EFFECTS OF UREA OR LIME STONE AMMONIUM NITRATE (LAN) ON BIOMASS YIELD AND CHEMICAL COMPOSITION OF SILAGE FROM PURE STAND AND INTERCROPPED LABLAB, TSWANA COWPEA, MILLET AND BUFFEL GRASS IN BOTSWANA

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Effects of Urea or Lime Stone Ammonium Nitrate (LAN) on Biomass Yield and Chemical Composition of Silage from Pure stand and Intercropped Lablab, Tswana cowpea, Millet and Buffel grass in Botswana

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A Dissertation presented to the Department of Animal Sciences in partial fulfilment of the requirements for the Degree of Master of Science (MSc) in Animal Science (Animal Nutrition).

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DECLARATION

I declare that the thesis hereby submitted by me for the Master of Science Degree at Botswana University of Agriculture and Natural Resources (BUAN). It is my own independent work and has not previously been submitted by me at another university/ faculty for the award of any degree or diploma. It is original except where references were made.

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GENERAL ABSTRACT

This study investigated if Urea or LAN had any effect on biomass yield and chemical composition (Macro and micro mineral) of silage made from fodder crops of Lablab (*Lablab purpureus*), Tswana cowpea (*Vigna unguiculata*), millet (*Panicum miliaceum*) and Buffel grass (*Cenchrus ciliaris*). The crops were cultivated as monocrops (pure stand) as well as intercropped. The intercropping was done between legumes and cereals as follows: Tswana cowpea with millet, Tswana cowpea with Buffel grass, Lablab x millet and Lablab with Buffel grass. The experimental design adopted for this study was Completely Randomised Design (CRD). The crops were planted at Botswana University of Agriculture and Natural Resources (BUAN), Notwane farm in October 2009. Harvesting of the crops was in January 2010 and the silages were made immediately after harvesting of the forages. All chemical and mineral analysis was done at the Botswana University of Agriculture and Natural Resources (BUAN)'s Animal Nutrition laboratory.

The first study dealt with biomass yield of pure stand as well as intercropped forages fertilized with urea or LAN or without fertilizer application. The results from the study showed that dry matter (DM %) content, fresh yield and biomass yield of both pure stand and intercropped forages were significantly different with crop variety ($P < 0.05$). The pure stand legume forages had low dry matter content whereas pure stand cereal forages had high dry matter content. In contrast, pure stand cereal crops had low fresh yield and biomass yield than pure stand legumes crop forages. Pure stand Lablab forages had the highest fresh yield as well as biomass yield of 52,648.5 kg/ha and 9,975.17 kg/ha respectively than the rest of the pure stand crop forages. In intercropped forages, Lablab with Buffel or millet had higher fresh yield as well as biomass yield than Tswana cowpea intercropped with the same. Lablab

with Buffel grass produced the highest fresh yield as well as dry matter yield (biomass) of 45,548 kg/ha and 9,103.87 kg/ha respectively. The result further indicated that Tswana cowpea with Buffel grass yielded the least dry matter (DM %) content of 19.28 DM %.

The second study focused on chemical composition (Ash, NDF, ADF, ADL and CP), macro and micro mineral compositions of silages made from pure stand and intercropped forages fertilized with either urea or LAN or without fertilization. The result of the study indicated that the chemical composition of pure stand crops silages were significantly different with ($P < 0.05$) crop varieties except for ADL content ($P > 0.05$). The results further indicated that pure stand legume crops had higher ash and crude protein content as well as low NDF and ADF than cereal forages of the same. Under macro element composition, magnesium composition of pure stand crop forages was highly significant ($P < 0.05$)). However, phosphorous (P) and Sodium (Na) concentration tended to be affected by crop type ($P \geq 0.05$). In general, the micro element concentration such as Cu, Zn, Mn and Fe of silages made from pure stand crops were found to be insignificant ($P > 0.05$. However, pure stand Tswana cowpea silage exhibited higher and insignificant iron (Fe) concentration of 103.85 mg/kg DM than rest of the pure stand crops silages.

The results further indicated that the chemical compositions of intercropped silages were not significantly ($P > 0.05$) different between crop varieties. Nevertheless, the ash and crude protein (CP) content tended to be significant ($P \geq 0.05$). Still ash and crude protein content were higher in intercropped silages than pure stand crop silages. In macro element composition, the calcium (Ca) concentration of intercropped silages was highly significant ($P < 0.05$) whereas magnesium concentration tended to be significant ($P \geq 0.05$). Similarly, concentration of sodium and phosphorous were not significant ($P > 0.05$). In General, micro element concentrations of intercropped silages were not significantly different between, crop were also not affected due to urea or LAN application. In general, the micro mineral such as Cu, Zn, Mn and Fe concentration of intercropped silages were not significantly ($P > 0.05$) different between crop varieties. From these results it is clear that the iron concentration for intercropped silages were highly significant ($P < 0.05$) due to crop variety

Based on the results of this study, it can be concluded that intercropping is an effective method for farmers to produce quantity and quality forage. Legume forages such as Lablab and Tswana cow peas were found to be better forage crops since they resulted in higher biomass yield as well as higher CP content than cereal crop forages. This study also indicates that fertilizer application may not be necessary every time, probably suggesting the need for soil testing before attempts to apply fertilizer. Further research is needed regarding the effects of these silages on productivity of growing and lactating animals (growth rate and milk yield). In conclusion, biomass production of forage crops depends on environmental conditions such as rainfall, fertile soils, cultivars or variety of the crops being used, in addition to the methods or patterns of crops being cultivated.

DEDICATION

This work is dedicated to my family members who has supported me financially and morally throughout my studies. My daughters and my husband Mr. Wilson Varghese who encouraged and inspired me to pursue this MSc programme. To all, this is for you.

ACRONYMS AND ABBREVIATIONS

AAAP	ASIAN Australian journal of Animal Sciences
ADF	Acid Detergent Fibre
ADL	Acid Detergent Lignin
AOAC	Association of Official Agricultural Chemists.
APRN	Asian Research Publishing Network.
ARNAB	African Research Net work on Agro industrial Product.
ARNAB	African Research Network on Agricultural By-products
ASA	American Society of Agronomy
NSAIS	National Sustainable Agriculture Information Service
Biomass	It refers to plants or plant-based materials that are not used for food or feed, and are specifically called lingo cellulosic biomass.
BUAN	Botswana University of Agriculture and Natural Resources.
Ca	Calcium
CP	Crude Protein
Cu	Copper
DM	Dry Matter: the ability of a certain cultivar to compensate Increase the ratio of dry weight and total fresh yield Production
EUCARPI	European Association For Research and Plant Breeding.
FAO	Food and Agriculture Organization
Fresh Yield	The amount of raw materials and the amount of finished product actually produced.
GLM	General Linear Model
ICP	Inductively Coupled Optically Emitted Spectrometer.
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IGAD	Inter Governmental Authority on Development

IGAD-LP	IGAD – Livestock Policy Initiative
ILCA	International Livestock Centre for Africa.
ILRI	International Livestock Research Institute.
LAN	Limestone Ammonium Nitrate
LC	Lablab intercropped with *Cenchrus ciliaris* (Buffel)
LM	Lablab intercropped with Millet
LSD	Least Square Mean
Mg	Magnesium
NCAT	National Centre for Appropriate Technology
NDF	Neutral Detergent Fiber
NRC	National Research Council
P	Phosphorus
PPM	Parts Per Million
RAPD	Random Amplification of Polymorphic DNA'.
RIRDC	Rural Industries Research and Development Corporation
SAS	Statistical Analysis Software
SE	Standard Error
SL	Significant Level
TC	Tswana cowpea intercropped with *Cenchrus ciliaris* (Buffe grass).
TM	Tswana Cowpea intercropped with millet
WP	Within population
Zn	Zinc
UNISWA	University of Swaziland

CHAPTER 1

GENERAL INTRODUCTION

1.1 Background

Livestock in Botswana is maintained on feedstuff that comes from rangelands. Fodder trees, leaves and foliage are also used as feed resources; e.g. *Acacia* species such as *Acacia tortilis, Acacia karoo* and *Luciana Leucocephala. Colophospermum mopane* (Mopane) are important fodder trees found in Botswana. A study conducted on the nutritive value of Mopane browse plant showed that its leaves are not palatable and had high tannin content that affect the growth rate of goats (Macala et al., 1992). Moreover, these fodder trees are also deciduous (leaves fall off) during winter dry seasons. Sun drying may reduce the deleterious effect of tanning on animal performance.

The productivity of the rangeland is declining and that cannot fulfill the need of increasing livestock population (APRU, 1980). Botswana is also continuously experiencing fodder deficiency due to recurrent droughts and the attitude of farmers to rely entirely on natural pasture without intervention of conservation of feed. Livestock mortality is common due to lack of sufficient feed resources (Mosimanyana, 1993). For example, the government imported 5,978.6 tons of roughages from neighbouring countries in 1984 to subsidize livestock feeds to farmers (Mosimanyana, 1993). Currently, in the year 2016it has been reported that the government imported 6,219.6 tons of feed from neighboring countries like South Africa and Namibia (Sunday Standard Reporter, 2017). Botswana livestock production report revealed that the feed deficiency problem is still persisting. However, some farmers are now growing *Dolichos lablab* (Lablab) and *Atriplex nummularia* (Salt man's bush) in order to overcome fodder deficiencies (Moreki, 2009).

The use of adequate, well balanced diet can maximize livestock production and minimize losses by providing well-balanced and nutritious rations. Some farmers assume that tropical breeds such as Brahman cattle perform better under minimum feed resources. But optimum nutrition and feed management is still essential to enhance beef and dairy production (APRU, 1980). An animal requires energy, protein, minerals and vitamins to maintain body weight, lactation, growth and reproduction. Good quality forages are important for ruminant livestock production and during years of abundance, forage needs to be preserved to conserve the quality and to avail required nutrients during time of feed scarcity. One way of preserving fodder and forages is ensiling. In this study silage was made by placing the green cut intercropped forages of Tswana cowpea with Buffel, Tswana cowpea with millet, Lablab with Buffel and Lablab with millet as well as pure stand forages of Buffel grass, millet, Tswana cowpea and Lablab in an air tight silo bag and fermented for forty days. Silage nutritive quality was then assessed.

1.2 Justification of the study

Lack of feed resources as well as poor nutrition is the major constraints to livestock production in Botswana (Aganga and Omphile, 2000). Botswana livestock depends on natural rangeland that includes grasses, trees, shrubs and forbs. Fodder tree leaves and foliage from such trees as *Acacia tortilis*, *Acacia robusta*, *Boscia albitrunca, Dichrostacys cinerea, Ziziphus mucronat, Leucaena leucocephala* and *Colophospermum mopane* (Mopane) are feed resources to grazing and browsing ungulates (Field, 1978). Fodder trees leaves and shrubs contain high level of tannin, which make them unpalatable and reduce protein digestibility (Silanikove et al., 1997). However, at concentration of levels less than 50g/kg DM condensed tannins protect protein from rumen degradation, resulting in an increase in the supply of amino acids in the small intestine (Min et al., 2003). Leguminous forages could be cultivated to compliment natural pasture.

Increasing animal feed availability and its quality throughout the year may help to improve livestock production in Botswana. Therefore, it is essential to increase biomass yield and enrich nutrient composition of the forage. Planting various types of forage legumes, cereals or grasses using fertilizers as well as practicing intercropping is likely to increase biomass yield as well as enrich nutrient composition of fodder crops.

