them has contained nine treatments. The plot size was 12 m^2

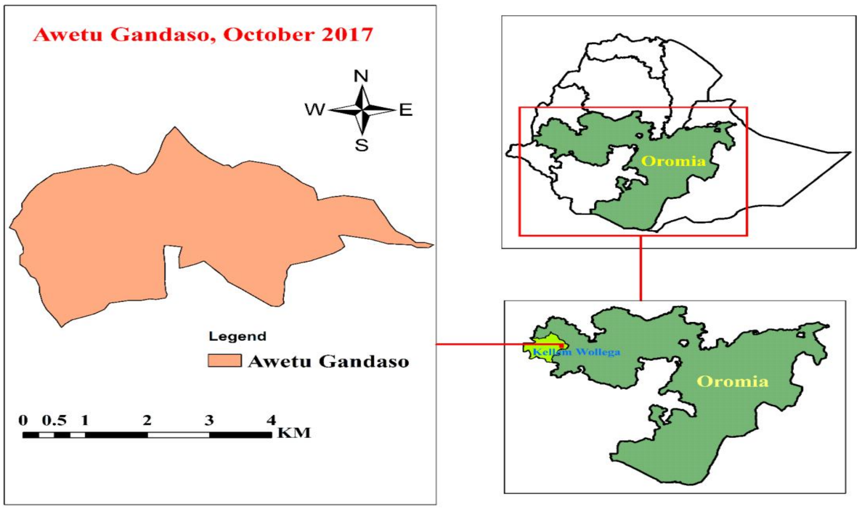

Fig 1: Map of the purposed study area.

Table 1: Agro-metrological data of the study area during 2017 at Haro Sabu Agricultural Research Center, Oromia, Ethiopia.

Description	Months of the year 2017											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
RF (mm)	0.0	17.6	16.2	158.2	248.7	180.1	291.5	307.1	223.2	117.8	33.1	0.4
T°C (Max.)	33.0	32.9	Xx	Xx	27.4	27.2	24.6	25.2	26.1	26.7	27.3	29.7
T°C (Min.)	Xx	8.8	14.5	15.7	14.6	11.6	11.4	11.3	11.2	10.9	10.5	10.3
RH (%)	37.2	54.5	45.3	58.3	66.9	69.0	77.2	73.8	74.7	77.5	72.7	53.7

Remarks: Max.= Maximum; Min.= Minimum; mm= Millimeter; RF= mean rain fall; RH= Relative humidity; T°C = Mean temperature in degree celsius; xx= Data not available. Source: Asosa Meteorological Agency (2017).

Table 2: Row spacing, plant spacing and intra row structure of the Napier grass during the experimental periods.

Treatments	Row spacing (m)	Intercropped materials	Area/plant (m^2)	No. Napier grass/plot
T1	1	-	0.5	24
T2	0.75	Lablab	0.375	32
T3	0.5	Cowpea	0.25	40
T4	1	Cowpea	0.5	24
T5	0.5	Lablab	0.25	40
T6	0.75	-	0.375	32
T7	1	Lablab	0.5	24
T8	0.75	Cowpea	0.375	32
T9	0.5	-	0.25	40

Where, T1= Pure Napier grass at 1m row spacing; T2= Napier grass intercropped with lablab at 0.75 m row spacing; T3= Napier grass intercropped with cowpea at 0.5m row spacing; T4= Napier grass intercropped with cowpea at 1 m row spacing; T5= Napier grass intercropped with lablab at 0.5m row spacing; T6= Pure Napier grass at 0.75 m row spacing; T7= Napier grass intercropped with lablab at 1m row spacing; T8= Napier grass intercropped with cowpea at 0.75m row spacing; T9= Pure Napier grass at 0.5m row spacing.

(4 m × 3 m) and spacing between plot and between blocks was 1m and 1.5m respectively. Treatments were assigned to each plot within a block by SAS 9.3 version generated randomization code to each plot.