Silage making is a good practice and an excellent method of conserving forages among livestock farmers (Chedly and Lee, 1999). Although the pasture grasses and short term forage crops such as cowpeas, Lablab and cereal crops are available, they seem to perish quickly and if not wisely conserved then livestock will experience under-nutrition. Therefore, the work presented through this research explores the possibility of using legumes, cereal grass forage for making silage, biomass production and nutritive value of resulting silages. This research comprises of two studies.

Main objectives are:

To determine the effects of urea / LAN on biomass and chemical composition of silage made from Tswana cowpea (*Vigna unguiculata*), Lablab (*Lablab purpureus*), millet (*Panicum miliaceum*), Buffel grass (*Cenchrus ciliaris*).

Study 1

To evaluate the effects of urea / LAN on biomass yield of intercropped and pure stands fodder crops of Tswana cowpea, Lablab, millet and Buffel grass.

Specific objectives

The specific objectives were:

- To determine the influence of urea /LAN on biomass yield of pure stand crops of Tswana cowpea, Lablab, Buffel and millet.

- To determine the biomass yield of intercropped fodder crops of Tswana cowpea with millet, Tswana cowpea with Buffel grass and Lablab with millet and Lablab with Buffel grass under different fertilization regimes; with either Urea or LAN.

Hypothesis (study 1).

Ho: The application of Urea or LAN will not influence the biomass yield of pure stand or intercropped fodder crops of Tswana cowpea, Lablab, millet and Buffel grass.

Hà: The application of Urea or LAN will influence the biomass yield of pure stand or intercropped fodder crops of Tswana cowpea, Lablab, millet and Buffel grass.

Study 2

Determination of the silage chemical composition, (macro and micro) mineral composition of silage made from inter cropped and pure stands crops of Tswana cowpeas, Lablab, millet and Buffel grass fertilized with either Urea, or LAN.

Specific Objectives:

The specific objectives were:

- To determine the chemical composition, (macro and micro) mineral composition of silage made from pure stand crops of Tswana cowpea, Lablab, Buffel and millet fertilized with either Urea, or LAN or no fertilization
- To determine the chemical composition, (macro and micro) mineral composition of silage made from intercropped crops of Tswana cowpea with millet, Tswana cowpea with Buffel grass and Lablab with millet and Lablab with Buffel grass fertilized with either Urea, or LAN.

- **Hypothesis (study 2).**
- **H_0:** The application of Urea or LAN does not influence silage chemical composition, macro and micro mineral of silage made from pure stand or intercropped fodder crops of Tswana cowpea, Lablab, millet and Buffel grass fertilized with either urea, or LAN
- **H_A:** The application of Urea or LAN does influence silage chemical composition; (macro and micro) mineral composition of silage made from pure stand or intercroppe fodder crops of Tswana cowpea, Lablab, millet and Buffel grass fertilized with either urea, or LAN.

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CHAPTER 2

LITERATURE REVIEW

2.0 Forages

Natural rangeland is the basic feed resource for ruminant production. Livestock in Botswana mostly depends on extensive grazing of native rangeland pastures for their nutrient requirement, which consists of grasses, shrubs and browseable trees. However, the quality and quantity of feed resources are affected by climatic variation and mismanagement (Nsinamwa et al., 2005). Increasing the production of seasonal forage for livestock can solve the shortage of feeds. Forage supply can also be increased through the use of irrigation, growing cultivars of improved forage species (Lucerne and legume crops) and the use of fertilizer application (Frawley, 1980). Therefore, farmers should be encouraged to grow and increase fodder yield to supplement rangeland pastures. In Botswana, farmers grow legume forages such as Lablab, Tswana cowpea and Lucerne and grass cereal crops such as Buffel grass (*Cenchrus ciliaris*), millet and sorghum. Millet, sorghum and Tswana cowpea are mainly grown for human consumption (grains) and their residues used as livestock feed. They are planted in both monocultures as well as in intercropped manner in order to increase forage quality and quantity (APRU, 1980).

2.1 Legume forage crops

Cowpeas (*Vigna unguiculata*) and Lablab (*Lablab purpureus*) are fast growing, annual, and summer legumes. As indicated earlier, cowpeas are traditionally grown for grain production for human consumption but can be adopted as forage crops while Lablab is popular legume forage. They provide high quality feed for grazing animals during the dry periods (summer and autumn). Cowpeas are capable of producing higher yields if planted in summer since it is a summer crop. Cowpea is also excellent forage for fattening animals such as sheep, cattle, and goats. It is also regarded as good feed for milking cows (Mullen, 1999). There are different varieties of cowpeas such as erect, semi-erect, prostrate (trailing), or climbing varieties (Singh et al., 1992). Among these varieties, the non - vining type cowpea grows fast and gives better forage yield (Singh et al., 1992). According to Singh and Sharma (1996), medium size erect cowpeas that grow straight give high grain yield whereas medium maturity semi erect varieties gives high fodder yield. However, the International Institute for Tropical Agriculture (IITA) in Idadm, Nigeria has developed a high yield, short season and multiple disease-resistant varieties of cowpeas that give high forage yield within 60 days. The yield of cowpea ranged from 500 kg/ha to 4,000 kg/ha DM in irrigated areas (Davis et al., 2002). In West Africa, mature cowpeas are harvested and the haulms (collective parts of peas) are cut while still green and rolled into small bundles and stored on roof forks as an animal feed in the dry season (Singh and Tarawali, 1997). Cowpea is an excellent nitrogen fixer and is sometimes grown as a cover crop or for livestock feed (Chin, 2002). Besides cowpea, there are some leguminous crops that are grown solely as fodder by farmers for their livestock such as Lablab.

Lablab is a multipurpose crop grown for pulse, vegetable and forage. It is an excellent nitrogen fixer and is sometimes grown as a cover crop or for livestock fodder (Agishi, 1999). Lablab also produced around 500 kg/ha to 5,000 kg/ha DM (Akbar et al., 2003). Lablab is an excellent in fixing nitrogen and is sometimes grown as a cover crop or for livestock fodder (Chin, 2002). Lablab gives high forage yield, especially in the dry season since the plant is resistant to sustain in drought conditions. It has high nutritive value since it contains high Crude Protein (30 % DM on leaf), Crude Fiber (CF) roughly 30.49 % DM in whole plant and phosphorous content of 4-5g/kg DM (Murphy and Colucci, 1999). Lablab is common in Africa; it grows in a wide range of environmental climate and various types of soils, rainfall, temperature and altitude (Eskandari et al., 2009). The growth period of Lablab varies approximately from 75 to 300 days under suitable conditions (Cameron, 1988). The dry matter yield of Lablab varies with rainfall, soil conditions and time of planting (FAO, 2012). The forage yield is affected by variety of the Lablab planted for forage purpose. For example, the *Rongai* cultivars grow vigorously, the leaves are broad and trifoliate with long petiole which provide high biomass yield as compared to short or purple grain Lablab (Hendricken and Minson, 1990). In irrigated areas the yield of Lablab was recorded to be 14 000 kg ha. In general, Lablab or cowpea gives maximum crop yields of around 3500 to 4500 kg / ha DM (Mullen, 1999). Because of their high crude protein (CP) compared to other forage crops, cowpea and lablab are used to complement cereal forage crops and grass.

2.2 Cereal forage

Cereal crops can be successfully used as a source of forage for livestock. Oats, barley and triticale (hybrid wheat) are the common cereal forages used in America (Mapire et al., 2002). Aanga and Tshwenyane (2003) reported that in Botswana, cereal crops such as sorghum, millet and other monocot plants such as Buffel grass and Napier grasses are grown as livestock forage. Sorghum and millet are used as a crop residue after harvesting the grain. Buffel grass is one of the forage grass commonly grown in Botswana as livestock feed. It is well adopted to dry climate as well as in sandy soil (Henze et al., (2015). Buffel grass yield is not higher than millet or Napier grass since it takes time for it to establishment (Gardner, 1984). All fodder crops need water and fertilizer in order to grow vigorously. Similarly, Buffel grass also needs moisture, fertilizer like nitrogen and phosphorus for its growth and yield. The forage yield may decline with depletion of nitrogen and phosphorous in the soil (Smokewood, 2001). A report from Buffel grass Seed Company in Ontario, Canada (2001) indicated that Buffel grass forage yield depends on the selection of the Buffel grass seed. There are many varieties of Buffel grass and even new ones are currently being developed (Patridge, 2003). Generally, used variety of Buffel grass such as 'T-4464' is common in USA and Canada because of its excellent performance and low cost compared to the newly developed Buffel grass (Marshall et al., 2012). Besides that, stages of maturity at harvest is also the most important factor determining the biomass yield and quality of Buffel grass forage (Smokewood, 2001).

Sweet sorghum (*Sorghum bicolor*) is commonly known as *sweet reeds*, another potential cereal forage crop, which could be used as livestock feed. It is well adapted to the climatic conditions of Botswana. Smallholder farmers plant and sell the stem for money. The juicy stem is chewed as snack and the vegetative materials and seeds are used for forage and silage. It is a high energy crop, with a high photosynthetic rate and it gives high yield compared to maize (Ali et al., 2008). This is the reason why sweet sorghum is an excellent crop for silage making in China and Botswana (Karikari et al., 1998). Water shortage is a global problem that reduces forage growth and its productivity. Improved cultivars of cowpeas, Buffel and millet forage crops are used in order to reduce water consumption as well as for better forage yield.

Millet is another cereal crop grown in semi-arid as forage and for grain in many areas of Africa (Sergio, 2000). Millet yield is also dependent on moisture content in the soil (Al- Suhaibani, 2011). An experiment conducted by Al-Suhaibani (2011) on millet biomass yield showed that high forage yield can be achieved with well irrigated pearl millet (*Pennisetum glaucum*) compared to low irrigate ordinary millet (*Panicum miliaceum*). Pearl millet (*Pennisetum glaucum*) is one of the varieties of millet, which is widely grown in Pakistan as livestock fodder (Crawford et al., 2003). Pearl millet gives higher forage yield even in moisture stress conditions than ordinary millet (*Panicum miliaceum*) (Rao et al., 1986).

2.3 Yields of Intercrop Forages

Mixtures of cereals and legumes are normally used for forage production. Mixing field peas with a cereal grain for forage is common in the past several years in Asian countries like Pakistan and Punjab (Opuma et al., 2010). The primary benefit of mixing peas with small grains is to improve forage quality as well as forage yield (Albayrak and Ekiz, 2005). Another advantage of mixing legumes with grass is to help minimize the use of the fertilizer since legumes supply nitrogen to the soil by nitrogen fixation (Preston, 2003). Legumes such as Lablab and cowpeas can be intercropped with cereal forages of livestock feed (Davis et al., 1999). Some studies on effect of biomass yield of intercropped forage proved that intercropping legumes with cereals can improve forage yield, quality and reduce moisture content since less water absorption occurs during mixed crops (Doonan et al., 2003). In a study conducted by Kabirizia et al., (2007) regarding intercropping elephant grass (Napier grass) with Lablab, showed that growth and forage yield was higher in mixed crops than sole crop of the same. In another experiment, intercropping sorghum with Lablab showed that the total forage yield was greater in mixed crops compared to when sorghum was cultivated alone (Shehu et al., 1999).

Perennial grasses require nitrogen released slowly or gradually from organic fertilizers such as composts (Hauggard et al., 2001). Composts kraal manure releases nitrogen very slowly compared to inorganic fertilizers like urea or LAN. A field study was conducted to compare the biomass yield due to the effect of nitrogen in legume-grass forage mixture and monocrop of grass. The results from this study indicated that repeated applications of various composts sustain perennial forage grass like Rye grass, Panic grass (any grass from Panicum genus) and Needle grass yields compared to the same crop treated with inorganic fertilizer (Lynch, 2004). Buffel grass yield decreases with low nitrogen in the soil, while forage yield was high in intercropped system using legume (Stylo species) (Lynch, 2004). In another experiment carried out to test the effect of organic manure on the biomass yield of maize fodder showed that the treatment maize had higher biomass yield compared to the control crops (Rahman et al., 2008). The studies show that the biomass of forage is based on cultivars, fertilizers of both organic and inorganic and moisture content in the soil as well as the complementarities of legumes.

2.4 Silage

Ensiling is one of the methods of conserving forage. Silage consists of green forage preserved by fermentation in a silo to be used when the feed sources are scarce. Silage is made by the fermentation of green fodder and material is stored in silo pits or silo bags under anaerobic conditions. In the absence of air, facultative anaerobic bacteria naturally present in the forage produces natural organic acids such as lactic acids, which preserve the fodder (Coblentz, 2002). Silage making is practiced widely in intensive animal production systems in temperate regions. This silage could be a high quality feed when a feed is scarce. Corn and hay crops such as legumes, grasses and mixture of grasses and legumes are suitable for silage (Mallory, 1994). Crops for silage making should be harvested at the right time of maturity especially at the booting stage. For example, forage sorghum should have seed that is at hard-dough stage, while Bana grass should be about a meter high and the legumes should be in young bean stage for silage (Gang and Nogan, 2005).

Research has proved that forage sorghum and Bana grass are ideal forage plants for silage in the semi-arid area of Southern Africa (Gash and Renard, 1991). Cereal forage contains enough sugar for fermentation but low in protein (Drennan et al., 2006). Legumes such as cowpea and Dolichos bean (*Lablab purpureus*) have high protein content but their sugar content is inadequate for good fermentation for silage (Mhere et al., 2002). Therefore, legume crops should be mixed with cereal crops to get good quality legume silage. Roughage is the principal component of cattle diet and it influences the cost of production. Making use of local roughage would result in cutting down the cost and improve the profit in the livestock industry. Developed countries normally make use of locally available agro–industrial waste products such as maize, sorghum, millet crop residues and dairy waste in cattle feeding (ZoBell and Burrel, 2002). The above mentioned agro industrial residues are available locally, which suggest that they could benefit local farmers. Challenges could be changed in nutritional quality required to supplementary feeding by local farmers could be changed.

In the US, dairy by-product are used as cattle feed that is mixed with other feed resources. In dairy industry, after the cheese and yogurt have being fermented, a by-product is formed called whey. The whey is mixed with crop residues such as small grain, straw and wheat middlings, silage is made called whey silage (Zobell and Burrel, 2002). A study on producing whey silage for growing and finishing cattle indicates that the DM of whey silage is 46.4% and the crude protein content is12.8%. The results further indicated that the nutritive value was higher than other silages such as intercropped maize-cowpea silage and maize silages (ZoBell and Burrel, 2002).

2.5 Forage Quality

Forage quality refers to how well animals consume a forage and how efficiently the nutrients in the forage are converted into animal products (Linn and Martin, 1999). The forage quality is important for so many reasons, such as helping to calculate rations for animals and evaluating forage management practices and marketing the forages (Linn and Martin, 1999). The quality of silage can be analyzed both physically and chemically to determine its composition and nutritive value. Nutrient composition of the silage can be determined partially by its physical qualities such as color, texture and smell. Well-fermented silage has bright yellow colour and lactic acid smell. Poorly fermented silage has dark green color and a smell of ammonia or tobacco (AIC, 2003). The silage composition is related to the effects of microbiological processes that occur in the silo (AIC, 2003). The nutrient composition of the silage depends on the type of materials ensiled and the concentration of the fermentation products such as pH, lactic acid and ammonia content present in the silage (Miller, 2000). However, pH is the key indicator that determines the quality of the silage. Well-ensiled silage has an average pH of 4 (Gang and Nogan, 2005).

According to Coblenz, (2002) wilting and chopping of the forage also enhance the silage quality. Wilting reduces moisture content and the small sized forages are able to compact easily and air is removed easily. The degree of wilting determines the type of fermentation in the silo (Morgan, 1996). Wilting of the crops also influence the silage chemical composition. A study conducted by Kim et al., (2001) on Rye crops silage under different wilting period such as fresh, one day and two days wilting of the forages indicated that wilting crops influenced the crude protein, NDF and ADF content of the silage. Wilted forage has low concentration of sugar that is fermented to lactic acid which improves ADF, NDF and CP of the silage (Herson and Kunkle, 1989). Nutritive value of the silage also depends on the type of soil where the crops were grown as well as the application of fertilizers (Mooi, 1991).

The quality of the ensiled product also depends on the feeding value of the material before ensiled. Prior to ensiling, additives and preservative such as molasses and ammonia can improve silage quality since they improve fermentation end products (Linn and Martin, 1999). A study conducted by Aganga et al., (2004) showed that ensiling Rye grass with molasses as an additive improved the nutrient composition of the silages compared to the silages without molasses. Molasses improved the amounts of fermentation end products by providing readily fermentable carbohydrates. An experiment conducted by Yokota et al., (1998) on Napier grass silage with additives and its different stages of growth indicated higher nutritive values. Apart from additives nitrogen fertilizer can also improve silage quality.

A study conducted by Mullins et al., (1998), showed that sorghum and maize crops fertilized with nitrogen had high CP and low fiber content in their silages compared to their control crop silages. Grassland management, the type of crop and weather conditions can also influence ensiling (AIC, 2003). Different ensiling techniques such as pit silage, silo silage and bag silage also contribute to variation in fermentation quality (Muck, 1998). Application of fertilizer can improve silage quality. A study conducted by Mullins (1998), showed that sorghum and maize crops fertilized with nitrogen had high CP and low fiber content in their silages compared to control crop silages. Maturity of the crop also determines silage quality. The CP content was decreased with increasing maturity of the forages especially at flowering stage. The ADF and NDF value also increases as maturity progressed at booting stage (Muck, 1998).

According to McDonald et al., (1991) silage quality is improved by exclusion of oxygen as well as prevention of aerobic decomposition during ensiling. This can be done by pressing silo bags well until the air goes out and then tightened them with a string. Therefore, it is important to exclude oxygen from the forage as stated above while ensiling. Both oxygen and plant sugars encourage aerobic respiration by microbes (Yokota et al., 1998). The volume of air trapped in a silo affects the duration of respiration and anaerobic microorganisms activity (Linn and Martin, 1999).This leads to losses of nutritive material and fermentable substrates as lactate production will be preferred (Shaoi et al., 2005). Fermentation and complete exclusion of fresh air from the forage can breakdown in the cell wall and in the juice (NRC, 1989). Thus ensiling density is important in the fermentation process and the final fermentation quality. However, a study conducted on the density effect of Guinea grass silage showed that the silage attributes such as pH were low in less denser silage low and high denser silage (forage pack density) (Shaoi et al., 2005).

2.6 Silage Crops and their features

Cowpea is an important fodder legume used as human food and livestock fodder due to its nutritive value. Several experiments on cowpea-intercropped system with cereal crops showed that intercropped forage for silages results in higher nutritive value compared to sole crops (Singh et al., 2003). According to Mccallum and Oliver (1997) maize silage is poor in protein content; it has 7.5% CP. Maize silage is generally used as dairy feed and therefore protein supplementation would be required for maintenance and production of low yielding dairy cow on a maize silage ration (Mupunga and Dube, 1997). Higher, levels of energy and protein in the ration are necessary for high yielding dairy cows (Xypoleas, 2015).

Corn, sorghum, barley, and oats continue to be dominant feed grains for cattle. Soybean meal and cottonseed meal are important plant protein supplements for high yielding dairy cow (NRC, 1989). As indicated earlier, legume silage has high protein content compared to grass silage. Legume material on its own is extremely difficult to ensile because of its high buffering capacity and low level of fermentative carbohydrates (AIC, 2003). According to Titterton and Maasdorp (2002) legume crops can be ensiled well with maize plant and has the capacity to improve silage nutritive value. A study conducted on different varieties of legume such as Lablab, cowpea by Titterton and Maasdorp (2002) showed that the chemical composition of the legume silage as well as the mixed silage were not different. However, this experiment proves that mixing legume material with maize while ensiling would improve silage protein and reduce fiber content such as NDF and ADF (Haustein, 2003).

2.7 Potential forage crops

Legumes such as Lucerne, Lablab and cowpea are used for livestock feed in the form of grazing, hay making or for making silage. The main forage legume crops of Botswana are Lucerne, cowpea and Lablab which are used both fresh as well as crop residues for cowpeas (Mosimanayana and Kiflewahid, 1987). Cowpea would usually be used as a crop residue; both its stem and haulms are feed to ruminants. Legume forages are usually richer in protein, calcium and phosphorus than grass (Macdonald et al., 1998). Additional benefits of having legume forages in cropping systems are that they enrich the soil by nitrogen fixation as well as retain moisture content in the soil (Pederson, 2006). There are a number of legume forage species that are grown on wide range of environmental conditions in the world. In Mediterranean Europe (Italy, France and Spain) annual forage legumes are mixed with winter cereal such as oats, barley and other grasses (McDonald, 1999). In these countries, dairy cow farming rate is increasing and the milk yield is higher than in Botswana. The feeding system for these dairy cows is mainly based on hay and silage rather than grazing (Boka et al., 2000). However in Australia and New Zealand a common combination is Ryegrass and white or red clover is offered through grazing and the use of silage is limited to winter (Baudracco, 2011).

2.7.1 Lablab (*Lablab purpureus*)

Dolichos Lablab is generally called Hyacinth bean, Field bean, and Lablab bean. It is a summer legume which could be used either as annual or biennial crop (Hendricken and Minson, 2009). It is a dual-purpose legume, grown as pulse crop for human as well as for livestock feed (Agishi, 1999). According to Murphy and Colucci (1999) the nutritive value of Lablab is as follows; the leaf has crude protein (CP) content of 22-38% but the crude protein is much lower in stem than that of leaf (7-20%). The whole plant contains 20-28% CP (Humphry et al., 2002). While digestibility ranges from 56-75%, it is high in the leaves which are highly palatable compared to the stem (Cameron, 1988). The leaves do not contain anti-nutritive factors such as tannins (Phale and Madibela, 2006). The grains are high in vitamins A, B and C and palatability of the grain is low to moderate depending on a variety of the plants (Agishi, 1999). The high protein content in the Lablab plant can cause bloat in animals (FAO, 2012).However, mixed with cereal forage such as sorghum, can prevent the occurrence of bloat (Rasby, 2010). The grain contains tannins, phytate and trypsin-inhibitors, the concentration may vary among varieties (Ramkrishna et al., 2006). Soaking or cooking reduces the activity of these compounds (Murphy and Colucci, 1999). Lablab has various characteristics that can be used successfully to grow under various conditions. Its adaptability and drought resistant are important qualities (FAO, 2014). Its high nutritive value means farmers can also use it as an important forage crop for both beef and highly productive dairy cows, the leaves of Lablab can also make excellent hay. In Botswana, it is also a popular livestock feed with small stock farmers (Mosimanyana, 1993). But for crop-livestock farmers who cultivate cowpeas, these could be an important livestock feed resource especially after harvesting.

2.7.2 Tswana Cowpea (*Vigna unguiculata*)

Cowpea is the major legume used as human pulse, leafy vegetable or fodder for livestock. Cowpea leaves have a high nutritive value. According to Barret (1987) cow pea grain has 24.8 % crude protein (CP), 1.9 % fat and 6.3% fiber and it serves as an important source of protein in the diet of many people. The crude protein levels of leaves and shoots are usually over 20 %, depending on the crop's stage of growth and seasonal conditions while stems usually contain only about 10% of crude protein (Davis et al., 1991). The crude protein levels of the whole cowpea plant are similar to Lucerne (25 %) and greatly superior to most tropical grasses and forage sorghum (Barrett, 1987).