The Napier grass ILRI 16840 (*Pennisetum purpureum*) which was used as a parent plant material was cut into stems with a minimum of three nodes per cut for planting and was planted 15-20 cm deep at angle of about 30°-45° (Ansah *et al*., 2010) and the seed of *V. unguiculata* was drilled in between the rows of Napier grass at a seeding rate of 10 kg/ha (Mullen *et al*., 2003) and *L. purpureus* was drilled in between the rows of Napier grass at a seeding rate of 8 kg/ ha in 7-10 cm depth (ILRI, 2010b). Fertilizer was applied at the rate of 100 kg ha^{-1} DAP during establishment for all experimental units. Weeding was done as early as possible to eliminate re-growth of undesirable plants and in order to promote fodder grass growth by increasing soil aeration the plots was kept weed free throughout growth period (Orodho, 2006). The field experiment was done for three months (90 days) at Haro Sabu Agricultural research center field experimental station. Then after *in vitro* and *in sacco* dry matter was done at Holeta Agricultural research center animal feed analytical laboratory for three months.

Data collected

***In vitro* dry matter digestibility**

Chemical analysis was used performed on all for samples used *in vitro* dry matter digestibility (IVDMD). The two-stage rumen inoculates pepsin method of Tilley and Terry (1963) was used to determine IVDMD. Rumen liquor was collected from three rumen fistulated steers and transported to the laboratory using thermos flask that have been pre-warmed to 39°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°C for a period of 48 h for microbial digestion followed by another 48 h for enzyme digestion with acid pepsin solution. Blank samples containing buffered rumen fluid were incubated in duplicates for adjustment. Drying of samples residues were done at 105°C for 24 h. The samples were then ashed to estimate IVOMD. An IVOMD analysis was carried out at Holeta Agricultural research center animal feed analytical laboratory.

Metabolisable energy (ME) was calculated from IVOMD using the equation: ME (MJ kg^{-1} DM) = 0.15*IVOMD (Pinkrton, 2005).

***In sacco* digestibility**

In Sacco digestibility was carried out at Holeta Agricultural Research Center Animal Nutrition Analytical Laboratory. Composite samples of Napier grass for each treatment were taken and dried in a forced draft oven at 60°C for 72 h. Samples were ground and passed through a 2 mm screen (mesh) using Wiley mill for *in Sacco* digestibility.

A numbered Nylon bag with 6.5×14 cm^2 dimension with a pore size of 41 mm was taken into an oven and dried at 60-65°C for 30 minutes. Contented was weighed immediately or after allowing to cool to room temperature in a desiccators and 3.0 g of dried forage samples were tightly packed using nylon string which is resistant to rumen micro-organisms and then taking in three rumen fistulated steers for 0, 6, 12, 24, 48, 72 and 96 h. Each feed sample was incubated in duplicate in the three steers for any one incubation time. At the end of each incubation hours, all the bags (including the zero hour samples) were immediately washed with cold water for about 30 minutes under running tap water while rubbing gently between thumb and fingers until the water runs clear and then the washed bags were dried in an oven at 60-65°C for about 48 hours. Duplicate bags of each sample were washed without incubating in the rumen in order to determine the washing loss. The dried bags were then taken out of the oven and allowed to cool down in desiccators and weigh immediately.

The digestibility or Disappearance of DM (DMD) and OM (OMD) of each incubation time were determined as (AOAC, 1990).

$$\text{Disappearance} = \frac{(SWa - BW) \times DMa - (SWb - BW) \times DMb}{(SWa - BW) \times DMa}$$

Where,

SWa = Weight of the original sample + nylon bag.

BW = Weight of empty nylon bag.

DMa = Dry matter of feed sample.

DMb = Dry matter of residue sample.

SWb = Weight of the sample + nylon bag after incubation.

The DMD and OMD values at various times of incubation are 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 *et al.* (1981) using the Neway Excel programme(Chen, 1995). The potential degradability (PD) was estimated as

$$PD = a + b$$

whereas 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 for grass rumen out flow rate (k). Where a, b and c are as described above and k = passage rate.

Statistical analysis

Data were subjected to ANOVA procedure by using SAS software version 9.3 (Littell *et al*., 2002). Significant means were separated and compared using Least Significant Difference (LSD) test at 5% significant level. The analysis of variance model for the *in Sacco* degradability parameters were

$$Y_{ij} = \mu + T_i + A_i + e_{ij}$$

Where,

Yij = individual observation.