The digestibility of cowpea forage legume is about 50to56 % DM on a whole-plant basis and the leaf is much more digestible than the stem (Davis et al., 2002). The quality appears to vary with the crop's age or with changes in environment (Mortimore and Adams, 1997). According to Mortimore and Adams, (1997), leaf parts have 60 to 75 % digestible dry matter while stems have been analyzed to have 50 to 55 % dry matter digestibility. With regards to animal intake, it declines as leaf availability declines (Cook, 2008). Livestock selectively browse the leaf parts; cattle and sheep prefer to browse leaves than stems (Mirza et al., 2003).

The crude protein in cowpea seed is rich with a high profile of amino acids such as lysine and tryptophan, compared to cereal grains (Jasser, 2010). However, it is deficient in methionine and cysteine when compared to animal proteins (Singh et al., 2003). Cowpea seed is valued as a nutritional supplement for animal feeding compared to cereal grain. In many areas of the world, the cowpea is the only available high quality legume hay for livestock feed in countries like Australia and Canada (Mune et al., 2013). Digestibility and yield of certain cultivars of cowpea is almost same as Alfalfa (Moreki, 2009). Cowpea can also be used as green or dry fodder since legume forages are used as protein supplements, the basal diets usually consists of grasses or cereal fodder (Davis et al., 2002). The grass can be in the form of natural grasses or planted pastures while cereal fodder crops are always planted as crops.

2. 8 Cereal fodder crops (Grass).

Green grasses are a good source of vitamin A, which is present in the form of carotene (Agishi, 1999). It is documented that 1kg of green grass provides 50 mg of vitamin A (Agishi, 1999). This vitamin is necessary to maintain the health and reproductive status of animals. Grasses such as wheat and Rye grass are also good source of protein (15 %) in the form of gluten. One kg of green fodder gives 15 to 20 g of proteins that are required for the animals' health (Smith, 1995). There are different species of grasses such as Timothy, Rye, Gamba, Napier, Buffel and Bermuda grasses that can be mixed with legumes as well as used as a sole crop (Smith, 1995). *Panicum maximum* (Guinea grass), Buffel, Napier and Gamba (*Andropogon gayanus*) grasses are some of the common grasses found in Botswana.

2.8.1 Buffel grass (*Cenchrus ciliaris)*

Buffel grass grows in summer and is tolerant to cold and has a well-developed fibrous root system (Patridge, 2003). It is also found in East Africa, Saudi Arabia, Afghanistan, Pakistan and in India ((Patridge, 2003). It makes a reasonable quality hay when cut in the early flowering stage, yielding up to 250 kg /ha DM (Lee et al., 1999). It can be good cattle feed depending on different cultivars such as Gayndah cultivar, American cultivar (Cameron, 2010). The nutritional value of Buffel grass is not high compared with other pasture grasses. Crude protein values are mostly in the range of 6-16 % DM and digestibility ranges between 50 and 60 %, depending on the age of growth and cultivar. However, it can provide useful fodder if it is well managed (Smith, 1995). According to Aganga et al., (2005), Buffel grass establishes well on loose soils and soft surface. But it grows well in loamy, light textured soil. It requires phosphorus and pH of 5.5. The seeds are spread by wind or water. Buffel grass is sensitive to soil containing high level of aluminum. So, if available phosphate is low, phosphate should be applied at sowing time either as fertilizer or as seed pelleting material (Bogdan, 1977). Nitrogen should be supplied to the pasture, intercropping with legume can also improve the yield (Cameron, 2004).

2.8.2 Millet (*Panicum miliaceum*)

According to NRC (1996), millet is a tall erect annual cereal crop with an appearance similar to maize. The plants are varied in appearance and size, depending on varieties. It grows from 1.7 m to 2.6 m tall. Generally, the plants have coarse stems, growing in dense clumps and the leaves grass-like, numerous and slender, measuring about 2.5 cm wide and up to more than 1.8 m long (Railey, 2009). Millet is a major food crop in many countries, particularly in Africa and in the Indian subcontinent (Railey, 2009). Millet is used as both human and livestock feed. Millet grows well on poorly fertilized and dry soils and fits well in hot climates with short rainfall periods and cool climates with slow warm summers (Wishart, 2001).

The plant needs good drainage and has a low moisture requirement and does not do well in waterlogged soils (Morgan, 1996). Millet grain is highly nutritious, non-glutinous and rich source of magnesium and minerals quinoa (Railey, 2009). It is not antacid forming food so it is easy to digest. In fact, it is considered to be one of the least allergenic and most digestible grains available (Crawford et al., 2003). Millet is tasty, mild sweet, has a nut-like flavor and contains good amount of beneficial nutrients. It contains about 15% protein and high amounts of fiber (Whitehead and Jonnes, 1996). It also contains vitamins B complexes including niacin, thiamin, and riboflavin, the essential amino acid methionine, and some vitamin E (Anne, 1999). It is particularly high in the minerals iron, magnesium, phosphorous, and potassium (Anderson et al., 2000).

Pearl millet (*Pennisetum glaucum*) is one of the most widely grown varieties of millet. It is grown in Africa and Indian subcontinent. It is well adapted to the production system characterized by drought, low soil fertility and high temperature (Myres, 1999). Pearl millet grain is comparatively high in crude protein and has a good amino acid balance (Cade et al., 2007). It is high in lysine (424mg) and methionine (442 mg) and cystine levels. It contains twice as much methionine than sorghum, thus it is an important trait for poultry production (Basavaraj et al., 2010). The hay has high protein (15%) content, highly digestible (65%DM) and free from prussic acid. Therefore, it is an important feed for beef and cattle (Virk, 1988).

2.9 Intercropping

Intercropping is an agricultural practice of cultivating of two or more crops into the main crops using different species in the same space at the same time (Bruulsema, 2066). It is commonly used for cultivating fodder in tropical parts of the world and by various people (Altieri, 1999). Intercropping is common in Europe, Africa, North America and Asia. It benefits crop yield since one of the crop may be a legume that supply extra nitrogen by nitrogen fixing in the soil (Nielson et al., 2001). There are different types of intercropping system such as mixed and alternative intercropping (Opuma, 2010). The second crop must be planted prior to the flowering stage of the first crop (Takashashi, 2005). The main aim of intercropping is to produce maximum yield on a given piece of land by utilizing maximum resources (Satish, 2011).

Planning is necessary before intercropping. Select the crop properly; avoid aggressive and fast growing crops. Crops with short term maturity plant after planting long term maturity plant (Engel and Paterson, 2005). Soil, climate and cultivar should also be considered. Crop which over-spread and utilize more space (aggressive crops) are not suitable for intercropping. The deep rooted plant should be planted first, followed by shallow rooted plant (Jenson, 1996). An example of tropical multi system where coconut palm come first, banana in the middle other species such as ginger, pineapple, fodder and other medicinal plant comes under lower tier (Chand, 1997). Legumes are suitable for intercropping. The root nodules of leguminous plant have the capacity of capturing atmospheric nitrogen and converting it into soluble nitrates. Therefore, the nitrogen fixation process increases soil nitrate (Rămert, 1995). Thus intercropping legumes have ecological benefit such as weed control as well as nutrient stabilization in the soil. Intercropping also reduces pests on crops. For example, the carrot fly, (*Psila rosae)* (F) is a serious pest on carrot (*Dacus carota)* in the temperate region of the world. A study conducted by Ramert (1995) proved that intercropping carrot and Lucerne can reduce *Psila rosae* on carrot (*Dacus carota)*. Silage made from intercropped forage crops usually have high nutritive composition compared to sole one. In an experiment conducted on intercropped maize and cowpea silage at different seed rate ratio of 85:15 and 70:30 showed that intercropped maize and cowpea silage with high seed ratio had a high CP content compared to sole maize silage with low seed ratio (Azim et al., 2000).

2. 9 Fertilizer Effect on Forage crops.

Soil fertility can compromise crop yield. Therefore, knowing the soil status is the first step in place or strategy to remedy the problem. Soil sampling and testing gives status of soil nutrients which are important for crop production (Mckenzie, 1998). Soil nutrients vary in the field; variation can be observed from region to region and also varies from year to year. The nitrogen content in the soil usually varies due to climate and rainfall whereas the level of potassium and phosphorus will not change due to climatic and rainfall effects (McKenzie, 1998). To remedy for low soil fertility, chemical fertilizers are usually applied. The chemical fertilizers can be broadly classified into: nitrogen, phosphorus, and potassium fertilizers. A single straight fertilizer contains only one of the nutrients whereas a compound fertilizer contains two or more nutrients. Mixing of two or more ingredients that would react chemically forms the complex fertilizer (McKenzie, 1998).

One of the most important element impeding crop growth and yield is nitrogen and several chemicals are available which can be used to correct nitrogen imbalances (Zhao et al., 2005). The important nitrogen fertilizers are Ammonium Sulphate ($NH_4 (SO4)_2$). Ammonium Nitrate (NH_4NO_3), Limestone Ammonium Nitrate (LAN) and Urea. The amount of nitrogen fertilizer needed for farming depends on the type of crops, soil status and the expected yield (Dana, 2001). Nitrogen fertilizer does not work well under acidic soils (Vagts, 2005). Limestone Ammonium Nitrate (LAN) in the soil can stimulate seed germination. In dry areas, lime and potassium is needed in large quantities. In waterlogged areas, the soils are acidic as well as the presence of aluminum and manganese, such soils require fertilizers for satisfactory plant growth and yield (McKenzie, 1998).

Fertilizers can stimulate nitrification processes that occur in soil by bacteria. Soil conditions such as moisture, temperature, pH and oxygen supply are essential for nitrate production (Camberato, 2001). Application of Ammonium Nitrate in the soil will maintain deserved soil pH and optimum pH level in the soil is necessary for the growth of nitrifying bacteria. Adding lime to the soil improves soil pH; neutralize soil acidity and increase the rate of nitrification of soil bacteria (Mamo et al., 2009). Urea initializes pH by hydrolysis and provides a favorable environment for nitrification in the soil. Decomposition of urea occurs as soon as it mixes with soil in the presence of water (Brouder et al., 2005). The enzyme urease is present in urea and the moisture content facilitates hydrolysis and release of ammonia (NH_3) and carbon dioxide (CO_2) which elevates pH in the soil (Overdahl et al., 1991).

The soils of Botswana are not rich in minerals for optimal vegetation growth (Parsons, 2010). They lack nitrogen and phosphorous (Field, 1977). Nitrogen deficiency can easily be identified by plant morphology or external appearance. The symptoms are pale green leaves, stunted growth in monocot plant like maize and sorghum the leaves are inverted 'V' shaped and the leaf edges die off without growing (Wood, 1996). Phosphorus and nitrogen are essential macro elements which are important for satisfactory crop growth and production. Nitrogen, copper, iron and manganese are essential micro elements for growth of forage crops (Field, 1978). Sometimes the soil is deficient of these, which can be supplied to the forage by the application of fertilizers to the soil.

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CHAPTER 3

Biomass yield of pure stand crops (mono crops) and intercropped fodder crops of Tswana cowpea (*Vigna unguiculata.L.*), Lablab (*Lablab pursuers*), Buffel grass (*Cenchrus ciliaris, L.*) and Millet (*Panicum miliaceum*) *fertilized with either Urea or LAN* (Limestone Ammonium Nitrate).

Abstract

This study investigated the effect on biomass yield of pure stand and intercropped fodder crops of Lablab, Tswana cowpea, Buffel grass and Millet treated with either Urea or LAN. The study was conducted at Botswana University of Agriculture and Natural Resources (BUAN) at the Notwane farm. The experimental design adopted for this study was a Completely Randomized Design (CRD). For mono-crops, the treatments were Lablab without fertilizer (LC) with urea (LU) or LAN (LLAN). Tswana cowpea without fertilizer (TCC), with urea (TCU) or LAN (TC LAN); Buffel grass without fertilizer (BC), with urea (BU) or LAN (BLAN); millet without fertilizer (MC), with urea (MU) or LAN (MLAN). The treatments for inter-cropped forages were Lablab/Buffel grass without fertilizer (LBC), with urea (LBU) or LAN (LBLAN); Lablab/Millet without fertilizer (LMC), with urea (LMU) or LAN (LMLAN); Tswana cowpea/Buffel grass without fertilizer (TCBC), with urea (TCBU), or LAN (TCBLAN); Tswana cowpea/millet without fertilizer (TCMC), with urea (TCMU) or LAN (TCMLAN).

The results from this study show that dry matter percentage (DM %), fresh yield and dry matter yield of pure stand forages was highly influenced ($P < 0.05$) by crop variety. Pure stand Buffel grass (27.24 DM %) and millet (25.42 DM %) had higher dry matter percentage (DM %) than pure stand of legume forages of Lablab and Tswana cowpea (18.1 DM % and 16.1 DM % respectively). Pure stand cereal forages showed low fresh yield and biomass yield whereas pure

stand legume forages had higher fresh yield and biomass yield. The results further indicated that pure stand of Lablab had the highest fresh yield (52,648.5 kg/ha) and biomass yield (9,976.17 kg/ha) than other crops (4164.2, 3,939.9 and 3,411.7 kg/ha) for Tswana cowpea, Buffel grass, and millet, respectively. The fertilizer Urea or LAN had no effect on pure stand forages dry matter percentage, fresh yield and biomass yield (P > 0.05). However, the LAN treated pure stand crops forages had higher though insignificant P > 0.05) fresh yield mass of 28,488.76 kg/ha than urea treated pure stand crop forages (26, 999.37 kg/ha). The pure stand crops without fertilizer (control crops) showed the lowest fresh yield of 20,432.1 kg/ha than Urea and LAN. For intercropped forages, the results of the study indicated that the intercropped forage materials had significant differences (P < 0.05) in percentage dry matter (DM %), fresh yield and dry biomass yield due to intercropping. The dry matter percentage, fresh yield mass and dry biomass yield were higher in Lablab intercropped with cereals (Buffel and millet) than Tswana cowpea intercropped with the same. In this case, Lablab intercropped with Buffel produced the highest fresh yield (45,548.33 kg/ha) and dry biomass yield (9,103.87 kg/ha) than rest of the intercropped forages. The result also indicated that Tswana cowpea intercropped with millet had the lowest Dry matter percentage (DM %) of 19.28 DM %. than rest of the intercropped forages.In general, Urea or LAN had no effect on intercropped forages' percentage dry matter (DM %), fresh yield and dry matter yield (P > 0.05). The LAN treated intercropped forages had the highest though insignificant fresh yield (38, 882.5 kg/ha) and dry biomass yield (8,096.88 kg/ha) than urea treated intercropped forages. The results further indicated that intercropped forages without fertilizer (control) exhibited the highest yet insignificant fresh yield of 39,123.76 kg/ha than rest of the two treatments (urea or LAN). This suggests that where intercropping is practiced, fertilization with the view of increasing yield would not be necessary.

3.1 Introduction

In high performing animals such as dairy cows, feedlotted animals and young growing animals, high quantity of feeds of high quality are required. For ruminant animals, which rely on roughages due to their digestive system, pastures either natural or cultivated provide a large proportion of their diet. However, the quality of pastures may deteriorate at certain times of the year, necessitating fertilizer application to improve quality and stimulate growth. In general, fertilizer application may be costly, especially to resource limited farmers and there also may be danger of pollution of water resources by chemical fertilizers. Therefore, legumes combined with appropriate grass has the potential to improve the quality and increase quantity of the fodder and reduce the use of fertilizer (Stubbs, 2000). Grass species such as Star, Kikuyu, Napier, Bana and Guinea are suitable for semi-arid conditions but their nutritive value is low, to produce the production levels seen in commercial dairy or feedlots without supplementation.

On the other hand, Lablab and cowpeas are legumes that are cultivated as fodder for livestock and grain and vegetables for human, respectively. Crop residues after cowpea grain harvesting are valuable feed resource for small-scale livestock farmers (Singh et al., 2011). They are good quality feed because they contain high levels of proteins (Barret, 1987). Fodder quality is affected by several factors; adequate temperature (25°C - 30°C), soil moisture and nutrients and these are essential for optimal growth of pasture species (Collar and Aksland, 2001). The leaf area and its growth rate affect the total yield of pasture. If the leaf density increases it give more forage mass. The more leaf area the more forage mass and yield. To achieve these growth rates fertilizer applications is normally used for pastures in semi-arid areas (APRU, 1980). It is generally practiced after soil testing which determines the status of minerals like potassium (K) phosphorus (P), Nitrogen (N) calcium (Ca) and Magnesium (Mg) since they are major mineral for plant growth.

Sandy soils, typical of most soils in Botswana require high levels of nitrogen and organic matter to promote the required yields because it does not contain enough minerals (Burdige, 2007). Nitrogen is essential for plant growth and is one of the major factors limiting crop yield (Zaho et al., 2005). There is a need to use the required amount of nitrogen (ideally 67kg/ha) to obtain maximum growth rate at any time during the growing seasons and for reproduction (Sheehy et al., 1998). Nitrogen is also essential for photosynthesis (Oosteroma et al., 2001). For instance, application of nitrogen fertilizer increases sweet sorghum stem yield and corn fodder yield (Galani et al., 1991). These fodder crops are made of structural carbohydrates, which cellulose is the most abundant. Many mono-gastric animals, including man are not able to utilize fiber carbohydrates, but the ruminant animal is able (Bonjar, 2000). Ruminants are therefore important in human food chain in that they convert poor quality protein and fibrous non-protein nitrogen resources into high quality protein as meat and milk (Eskandari et al., 2009). Such resources include cereal plants, their residues and grasses.

The use of cereals for livestock feed in developing countries has increased (Bonjar, 2000). Cereals such as wheat, sorghum, millet and maize are grown for forage as well as for human consumption in Asia (Mpairwe et al., 2002). Elsewhere (North America) wheat and maize are important and mainly used in the rations of ruminant animals since they supply large amounts of energy for animals (Leaver and Hill, 1992). Cereal forage contains low crude proteins (7-9 %) so it is necessary to provide livestock with protein supplements (Machado, 2009). It is a well-known fact that commercial proteins feeds are expensive. Source limited farmers in developing countries may not be able to afford them and hence may not attain high efficiency of livestock production. Increasing quality of available forage is one of the best methods to improve overall feed efficiency. Legumes are good sources of protein and can be used to compensate for cereal protein shortage (Gebrehiwot et al., 1996). Thus, intercropping cereal forage with legumes can increase protein content in fodder crops. Intercropping has also many other advantages. It can improve soil fertility by nitrogen fixation by leguminous crops (Aganga, and Tshwenyane, 2003). The system of companion plants also reduces pest attack, weeds and diseases (Hauggard et al., 2001). In Botswana, the major constraint for increasing livestock production is lack of adequate feed (quantity and quality) particularly during the dry season (Mosimanyana and Kiflewahid, 1987). The aim of this study was to determine the effect of applying Urea or LAN on the biomass yield of pure stands as well as intercropped fodder crops of Lablab, Tswana cowpea, Buffel grass and millet.

3.2 MATERIALS AND METHODS

3.2.1 Study Area

The study was conducted at Botswana University of Agriculture and Natural Resources (BUAN) at the Notwane farm. Notwane farm is situated in Sebele about 10km North of Gaborone city center and 5km away from Botswana University of Agriculture and Natural Resources (BUAN), along the Gaborone - Francistown (A1) road. According to Botswana Meteorological Report (Parsons, 2005), the study site experiences semi-arid climates. The area receives annual average rainfall of 406 mm from October to March and the temperatures ranging from 6°C (minimum) in July and 32°C maximum in December (Hogan, 2008). The study site has zonal soil, (sandy soil) which is formed and influenced by climate (FAO, 2001). The soil samples were analyzed to determine nutrient status. The study site is surrounded by mixed Acacia, species such as *Haemato xylomellifera*, *Haemato Xylongriaffae*, *Boscia albitrunca*, *Diachtorachys cinerea*, *Bauhimia macrantha*, *Terminalia sericea* and *Acacia saligma* (in Africa, *Acacia erioloba* is known as Camel thorns (Field, 1978).

3.2.2 Pre - Planting Activities.

Prior to the experiments or planting forage crops, soil samples from the experimental sites were collected and analyzed for nutrients and pH. The results from the soil samples showed that soils had a pH of 4.9, low phosphate level with an average of 6.8 ppm and organic carbon with an average of 0.3 wt % (Soil Analysis Report, 2008). The normal optimum values required for soil pH should be > 6, phosphate of > 10.0ppm and organic carbon of > 0.2 (Soil Analysis Report, 2008). The results from the soil samples further indicated that the concentration of macro elements such as calcium (Ca), magnesium (Mg) and sodium (Na) were low. For example, the average calcium concentration was 0.04 ppm, magnesium was 0.05 ppm and sodium had a concentration of 0.4 ppm. The normal optimum concentration required for calcium is > 1.00 ppm, magnesium is > 0.030 ppm and sodium is < 1ppm as indicated in Soil Analysis Report, (2008). The soil analysis indicated that mineral nutrient of the study site was not adequate for crops. Therefore, basal dressing of lime was applied at 2 ton/ha, organic manure at 2 ton/ha and super phosphate at 100kg/ha. Urea and Limestone Ammonium Nitrate (LAN) were the major nitrogen suppliers in this experiment. Urea is normally selected as a nitrogen fertilizer for crops due to its fast decomposition rate, availability and as it is economical (Wood, 1996).

3.2.3 Experimental crops and method of cultivation

The following fodder crops were used in this study: Lablab, Tswana cowpea crops (legumes) and millet and Buffel grass (cereals). The crops were cultivated as single crops (pure stands) as well as intercropped system. The choice of these crops was on the basis of their availability and that they could easily be established in the semi-arid area (Railey, 2009). The intercroppings were as follows; Lablab with *Buffel* grass, Lablab with millet; Tswana cowpea with Buffel grass and Tswana cowpea with millet.

3.2.4 Experimental Design and Treatments

The experimental design adopted for this study was a Completely Randomized Design (CRD). The study site was divided into six subdivisions. The total area of the experimental field was 1,165 m^2 comprising of 96 smaller plots as shown in the experimental area layout in Appendix 1. Each division was 192 m^2 and was further divided into 16 smaller plots, measuring about 12 m × 1m (12 m^2). The spacing between the smaller plots was 2.5 m. The experiment was based on 4 x 3 arrangements (4 crops with 3 fertilizer applications; Urea or LAN or Control). The unfertilized crops were used as controls. Each experimental crop was replicated four times. Therefore, there were 12 plots of control crops, 12 plots treated with Urea and 12 plots treated with LAN that were planted as pure stand crops. Similarly, there were 12 controls of intercropped, 12 intercropped crops treated with Urea and 12 intercropped crops treated with LAN.