μ = overall mean.
Ti = Treatment effect.
Ai = Animal effect.
Eij = residual error.

RESULTS AND DISCUSSION

In vitro digestibility

In vitro dry matter digestibility

Napier grass at different planting densities intercropped with lablab and cowpea had significant effect (P<0.05) on the *in vitro* dry matter digestibility (IVDMD) (Table 3). Napier grass intercropped with lablab (T7) and cowpea (T4) at spacing of 1 m × 0.5 m has highest IVDMD with the mean result of (64.85±1.99%) and (66.92±0.66%) value, respectively while other mean comparisons were not significant (P>0.05). On the other hand, sole Napier grass planted at plant spacing of 0.5m × 0.5m (T9) had the lowest value of the IVDMD and IVDMD increased with wider spaces of Napier grass in the sole and intercropped at three different planting densities. The result noted by Bayble *et al*. (2007) for IVDMD of Napier grass at spacing of 1 m × 0.5 m intercropped with lablab harvested at 90 days was (68%) and it was higher than the mean result (64.85±1.99%) for Napier grass at 1m × 0.5m space intercropped with lablab of the present finding. Such variation could be associated with various factors like rain, humidity, light and temperature, soil fertility and other management practices have an influence on IVDMD of Napier grass (Assefa and Ledin, 2001).

The nutritive value of forages like voluntary feed intake, crude protein and structural carbohydrates and the digestibility of the grass could be improved when inclusion of associated legume with grass (Demissie Negash *et al.,* 2017). Grass associated with legume inclusion might increase feed intake as the IVDMD and feed intake are positively correlated (Van Soest, 1994). The IVDMD value of Napier grass with different space intercropping by lablab and cowpea of the current study fits the digestibility of tropical grasses which lies between 50 to 60% (Owen and Jayasuriya, 1989).

In vitro organic matter digestibility

The effect of intercropping of Napier grass with lablab and cowpea at different plating densities on IVOMD was significant (P<0.05). This is in line with the finding of (Mohammeda *et al*, 2016) who noted that Napier grass intercropped with lablab with different spaces or planting densities had significantly (P<0.05) higher values of IVOMD than sole Napier grass. Mixing of Napier grass with lablab and cowpea improved the IVOMD of the Napier grass indicating that the feeding value of Napier grass can be enhanced in terms of nutrient content and digestibility. The IVOMD values of all the treatments were above the critical threshold level of 50% required for feeds to be considered as having acceptable digestibility (Owen and Jayasuriya, 1989).

The forages below this level of IVOMD content may result in reduced feed intake due to lower nutrient content and digestibility. The highest IVOMD value (63.73%±0.98) was recorded with Napier grass intercropped with lablab (T7) at 1 m × 0.5 m space and the lowest value (52.58±0.65%) was recorded from sole Napier grass planted at 0.5 m × 0.5 m space without intercropped with legumes (T9) which was lower than the 67.96% noted by (Bayble

Table 3: Least square means and standard errors for *In vitro* dry matter (IVDMD), organic matter digestibility (IVOMD) and ME content of Napier grass.

Treatments	IVDMD and IVOMD percentage values (%)		
	IVDMD (%)	IVOMD (%)	ME (MJ/kg)
T1	55.75±1.74^{b}	56.86±2.29^{cd}	8.53±0.34^{cd}
T2	57.64±1.06^{b}	58.20±1.58^{bcd}	8.73±0.23^{bcd}
T3	55.82±1.17^{b}	62.22±0.82^{ab}	9.33±0.12$^{a\ b}$
T4	66.92±0.66^{a}	60.70±1.28^{abc}	9.33±0.19^{ab}
T5	54.26±2.01^{b}	60.39±0.58^{abcd}	9.06±0.08^{abcd}
T6	53.99±0.90^{b}	57.69±1.66^{cd}	8.65±0.25^{cd}
T7	64.85±1.99^{a}	63.73±0.98^{a}	9.56±0.14^{a}
T8	56.77±1.54^{b}	56.35±2.16^{de}	8.45±0.32^{de}
T9	53.03±1.87^{b}	52.58±0.65^{e}	7.88±0.09^{e}
Mean	57.67	58.75	8.81
P –value	<.0001	0.0012	0.0012

$^{a, b, c, d, e}$ Means in a columns, values followed by different letters differ significantly (P < 0.05); T1= Pure Napier grass at 1m row spacing, T2= Napier grass intercropped with lablab at 0.75m row spacing, T3= Napier grass intercropped with cowpea at 0.5m row spacing, T4= Napier grass intercropped with cowpea at 1m row spacing, T5= Napier grass intercropped with lablab at 0.5m row spacing, T6= Pure Napier grass at 0.75m row spacing, T7= Napier grass intercropped with lablab at 1m row spacing, T8= Napier grass intercropped with cowpea at 0.75m row spacing, T9= Pure Napier grass at 0.5m row spacing, IVDMD = *In vitro* dry matter digestibility*, IVOMD = In vitro* organic matter digestibility, kg = kilo gram, ME = Metabolizable Energy, MJ = MegaJoul.

et al., 2007) at ninety days of harvesting. Such variation might be due to a number of factors like climate, season, weather, soil type and fertility, soil moisture, physiological and morphological characteristics and these factors may vary with annuals versus perennials, grasses versus legumes, *etc.*(Kilcher, 1981). These factors bring rate of change in nutrient composition and digestibility with advancing plant development and maturity stages. Generally, IVOMD increased at wider spaces of Napier grass planted with lablab and cowpea than in the sole Napier grass planted.

Metabolizable energy

Since the ME was calculated from IVOMD values in this study, the ME content took a similar trend like that of IVOMD and generally increased with increasing proportion of legumes in the mixture. Metabolizable energy of all treatments were above the critical threshold level of 7.5 (MJ kg^{-1} DM) for roughages and forages as noted by Owen and Jayasuriya (1989).

***In sacco* digestibility**

***In sacco* DM disappearances and rumen degradability characteristics**

Analysis of variance show that there was a significant effect (P<0.05) of Napier grass intercropping with lablab and cowpea at different planting densities on the *in sacco* dry matter disappearances (INDMD) at 12 and 72 h of incubation time (Table 4). Across all incubation periods (Table 4) there was similar trend in variation of the incubation hours between Napier grass intercropped with two legumes and Napier grass planted alone at different planting densities. Napier grass intercropped with lablab at 1 m × 0.5 m spaces (T7) had higher disappearance percent value when compared with Napier grass grown alone at the same space (T6) and similar trend with Napier grass intercropped with lablab at 0.5 m × 0.5 m (T5) was quick degraded than Napier grass grown alone at the same space (T9) at 12, 96 and 48 h of incubation respectively. Napier grass intercropped with lablab with 0.75 m × 0.5 m (T2) had quick disappearance than Napier grass grown alone with the same space (T6) at 48 h of incubation. This was in agreement with (Mohammeda *et al.*, 2016) who noted that Interaction of intercropping and spacing has a significant effect on *in sacco* DM disappearance at 12 and 48 h of incubation times (P<0.05). Generally the DM disappearance was higher in Napier grass intercropped with lablab than alone.

Napier grass intercropping with cowpea (*i.e.* T3, T4 and T8) at three different planting densities had disappearance more than Napier grass grown alone at the same planting densities (*i.e.* T1, T6 and T9) at 72 h of incubation. *In sacco* DM recorded at 48 hours incubation period was highest in Napier grass intercropping with lablab and cowpea and the lowest value was recorded in Napier grass planted alone at three planting densities because 48 hours of incubation time is considered as good measurement of *in sacco* DM disappearance in the animal digestive system. Generally, from 12 to 96 h of incubation, the *in sacco* DM disappearance also increased. This is similar to the result reported by (Klopfenstein *et al.*, 2001a) who reported that *in sacco* DM disappearance increase with time incubation hours.

In general, effect of intercropping Napier grass with lablab and cowpea at different plants densities was significant for DM disappearances across the incubation time for 12 and 72 h incubation. The greatest DM disappearance at 12 h incubation was recorded in Napier grass intercropped with cowpea (T4) at 1 m × 0.5 m space (40.00±1.64%) followed by Napier grass intercropped with lablab (T5) at 0.5 m × 0.5 m space (38.09±1.75) and Napier grass intercropped with lablab (T7) at 1m × 0.5 m space

Table 4: Least square means and standard errors for *In sacco* DM disappearances of Napier grass.