3.2.5 Planting

Prior to planting experimental field was ploughed, weeds were removed and basal dressing of lime and super phosphate was done as indicated earlier. Seeds were sown in October 2009. Urea or LAN fertilizer was applied manually at a rate of 100kg/ha two weeks after the germination of the seeds. This was done because at this stage the roots of the plants were mature enough to absorb the fertilizers. The plots were irrigated using treated sewage water from Gaborone city ponds by drip irrigation carried out at intervals of alternative days in a week (Sunday, Tuesday, Thursday and Saturday).The composition of the elements (heavy metals) present in the sewage water was previously determined and it was found that the concentration of the elements such as lead (10mg/L), mercury (0.05mg/L), and cadmium (5mg/L) in treated sewage water was low and at an acceptable rate as indicated by Food and Agricultural Organization (FAO, 2001; Aganga et al., 2005). Sewage water did not harm growth of the crops.

3.2.6 Biomass determination.

The crops were manually harvested ninety days after planting before they become over matured. The crops were harvested plot-by-plot using a sickle and collected in black plastic bags. The harvested forages were sorted into pure stand or intercropped crops as well as on three treatments (Urea or LAN and Control). The harvested green forage was weighed separately and the weight was recorded according to the treatments mentioned above. Finally, the biomass of the harvested crops was calculated by dividing the green forage weight (kg) obtained from each plot by the area of the plot and expressed in hectare (ha).Dry matter was obtained by a representative sample from each harvested materials and determining dry matter at the laboratory (BUAN). Dry matter yield (DM) can be calculated by subtracting oven dried weight (DW) of the sample forage from initial fresh weight (FW) of the forage expressed as percentage or g/kg. In short, DM = FW - DW.

3.2.7 Data Analysis

The data on biomass yield was analyzed for analysis of variance (ANOVA) using Proc GLM procedure of SAS (2002 - 2008). The analysis tested the effects of plant variety, fertilizer application and plant variety x fertilizer application interaction on percent dry matter, fresh yield and dry matter yield for the pure stand crops. For the intercropped, the effects of intercropping, fertilizer application and intercropping with fertilizer application interaction on percent dry matter (DM %), fresh yield and dry matter yield. Where interaction had no effect, interaction was removed from Model 1 and Model 2 used. Where differences were observed, multiple comparison of means was conducted using the Least Square difference (LSD) was used to compare means and the minimum significance level was $P < 0.05$.

The following models were used in this study:

Model 1 = $Y_{ij} = \mu + C_i + F_j + CF_{ij} + e_{ij}$

Model 2 = $Y_{ij} = \mu + C_i + F_j + e_{ij}$

Where 'Y_{ijk}' is dependent variable of the 'i^{th}' crops or intercropped at 'j^{th}' fertilizer application, μ is the overall mean, C_i is plant variety or intercropping, 'F_j' is the fertilizer application and 'CF_{ij}' is variety or intercropping x fertilizer application.'μ' is the overall mean and 'e_{ij}' is the random variation treatment effect or error.

3.3 Results

According to Table 1, dry matter percentage, fresh yield and biomass yield of pure stand crops were significantly different ($P < 0.01$) due to crop type. Pure stand crops of cereals (Buffel grass and millet) showed low fresh yield and dry biomass yield whereas legume pure stand crops had higher fresh and dry biomass yield. The results also indicated that pure stand legume forages showed the lowest dry matter percentage (DM %) of 16.10 and 18.10DM % for Cowpea and Lablab respectively (Table 1).

Table 1: Effect of forage type on DM %, fresh yield and Dry matter yield of pure stand forages.

Pure stand crops	N[1]	DM (%)	Fresh yield(kg/ha)	Dry matter yield (kg/ha)
Buffel	12	27.24^{a}	13,838.75^{c}	3,939.87^{b}
Millet	12	25.122^{a}	8,418.17^{d}	3,411.66^{b}
Lablab	12	18.10^{b}	52,648.50^{a}	9,975.17^{a}
Tswana cowpea	12	16.10^{b}	26,217.50^{bc}	4,164.17^{b}
SE		0.87	4888.05	1043.34
SL		0.001	0.001	0.001

[1]N = Number of plots; kg/ha = Kilogram per hectare; DM-= Dry Matter; SE= Standard Error, SL = Significant level at $P < 0.05$

According to the result in Table 2, there is no significant difference in DM %, fresh yield and biomass yield due to fertilizer urea or LAN ($P > 0.05$). The DM %, fresh yield and dry biomass yield were found to be similar between three treatments.

Table 2: Effect of fertilizer on DM %, fresh yield and Dry matter yield of pure stand forages.

Treatments (Fertilizer)	N[1]	DM (%)	Fresh Yield (kg/ha)	Dry matter yield (kg/ha)
LAN	12	21.63	28,485.76	5,477.53
Urea	12	21.37	26, 999. 38	5,104.76
Control	12	22.51	20,432.70	5,535.86
SE		0.75	4042	903.56
Sl		0.93	0.45	0.45

N = Number of plots; kg/ha = Kilogram per hectare; DM-=Dry Matter; SE = STD Error, SL = Significant level at $P < 0.05$

According to Table 3, the type of intercropping had an effect ($P < 0.05$) on dry matter percentage, fresh yield and dry matter yield. Lablab intercropped with cereals (Buffel grass and millet) showed high level of fresh yield and dry matter yield than Tswana cowpea intercropped with cereals.

Table 3: Effect of intercropping forage arrangement on DM %, fresh yield and Dry matter yield of intercropped crops.

Intercropping	N	DM %	Fresh yield (kg/ha)	Dry matter yield (kg/ha)
Lablab+ Buffel	12	20.05[a]	45,548.33[a]	9,103.87[a]
Lablab+ millet	12	21.74[b]	41,938.75[a]	8,605.00[a]
Tswana cowpea + Buffel	12	19.28[a]	30,560.83[b]	5,923.54[b]
Tswana cowpea + millet	12	21.80[b]	28,617.50[b]	3,066.00 [b]
SE		1.07	3809.50	768.42
SL		0.01	0.01	0.01

N = Number of plots; kg/ha = Kilogram per hectare; DM = Dry Matter, SL = Significant level at $P < 0.05$

The effect of fertilizer (urea or LAN) on DM %, fresh yield and biomass yield were not significantly different ($P > 0.05$) as shown in Table 4. Nevertheless, fresh yield and biomass yield were varied in all three treatments in a non-significant way. The LAN treated intercropped forages had a higher but statistically insignificant fresh yield of 38,882.5 kg/ha and biomass yield of 8,096.88 kg/ha than urea fertilized intercropped forages. Crops without fertilizer (control intercropped forages) showed the highest though insignificant fresh yield of 39, 123.76 kg/ha than urea but were similar to LAN treated intercropped forages. The DM % among all three treatments was found to be similar as shown in Table 4

Table 4: Effect of fertilizer on DM %, fresh yield and dry matter yield of intercropped forages

Treatments (Fertilizer)	N[1]	DM (%)	Fresh yield(kg/ha)	Dry matter yield (kg/ha)
LAN	12	21.26	38,882.5	8,096.88
Urea	12	20.56	31,992.81	6,243.61
Control	12	20.34	39,123.76	7,926.22
SE		0.93	3299.12	665.5
SL		0.77	0.23	0.11

N= Number of plots; kg/ha = Kilogram per hectare; DM = Dry Matte SL= Significant level at $P < 0.05$

3.4 Discussion

3.4.1 Biomass Yield of Pure stand forages

The results in general showed that different pure stand forages produced different amount of biomass. Cereal pure stand varieties of the crops, Buffel and millet showed similar dry matter percentage (27.12 and 25.122 DM %). The biomass yield of the cereal crops were lower compared to that of legume crops as shown in Table 1. This could be due to the fact that: establishment of Buffel plant needs sandy soil (Hackert, 1996). It is documented that Buffel grass establishes well in sandy, loamy and light textured soils. Buffel grass has a fibrous root structure that spreads on the surface of the soil (Mirza et al., 2002). Light, sandy and loamy textured soil could help easy establishment of such fibrous roots (Mirza et al, 2002). In addition, low phosphorus and pH (5) could affect Buffel grass growth. As a result, the experimental field might not have been conducive to promote higher forage yield of Buffel grass. Pure stand millet also showed a low forage yield. Generally, millet grows well in poorly fertilized dry soils. However, ordinary millet (*Panicum miliaceum*) requires cold climate with moderate (19 - 22^{0}C) temperature for its normal growth (Hackert, 1996). In the present study, the forage seeds were planted in summer (October, 2009) and the temperature was 32°C. The experimental area may not have been suitable for the healthy growth of the millet that resulted a low forage yield.

The highest fresh and dry matter yield was obtained from Lablab i.e. 52,648 and 9, 975.17 kg/ha, respectively. This was significantly higher than Tswana cowpea. Kay (1979) reported that Lablab grows well in a wide range of soil types, from deep sands to heavy clays. Lablab grew well under phosphate fertilizer and on semi-arid climate with an average rainfall of 200 – 250 mm (Pederson, 2006). The current study site was probably similar to Kay (1979)'s which to my observation was quite conducive to the growing of legumes such as Lablab. There are varieties of cowpeas such as IT89KD-391, IT93K-452-1, IT90K-277-2, and their growth pattern also varied among them (Singh, et al., 2002). In fact, some of the vigorous, vining varieties of cowpeas as well as semi erect varieties give high forage yield (Davis et al., 1999). The cowpea used in this experiment must be low forage yield variety; it could be grain yield variety. This could be the reason why Tswana cowpea had low biomass yield.

A study conducted by Etna (2013) on herbage yield of cowpea and Lablab showed that the fresh yield and dry matter yield of Lablab was higher than that of cowpea yield. Another study conducted by Alemseged and King (1996) on Lablab, cowpea and maize yield indicated that biomass yield was higher in legume crops than cereal ones. A study conducted by Azim et al., (2000) on fodder yield of cereals such as maize and cowpea indicated that cowpea yield was higher than that of maize fodder yield. The current study result is in agreement with the above studies. However, when comparing the two legumes, the biomass yield of Tswana cowpea was lower than that of Lablab.

3.4.2 Biomass Yield of Intercropped forages

This study also investigated if intercropping legumes with cereal grass had any effect on dry matter percentage, fresh yield and dry matter yield. The results showed that intercropping had effects on dry matter percentage, fresh yield and dry matter yield as shown in Table 3. This could be due to the following reasons: the system of intercropping is an important factor which affects the quantity due to N fixed by legumes (Rerkasem et al., 1988). This is so because, Buffel and millet in this experiment are smaller crops and has a surface spreading fibrous root system which is likely to absorb water and nutrient more quickly from the soil (Carr et al., 1998). As a result this is likely that they benefit from the legumes component of cowpeas and Lablab as they fix N from the atmosphere (Haggard et al., 2001). Thus, cereal crop gets its required nitrogen from the soil and cowpea from biological fixation of atmospheric N. In intercropping, cereal crops are most likely to get more nitrogen .Because of this forage yield of cereal crops would be improved by intercropping due to more nitrogen availability for cereal crops (Jensen, 1996).

The results also showed that Lablab intercropped with cereals had the highest biomass yield (9,103.87kg/DM). The Lablab leaves, stems are thick and denser, leaves are large and trifoliate, having a broad ovate-rhomboid shape leaves measuring of 7 to 15 cm long (Murphy and Colucci, 1999). Therefore, the plant features like thick stem and broad leaves are likely to contribute to higher biomass yield compared to Tswana cowpea. Apart from that, Lablab grow vigorously compared to Tswana cowpea (Singh, 1995). A study conducted by Lemlem (2013) reported that intercropping Lablab with sorghum results in higher biomass yield than clover intercropped with sorghum. The results of the present study are comparable with that of the study conducted by Lemlem (2013).