Treatments	*In sacco* DM disappearances (%) at Rumen incubation time (hr)					
	6	12	24	48	72	96
T1	21.68±1.17	33.41±0.72[bc]	43.08±4.63	66.77±2.35	72.02±0.14[bcd]	82.77±0.47
T2	23.22±0.67	37.23±1.84[ab]	45.27±2.50	71.60±0.58	73.84±0.68[abc]	83.74±0.50
T3	23.50±1.10	37.87±0.47[ab]	43.34±0.26	68.16±2.43	71.68±0.71[cd]	85.04±1.17
T4	21.11±1.07	40.00±1.64[a]	43.93±0.74	70.87±1.78	72.96±0.86[abc]	84.40±0.90
T5	21.47±0.89	38.09±1.75[a]	45.35±0.61	72.03±1.57	72.30±1.25[bcd]	83.50±0.92
T6	20.98±0.66	32.37±1.80[c]	42.94±0.66	67.73±0.45	70.40±1.17[d]	81.81±0.44
T7	23.80±0.24	38.36±0.84[a]	46.13±1.07	70.61±0.71	74.88±1.066[a]	85.28±1.28
T8	22.99±1.58	36.50±1.77[abc]	44.42±0.70	69.05±1.02	74.16±1.28[ab]	84.26±0.24
T9	21.70±1.18	36.30±0.82[abc]	42.81±0.23	66.84±1.43	70.57±1.07[d]	82.82±1.38
Mean	22.27	36.68	44.14	69.29	72.54	83.74
P- value	0.387	0.051	0.855	0.144	0.005	0.160

[a, b c d] means in a columns, values followed by different letters differ significantly (P < 0.05), hr = hour; DM = dry matter, T1= Pure Napier grass at 1m row spacing, T2= Napier grass intercropped with lablab at 0.75m row spacing, T3= Napier grass intercropped with cowpea at 0.5m row spacing, T4= Napier grass intercropped with cowpea at 1m row spacing, T5= Napier grass intercropped with lablab at 0.5m row spacing, T6= Pure Napier grass at 0.75m row spacing, T7= Napier grass intercropped with lablab at 1m row spacing, T8= Napier grass intercropped with cowpea at 0.75m row spacing, T9= Pure Napier grass at 0.5m row spacing.

(38.36±0.84%), whereas the lowest DM disappearance at 12-hour incubation was recorded from Napier grass at 0.75 m × 0.5 m space without intercrop (T6) (32.37±1.80%) followed by Napier grass 1m × 0.5m space without intercrop (T1) (33.41±0.72%) and Napier grass with 0.5 m × 0.5 m space without intercrop (T9) (36.30±1.77%). Napier grass intercropped with lablab (T7) at 1 m × 0.5 m space showed the greatest DM disappearances at 72 and 96 h incubation in contrast to the rest of the treatments (P<0.05).

Yet at a 48-h incubation, the Napier grass intercropped with lablab (T5) at 0.5 m × 0.5 m space had the greatest DM disappearances (72.03±1.57%) followed by Napier grass intercropped with lablab (T2) at 0.75 m × 0.5 m space (71.60±0.58%) and the least value of DM disappearances of Napier grass at 1 m × 0.5 m spaces without intercropping (T1) (66.77±2.35%) and Napier grass at 0.5 m × 0.5 m space planted without intercropping (T9) (66.84±1.43%).

Generally, the highest *in Sacco* DMD was recorded at 96 h incubation period and the lowest value was obtained at 6 hours incubation period in all treatments in the present study. This is similar to the result reported by Klopfenstein *et al.* (2001b) who indicated that the period of incubation period increases from 0 to 96 hours in the rumen and the *in sacco* DM degradability also increases.

Analysis of variance showed that there was a significant effect (P<0.05) of Napier grass intercropped with lablab and cowpea at different planting densities on the Rumen DM disappearances characteristics of Napier grass at k= 0.03 per hour of rumen fractional outflow rates for all treatments except for the slowly degradable fraction and rate of degradation(*c*) (Table 5). The greatest washing loss (*a)* of Napier grass was recorded in Napier grass intercropped with cowpea and lablab (T4 and T7) at 1 m × 0.5 m space while the least value recorded was in the Napier grass planted at 1 m × 0.5 m space without intercropping (T1). For potential degradability (PD) the highest value was recorded in Napier grass intercropped with lablab (T7) at 1 m × 0.5 m space while in the Napier grass planted with 0.5 m × 0.5 m space without intercropping (T9) recorded the least value (P < 0.05).

The highest effective degradability (*ED*) value was recorded in Napier grass intercropped with lablab (T7) at 1 m × 0.5 m space followed Napier grass intercropped with cowpea (T4) at 1 m × 0.5 m space and the least value was recorded in Napier grass planted at 0.75m × 0.5 m space without legumes intercropping (T6). Napier grass intercropping with lablab has higher Rumen DM degradability characteristics when compared with Napier grass planted alone at different planting densities. This was in agreement with (Njoka-Njiru *et al.,* 2006a) who noted that washing loss and effective degradability were significantly higher in the intercropped Napier grass than the sole Napier grass. Napier grass intercropping with cowpea at three different planting densities was higher than Napier grass grown alone with the same space by rapid soluble fractions (wash losing).

In sacco OM disappearances and rumen degradability characteristics

Analysis of variance showed that there was a significant effect (P<0.05) of Napier grass intercropping with lablab and cowpea at different planting densities on *in sacco* organic matter disappearances (OMD) at 6, 48 and 96 h of incubation time but No significant differences (P>0.05) were observed at the rest of hours of incubation time (Table 6).

Napier grass intercropped with lablab at 0.75m × 0.5m spaces (T2) had the greatest OM disappearances when compared with Napier grass grown alone planted with the same space (T6) at 6 h incubation and Napier grass

Table 5: Least square means and standard errors for *In sacco* dry matter rumen degradability characteristics.

Treatments	Rumen degradability characteristics				
	a	B	PD (*a* + *b*)	*c*	ED (kp= 0.03)
T1	7.09±0.93^{f}	77.66±3.93	84.75±4.75^{ab}	0.0343±0.007	47.23±1.88^{bcd}
T2	10.56±0.31^{cd}	75.86±1.63	86.42±1.90^{ab}	0.0303±0.002	48.45±0.72^{ab}
T3	12.88±0.82^{b}	76.96±2.34	89.85±2.71^{ab}	0.0247±0.002	47.39±0.34^{abcd}
T4	14.42±0.23^{a}	75.23±1.49	89.64±1.31^{ab}	0.0251±0.001	48.57±0.91^{ab}
T5	11.26±0.44^{c}	74.94±1.01	86.20±0.56^{ab}	0.0290±0.000	48.07±0.56^{abc}
T6	8.59±0.41^{de}	76.43±1.69	85.03±1.29^{ab}	0.0277±0.001	45.26±0.44^{d}
T7	15.29±0.10^{a}	76.10±3.29	91.39±3.39^{a}	0.0248±0.002	49.42±0.22^{a}
T8	9.75±0.70^{de}	77.36±1.43	87.11±0.84^{ab}	0.0286±0.000	47.51±0.02^{abcd}
T9	8.36±0.16^{ef}	75.66±0.71	84.03±0.58^{b}	0.0294±0.001	45.85±0.56^{cd}
Mean	10.92	76.25	87.16	0.02824	47.50
P-value	<.0001	0.989	0.036	0.404	0.032

[a, b c d e f] Means in a columns, values followed by different letters differ significantly (P<0.05), a= washing loss (rapidly soluble fraction), b= slowly degradable fraction, c= the rate of degradation, ED= Effective Degradability, PD= Potential Degradability, T1= Pure Napier grass at 1 m row spacing, T2= Napier grass intercropped with lablab at 0.75 m row spacing, T3= Napier grass intercropped with cowpea at 0.5 m row spacing, T4= Napier grass intercropped with cowpea at 1 m row spacing, T5= Napier grass intercropped with lablab at 0.5 m row spacing, T6= Pure Napier grass at 0.75 m row spacing, T7= Napier grass intercropped with lablab at 1m row spacing, T8= Napier grass intercropped with cowpea at 0.75m row spacing, T9= Pure Napier grass at 0.5 m row spacing.

intercropped with lablab at 0.5m × 0.5 m (T5), Napier grass intercropped with lablab with 1m × 0.5 m (T7) showed similar OM disappearances value with Napier grass planted alone with the same space (T9) and (T1) at 6 h incubation.