Cowpeas and Lablab are commonly used in intercropping, especially cowpea with cereal crops due to the following reasons: the root nodules of leguminous plant have the capacity of capturing atmospheric nitrogen and converting it into soluble nitrates. Therefore, the nitrogen fixation process increases soil nitrate (Rümert, 1995). According to Khan et al., (1987) intercropping with cereal such as maize or sorghum seems to be a logical technique to increase forage yield since legume crop produces nitrates in the soil that stimulate cereal crops that enables better growth and yield. This logic can be adopted for fodder production especially in mixed crop system practiced in Botswana.

Several studies showed that intercropping had an effect on forage yield. They are as follows: in an experiment conducted by Singh (1995), intercropping cowpea with millet, which were irrigated, and insects controlled showed higher forage and grain yield. In a similar study, the effect of biomass yield of cowpea intercropped with maize showed higher biomass yield (Eskandari et al., 2009). Another study conducted by Zougmore, et al., (2000) showed that the intercropped sorghum/cowpea produced higher forage yield compared to individual sorghum and cowpea. Another study conducted by Azim et al., (2000) showed that maize/cowpea intercropped forages had higher biomass yield as that of maize alone. In another study, maize, sorghum and wheat intercropped with Lablab showed that the intercropped cereal forage yield was high compared to pure stands cereal crops (Mpairwe et al., 2008). Similar to the above mentioned studies, the present study result also showed that intercropping had positive effects on dry matter percentage, fresh yield and dry matter yield as shown in Table 3.

3.4.3 Effect of Urea or LAN on pure stand and intercropped forages Biomass yield

The current study results indicated that the nitrogen fertilizer (Urea or LAN) had no effect on pure stand crops or intercropped forages' dry matter percentage, fresh yield and biomass yield. This could be linked to the following reasons: nitrogen fertilizer work very well in moist soils. The enzyme *urease* present in urea and the moisture content in the soil facilitates hydrolysis and release of ammonia (NH_3) and carbon dioxide (CO_2) which elevate pH in the soil (Overdahl et al., 1991). The nitrogen fertilizer supplied to the field, may not be fully absorbed by the crops. Some of it always stays in the soil, especially if too much fertilizer has been applied (Sarwar, 2010). Water or moisture content is also an important factor that influences the crops to absorb nitrogen fertilizer from the soil. Although the crops were watered by drip irrigation but the moisture content of the experimental field might not be enough for the utilization of urea or LAN. Perhaps this could be the reasons why pure stand crops or intercropped forages treated with UREA or LAN had no significant effect on their fresh yield, dry matter percentage and biomass yield. For legume crops, it is also possible that their nitrogen fixation was able to meet nitrogen requirements of plants, hence lack of effect of fertilizer application. Since the control also had similar biomass yield as fertilizer application, it could be that previous soil fertilization was sufficient for the plants hence cancelling the fertilizer effect. Perhaps, these could be the reasons why UREA or LAN treated pure stand or intercropped forages dry natter, fresh yield and biomass yield were not significantly different from the unfertilized crops.

Generally, intercropping provided a better biomass yield, if the crops were fertilized the yield would be expected to be even higher (Eskandari et al., 2009). Soil nitrogen availability is an important factor for forage production. Since nitrogen compounds are present in the soil in very small quantities, farmers have to keep on adding them when they want to cultivate crop plants (Niggli, 2010). Plants need nitrogen for their metabolic processes and also for growth. Nitrogen is a key component of amino acids, the building block of proteins and chlorophyll which stimulates growth and increase forage yield (Willey, 1979). Studies indicated that nitrogen fertilizer could improve forage field (Almodares et al., (2009. Another study conducted by Hassan et al., (2010) indicated that nitrogen fertilizer urea had no effect on cowpea forage yield. Similar result was reported by Khogali et al., (2011) which showed that Lablab fodder fertilized with nitrogen had no effect on Lablab fodder yield. A study conducted by Davenport, (1996) also reported that intercropped can beery yield and fruit quality showed that nitrogen treated crops had no effect on their crops and fruit yield. The current study results were consistent with results of Almodare's (2009), Khogali's (2011), Davenport (1996) and Hassan (2010).

Conclusion

The aim of the study was to investigate the effect of Urea or LAN on percentage dry matter and the biomass yield of intercropped and pure stand forage crops of Lablab, Tswana cowpea, millet and Buffel grass. The following conclusions can be drawn from this study:

- Legume forages showed higher biomass yield (Lablab and Tswana cowpeas) than cereal forage crops (Buffel grass and millet).
- Pure stand Lablab had higher fresh yield and biomass yield than pure stand Tswana cowpea.
- LAN or Urea had no effect on both intercropped and pure stand forages biomass yield. However, LAN treated intercropped forages had slightly higher and statistically insignificant level of biomass yield than Urea treated intercropped forage.
- Intercropped forages produced different amounts of biomass yield and dry matter content.
- Lablab intercropped with cereal crops had higher biomass yield than Tswana cowpea intercropped with cereals.

Recommendation

The following recommendations could be drawn from this study:

- Legume crops like Tswana cowpeas can be a suitable forage crops that can grow well in Botswana. In addition to already adopted Lablab.
- Intercropped farming method is a good technique, which can provide higher biomass yield and should be used to produce more forage yield.
- Crops should be well irrigated after the application of urea or LAN in order to improve nitrification process in the soil.
- Should fertilizer be used; compared to intercropping. Economic investigation to compare intercropping and fertilizer use should alone. Further research is needed on this topic.
- A similar study is conducted again to verify the present study results.

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CHAPTER 4

Chemical Composition of silage made from pure stands and intercropped fodder crops of Lablab (*Lablab purpureus*) Tswana cowpea *(Vigna unguiculata)*, Buffel grass *(Cenchrus ciliaris)* and millet (*Panicum miliaceum*) fertilized with either Urea or LAN.

Abstract

This study was carried out to determine the effect of chemical and mineral composition of silage made from pure stands and intercropped fodder crops of Lablab, Tswana cowpea, Buffel grass and millet, fertilized with either Urea or LAN and no fertilization. The mean content of ash NDF and CP of silages made from pure stand crops were significantly (P < 0.05) different due to crop type except the ADL (P >0.05 content). The same crop silages were not affected by Urea or LAN (P > 0.05). Macro element concentration of phosphorus and sodium of silages made from pure stand crops tended to be different between silages (P ≥ 0.05). However, difference in magnesium (Mg) concentration between different silages was highly significant (P < 0.05). Urea or LAN had no effect (P > 0.05) on macro elements concentration of the same silages. The effects of crop type of pure stand crops silages or fertilizer application on micro element concentrations were also not significant (P > 0.05).

On the other hand chemical composition of intercropped silages was not affected by crop type (P > 0.05). Nevertheless, crude protein (CP) and ash content of the same silages tended to be (P ≥ 0.05) different due to crop types. The results further showed that urea or LAN had no effect on the chemical composition of the same silages except for NDF (P < 0.05). Effect of intercropping on macro elements concentration showed that calcium (Ca) of silages was significantly different concentration (P < 0.05) while magnesium (Mg) concentration tended to be different (P ≥ 0.05) due to forage type.

Effect of fertilizer application or no application on concentrations of P, Ca, Mg, and Na of intercropped silages was the same (P > 0.05). Effect of intercropping as well as Urea or LAN treatment or no fertilizer application on micro element concentration of silages was not significantly (P > 0.05) different. However, the result further indicated that concentration of iron (Fe) was significantly (p < 0.05) different due to intercropping as well as with or no fertilizer application. These results imply that silages from legumes have higher nutritive value than pure stand cereal fodder silages. However, fertilizer application may not be necessary due to the absence of differences in nutritive value between urea or KAN and no fertilizer application. Fertilizer application may not be necessary when legumes are used as forage for silage making. Intercropping between legumes and cereal fodders causes differences in the nutritive values of their silages. However, as was the case with pure stand crops, fertilizer application may not be necessary. The lack of differences due to fertilizer application may be due to high fertility of the soil or history of fertilizer application.

4.1 Introduction

Inadequate forage production and quality is one of the most important nutritional challenges that need to be overcome in order to lessen seasonality of animal production. Forage quality can be defined in many ways. The definitions can be associated with nutrients, energy, protein, digestibility, fiber, mineral, vitamins and, occasionally with animal utilization (Van Niekerk et al., 2007). Quality of forage is influenced by forage type or variety, forage maturity, soil fertility and or fertilizer application (Bengtsson et al., 2003). On the other hand forage supply can be increased through the use of irrigation, improved forage species, cultivars and fertilizer application (Frawely, 1980). However, after production, utilization and shelf-life of such produced forage can be a challenge to farmers. Silage making is a useful method of fodder conservation to ensure the supply of quality forage to livestock throughout the year. It also avoids difficulties associated with hay making during rainy season (Titterton and Massdorp, 1997).

Feed supply for livestock can be increased by purchasing fresh or conserved feed from other farms or by ensiling agricultural or industrial by-products such as apple pomance, corn stover, and fruit rejects, waste potato and rice straw (Chin, 2002 and Crawshaw, 2001). However, purchase of forage may not be economical due to transporting bulky feedstuff from far away farms. Hauling forage such as silage from far away farms is also not economical as part of it is moist and this contributes to high cost and high carbon footprint. Therefore, producing ones' own silage may be worth exploring. Conserved forage made from a highly digestible crop can support increased rates of animal production since it has high nutritive value (Ahmad et al., 2007). Often silage from grasses and cereal crops has less protein content (Ayoub et al., 2004). On the other hand, if legumes do not undergo proper fermentation, it may result in poor silage due to lack of sufficient fermentable carbohydrates (McDonald et al., 1991). Therefore, a mixture of grasses and cereal crops with legumes may improve the quality of forage available for silage making.

Ensiling of energy rich cereal with legume material could be used to produce protein rich silage (Steen et al., 2002).

Generally, poor storage and harvest conditions lead to sugar losses when forage becomes weathered. This is because forage that is harvested and not properly dried continues to respire, causing soluble sugars to decrease (Linn and Martin, 1999). Under such conditions, silage becomes an ideal conservation method since oxygen is excluded and respiration is curtailed. The demand for animal products such as milk, meat and other protein resources are increasing, therefore there is a need to increase the productivity of forage available to ruminants without degrading natural resources. This can be achieved by increasing the production of cultivated forages. Increasing forage production can be achieved by mixing legumes and grasses or cereal crop due to high dry matter of legumes. Intercropping of cereals with legumes can also increase forage nutritive qualities. If it is fertilized, forage qualities are increased even more (Eskandari et al., 2009).

In Botswana, the production of silage, hay and fodder is still limited and is mainly done by commercial and institutional farms (Aganga et al., 2004). Therefore, livestock farmers including small-scale should be encouraged and taught how to produce silage in order to increase the productivity of their land and livestock. Fertilizer application is another way of increasing productivity of cultivated fodder crops. Mahmud et al., (2003) reported that application of nitrogen fertilizer increased crude protein in fodder and dry matter yield in forage sorghum. Currently, there is no information about silage making under Botswana conditions and let alone information on nutritive value of such silage. In the current study, the major aim was to evaluate nutrient composition of silage made from pure stands and intercropped fodder crops of Lablab, Tswana cowpea, Buffel grass and millet fertilized with either urea or LAN.

4.2 MATERIALS AND METHODS

The experimental forage crops such as Buffel grass, millet, Lablab and Tswana cowpea were planted in 96 plots measuring 12 m × 1m (12 m2) each was as described in Study 1. The crops were fertilized either with Urea or LAN or without been fertilized. The intercropping was arranged such that a grass or cereal is intercropped with a legume as follows; Lablab with millet, Lablab with Buffel grass; Tswana cowpea with millet, and Tswana cowpea with Buffel grass. Each arrangement was replicated four times. The planting was done at the end of October 2009 roughly on 20th - 31st. Accordingly, the crops were supposed to be harvested ninety days after planting. But due to some challenges (e. g. Lack of man power) the crops could not be harvested in the anticipated time and were harvested a week late i.e. January 31st and completed in February 5th 2010.