Napier grass intercropped with lablab at different planting densities had no difference disappearance per cent value than Napier grass planted alone with the same space at 48 h incubation. This result disagrees with Mohammeda *et al.* (2016) who noted that interaction of intercropping and spacing had a significant effect on *in sacco* OM degradability at 48 h incubation times (P<0.05). Nevertheless, improvement in the *in sacco* OM disappearances of Napier grass with three different spaces intercropped with lablab were higher than Napier grass planted without intercropping.

Napier grass intercropped with cowpea (T3) at 0.5 m × 0.5 m space had higher degradability than Napier grass grown alone with the same space at 96 hours of incubation while decreased in the rest of an incubation hours. Napier grass intercropping with cowpea (T4) at 1 m × 0.5 m space had the higher disappearance percent than Napier grass grown alone with the same space at 96 h incubation 6 and 96 h incubation. Napier grass intercropping with cowpea (T8) at 0.75 m × 0.5 m space had the highest degradability than at 48 hrs and no difference has been observed the in

Table 6: Least square means and standard errors for *In sacco OM* disappearances for Napier grass.

Treatments	*In sacco* OM disappearances (%) at Rumen incubation time (hr)					
	6	12	24	48	72	96
T1	21.24±0.67[bcd]	32.18±1.09[a]	41.79±1.64	68.30±2.08[ab]	74.21±1.32	76.00±0.3[d]
T2	23.74±0.58[a]	29.53±1.29[ab]	42.61±1.54	69.03±1.22[ab]	73.65±2.46	78.98±0.9[aBc]
T3	22.74±0.56[ab]	28.19±0.68[b]	37.93±0.18	67.77±1.31[ab]	76.46±0.85	79.36±0.42[ab]
T4	23.65±1.18[a]	29.64±0.80[ab]	40.41±2.44	70.45±2.76[ab]	74.91±0.11	80.07±0.18[a]
T5	22.39±0.17[abc]	29.09±1.98[b]	41.46±2.58	71.51±0.42[ab]	74.49±0.89	80.23±0.95[a]
T6	20.25±0.12[d]	30.41±0.82[ab]	39.79±1.04	68.93±0.92[ab]	73.97±1.39	77.36±0.80[bcd]
T7	20.41±0.17[cd]	28.48±1.59[b]	43.83±1.42	70.23±1.05[ab]	76.28±0.67	79.80±1.42[ab]
T8	21.35±1.17[bcd]	30.71±1.70[ab]	42.28±0.84	72.18±0.21[a]	73.49±3.04	78.27±0.39[abcd]
T9	22.11±0.46[abc]	30.67±1.68[ab]	40.38±1.11	67.39±1.59[b]	73.66±0.98	76.79±0.84[cd]
Mean	21.98	29.88	41.16	69.53	74.59	78.54
P –value	0.016	0.151	0.284	0.044	0.804	0.016

[a, b] Means in a columns, values followed by different letters differ significantly (P<0.05), hr = Hour, OM = organic matter, T1= Pure Napier grass at 1m row spacing, T2= Napier grass intercropped with lablab at 0.75 m row spacing, T3= Napier grass intercropped with cowpea at 0.5m row spacing, T4= Napier grass intercropped with cowpea at 1m row spacing, T5= Napier grass intercropped with lablab at 0.5m row spacing, T6= Pure Napier grass at 0.75 m row spacing, T7= Napier grass intercropped with lablab at 1 m row spacing, T8= Napier grass intercropped with cowpea at 0.75 m row spacing, T9= Pure Napier grass at 0.5m row spacing.

Table 7: Least square means and standard errors for *In sacco* Organic matter rumen degradability characteristics.

Treatments	Rumen degradability characteristics				
	a	*b*	PD (*a* + *b*)	*c*	ED (kp= 0.03)
T1	12.69±0.08[ab]	71.81±0.14[d]	84.50±0.18[d]	0.0257±0.001[a]	45.85±0.86
T2	13.78±1.54[a]	75.14±1.68[bcd]	88.92±1.46[bcd]	0.0229±0.002[ab]	46.27±0.67
T3	13.95±0.49[a]	83.21±1.55[a]	97.15±1.89[a]	0.0182±0.001[b]	45.23±0.38
T4	13.17±0.64[ab]	79.34±3.93[ab]	92.50±3.72[ab]	0.0220±0.002[ab]	46.25±1.21
T5	12.36±0.40[ab]	78.51±3.52[abc]	90.86±3.61[bc]	0.0233±0.002[a]	46.32±0.35
T6	12.01±0.56[ab]	75.63±0.92[bcd]	87.63±0.40[bcd]	0.0234±0.000[a]	45.14±0.16
T7	11.53±0.38[b]	78.39±1.148[abc]	89.92±1.52[bcd]	0.0241±0.001[a]	46.37±0.16
T8	11.28±0.42[b]	75.22±0.11[bcd]	86.505±0.53[cd]	0.0261±0.000[a]	46.25±0.81
T9	13.89±0.41[a]	73.86±0.76[d]	87.75±0.55[bcd]	0.0224±0.001[ab]	45.37±0.98
Mean	12.74	76.79	89.53	0.0231	45.89
P-value	0.050	0.014	0.009	0.0310	0.865

[a, b c d] Means in a columns, values followed by different letters differ significantly (P<0.05), a= washing loss (rapidly soluble fraction), b= Slowly degradable fraction; c = The rate of degradation, DMD = Dry matter degradability; ED = Effective degradability; PD = Potential degradability, T1= Pure Napier grass at 1m row spacing, T2= Napier grass intercropped with lablab at 0.75m row spacing, T3= Napier grass intercropped with cowpea at 0.5m row spacing, T4= Napier grass intercropped with cowpea at 1m row spacing, T5= Napier grass intercropped with lablab at 0.5m row spacing, T6= Pure Napier grass at 0.75m row spacing, T7= Napier grass intercropped with lablab at 1m row.

the rest the treatments. This was in agreement with (Njoka-Njiru *et al.*, 2006a) who noted that OM disappearance at 48 h of incubation was significantly higher for intercropped Napier grass than sole Napier grass. Generally, the extent of digestion of Napier grass when intercropped with lablab and cowpea at three planting densities were higher than with sole Napier grass.

The rumen degradability characteristics of treatments studied were presented in Table 7. Accordingly intercropping of lablab and cow pea had a significant effect for all Parameters (P<0.05) except Effective degradability (P>0.05) and Napier grass intercropping with cowpea (T3) at 0.5m × 0.5m space has the highest washing loss (rapidly soluble fraction), insoluble but slowly degradation fraction and potential degradability, but has the lowest rate of degradation. It reflected that these treatments had highly degraded materials as energy source and high degraded protein source in the rumen. However, the lowest value recorded for slowly degradable fraction (*b*) and potential degradability (*a* + *b*) in the Napier grass at 1 m × 0.5 m space without intercropped (T1). Moreover, the effective degradability of each treatment was not significantly (p>0.05).

CONCLUSION

Napier grass intercropping with lablab and cowpea at different planting densities at Haro sabu Agricultural research center in western Ethiopia has revealed the ability to produce high nutritional quality. The results further indicated that there were improvements of *in vitro* dry matter digestibility (IVDMD) and in vitro organic matter digestibility (IVOMD) of Napier grass than sole cropping system. Napier grass intercropped with lablab and cowpea at different planting densities had significant effect on the in vitro dry and organic matter digestibility (IVDMD, IVOMD) and increased digestibility. *In sacco* dry matter disappearances (DMD) and *in sacco* organic matter degradability (OMD) of Napier grass for many of the incubation hours was relatively higher for the Napier grass intercropping with lablab and cowpea at a planting density of 24 plants m^{-2} (T7 and T4) respectively. Accordingly, Napier grass intercropped with lablab and cowpea at a planting density of 24 plants m^{-2} could be a better choice based on forage quantity and quality for the first three months stage of harvest. Therefore to strengthen this research it is advisable to do animal performance trial based on animal feeding practice in order to come up with sound recommendation.

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