4.3 Silage Preparation

Four types of silages were prepared from pure stands crops of Lablab, Tswana cowpea, Buffel grass and Millet. Silages were also prepared from intercropped fodder crops as follows: Lablab with Buffel grass, Lablab with millet, Tswana cowpea with Buffel grass, Tswana cowpea with millet. Immediately after being harvested, the forage crops were chopped into small pieces of approximately 2 - 4 cm lengths. About 500g of chopped forage was placed into 50 x 25 cm clear plastic bags and compressed well using hands until all the air was removed. The bags were sealed and tightened with a cotton string and finally placed in a non-transparent bag (black plastic bag) and kept for 40 days for ensiling process. Ninety-Six (96) silo bags were used in this experiment for each pure stand crop and for intercropped ones, respectively.

After ensiling, the sample bags were opened to carry out various analysis of the silages such as the physical characteristics (smell, color and texture) and chemical composition. All the analysis was done in the Animal Nutrition Laboratory of Botswana University of Agriculture and Natural Resources (BUAN).

4.4 Chemical composition of the silages

Assessment of dry matter content (DM), Neutral Detergent Fiber (NDF), Acid Detergent fiber (ADF), Acid Detergent Lignin (ADL), macro mineral calcium (Ca), Phosphorous (P), Magnesium (Mg) and Sodium (Na) and micro minerals Iron (Fe), Copper (Cu), Zinc (Zn), and Manganese (Mn) was carried out on the silage material.

4.4.1 Determination of DM and moisture content of the silages

The silo bags were identified and labeled with respective plot numbers. A fraction of silage (250g) was taken from each silo bag and placed into a brown oven-proof bag in which plot numbers are indicated. The sample was weighed and the weight was recorded as moisture content corresponding to the plot numbers. This was followed by putting the silage in an oven drier at 60^{0}C for 48 hours. After drying, each sample was taken out of the oven, weighed again and the weight recorded. The final dry matter of the silage was calculated using the following formula; DM= Final dry weight (g) ÷ Initial wet weight (g) ×100 (AOAC, 1 990).

4.4.2 Silage Physical Characteristics.

Characteristics of the silage can be determined partially by its physical qualities such as colour, texture and smell according to AIC, (2003) and McDonald et al., (1991).

4.4.3 Nutrient Analysis of the Silage

The chemical composition of the silages was determined according to AOAC (1990) procedure. All 96 sub-samples of the oven dried silages were grounded, labeled and securely stored in a 250 ml glass jar. Kjeldhal procedure (AOAC, 1990) was used to analyze silage percentage nitrogen (N %) and crude protein content. The following formula was used to calculate N % and crude protein (CP);

$$\text{Dilute factor} = \frac{\text{digest volume (ml)}}{\text{Aliquot distilled}}$$

$$\%N = \frac{(\text{titer- blank}) \times \text{acid N} \times \text{Dil. Factor}}{\text{Weight of sample}}$$

Crude Protein (CP) = % N x 6.25

ANKOM 200/220 FIBER ANALYZER was used to determine the fiber component of the silage (NDF, ADF and ADL), where the macro and the micro elements were determined using Inductively Coupled Optical Emission Spectrometer (ICP) in the Crop Science Laboratory of Botswana University of Agriculture and Natural Resources (BUAN). Phosphorus content of the silage was determined using the Ultra Spectro Photometer (AOAC, 1990).

The following formula was used to calculate fibers.

$\% NDF = 100 (W_3-(W_1 \times C_1) \div W_2$

W_1= Bag tare weight

W_2= Sample weight

W_3= Dried weight of the bag with fiber

C_1= Blank bag correction (final oven dried weight ÷ Original blank bag weight)

$\% ADF = 100 (W_3-(W_1 \times C_1) \div W_2$

W_1= Bag tare weight; W_2= Sample weight

W_3= Dried weight of the bag with fiber

C_1= Blank bag correction (final oven dried weight ÷ Original blank bag weight)

% ADL =100 (W4 - (W1 x C1) ÷ W2

W_1 = Bag tare weight

W_2 = Sample weight; W_3 = Dried weight of the bag with fiber after acid digestion and drying

W4 = Weight loss upon ignition (weight of ashing beaker and filter bag sample (W_1 minus weight of beaker + ash; C_1 = Blank bag correction (weight loss up on ignition (W_4) ÷ Original blank bag weight.

4.5 Data Analysis

The data was analyzed for analysis of variance (ANOVA) using General Linear Model (GLM) procedure of SAS (2002-2008). The ANOVA was determined to find effect of intercropping, or crop type, fertilizer application and their interaction on chemical composition and mineral content of silages. Where differences were observed, multiple comparison of means was conducted using the least squares means separation which was performed using the PDIFF option (GLM Procedure in SAS (2002 - 2008) and P < 0.05 level was considered as minimal significant level. The following model was used in this study:

$Y_{ijk} = \mu + t_i + f_{ijk} + e_{ij} + t_j \times f_{ijk}$ where; Y_{ijk} is nutrient or mineral composition of the j^{th} crops at i^{th} treatment of the experimental unit. Where μ is the overall mean; t_{ijkl} is the treatment (intercropping) or crop type; f_{ijk} is fertilizer application (fertilizer); $t_{ijkl} \times f_{ijk}$ is interaction between treatment and fertilizer; e_{ij} is the random variation of the treatment effect.

4.6 RESULTS

4.6.1 Physical Characteristics of the experimental silage

All the silo bags were opened after 40 days of ensiling processes. Immediately after opening a silo bag, the silages were observed and their physical characteristics such as smell, colour and

:xture were recorded. The physical observation of the silage made from pure stand or ıtercropped fodder crops of Lablab, Tswana cowpea, millet and Buffel grass fertilized with urea r LAN are shown in Table 5.

:able 5: The Silage Physical Characteristics, observed by the researcher

Crops	Colour	Smell	Moisture%	Texture
Lablab	Dark	Ammonia smell	82.3	Slippery
Tswana cowpea	Dark	Ammonia smell	81.2	Slippery
Millet	Bright yellow	Fruity smell	74.5	Firm & smooth
Buffel grass	Bright yellow	Fruity smell	72.4	Firm & smooth
Lablab + Millet	Darkish yellow	Fruity--smell	78.5	Moist & soft
Lablab + Buffel	Darkish yellow	Fruity- smell	78.0	Moist & soft
Tswana cowpea + Millet	Dark - yellow	Fruity-ammonia smell	79.0	Moist & soft
Tswana cowpea + Buffel	Dark - yellow	Fruity-ammonia smell	78.0	Moist& soft

The general physical observation indicated that legume silages of Tswana cowpea and Lablab had the highest moisture content (81.2 – 82.3 %) and pungent or ammonia smell. They also had a slippery texture and were dark in colour. The physical quality of pure stand Lablab and Tswana cowpea (legume) silage indicated that they were moderately fermented since they had high moisture content and ammonia smell. The physical observation of the cereal crop silage such as Buffel grass and millet had the lowest moisture content of 72.4 and 74.5 % DM respectively, firm smooth texture, yellow colour and fruity smell. The cereal silages fermented well since they displayed yellow and fruity smells (AIC, 2003).The intercropped silages had fruity smell, a mixture of black and yellow colour, slightly firm and less moisture content than pure stand cereal silages. The results concluded that good quality silages had golden yellow colour, low moisture content and fruity smell; low quality silages had high moisture content, dark in colour and sour smell.

4.6.2 Silage Nutritive Qualities

Silage nutritive qualities such as ash, CP, NDF, ADF and ADL macro and microelements were determined and the results are shown in Table 6.

Table 6: Effect of crop variety on mean chemical composition (DM %) of pure stand silages.

Pure stand Crops	N	Ash	NDF	ADF	ADL	CP (DM %)
Buffel	12	14.26[a]	67.20[a]	49.76[a]	8.28	4.56[b]
Millet	12	12.82[a]	64.88[b]	44.66[a]	6.90	4.79[b]
Lablab	12	16.22[b]	48.08[bl]	38.05[b]	8.28	10.25[a]
Tswana cowpea	12	16.5[b]	44.06[b]	38.95[b]	9.28	10.27[a]
SE		0.86	1.43	1.45	1.32	0.55
SL		0.01	0.001	0.001	0.64	0.001

SE- Standard error; N-number; NDF- Neutral Detergent Fiber; ADF- Acid Detergent Fiber; ADL- Acid Detergent Lignin; DM-Dry Matter. SL - Significant level ($P < 0.05$).

The mean chemical composition of silage made from pure stand crop is shown in Table 6.The results indicated that ash, NDF, ADF and CP content were significantly ($P < 0.05$) different between silages except ADL content. Legume silages had higher composition of ash and CP content and low NDF and ADF content whereas cereal silages (Buffel and millet) had high NDF and ADF content. Millet crop silages exhibited the lowest and statistically insignificant level of ADL content (6.90 DM %) as shown in Table 6. The result further indicated that crude protein content was similar in both cereal silages as well in both legume silages. The result also indicated that the NDF content in pure stand Lablab silage was slightly higher than that of Tswana cowpea silage.

Table 7: Effect of fertilizer on mean chemical composition (DM %) of pure stand silages.

Fertilizer	N	Ash	NDF	ADF	ADL	CP (DM %)
Control	12	14.45	57.53	41.73	7.22	6.83
LAN	12	13.53	55.23	42.7	7.76	7.70
Urea	12	15.11	55.25	44.41	9.26	7.87
SE		0.74	1.24	1.26	1.14	0.48
SL		0.69	0.30	0.30	0.43	0.27

SE- Standard Error; N-number; NDF- Neutral Detergent Fiber; ADF- Acid Detergent Fiber; ADL- Acid Detergent Lignin; DM-Dry Matter. SL = Significant level ($P < 0.05$)

The effect of fertilizer (Urea or LAN) on silages made from pure stand crops' chemical compositions were not significantly ($P > 0.05$) different from that of control crop silages as shown in Table 7. Crude protein (CP) and NDF contents were similar in all three treatments as shown in Table 7.

Macro element composition of silages made from pure stand crop is shown in Table 8. The mineral composition (phosphorus and sodium concentration) of pure stand crops silages tended to be significantly ($P \geq 0.05$).different due to forage type. The result further indicated that concentration of magnesium (Mg) was highly significant ($P < 0.05$) also may be due to forage types. The result also showed that Buffel and Lablab silages as well as millet and Tswana cowpea silages exhibited similar Mg concentration. Phosphorous concentration was found to be the same in pure stand Buffel and Lablab silages as well as in Tswana cowpea and millet silages. Similarly, cereal silages (Buffel / millet) and legume silages (Lablab/Tswana cowpea) showed the same amount of sodium composition as shown in Table 8.

Effect of fertilizer on pure stand crop silages' macro element concentration was not significantly ($P > 0.05$) different. Nevertheless, control pure stand crop silages had low concentration of sodium than urea or LAN treated crop silages as shown in Table 8. Yet, these differences were not statistically different.

Table 8: Effect of pure stand crops silages as well as fertilizer effect on macro elements composition (g/kg DM).

Pure stand crops	N	P	Mg	Na	Fertilizers	N	P	Mg	Na
Buffel	12	0.045[a]	2.33[b]	14.20[a]	Control	12	0.04	2.68	7.69
Millet	12	0.051[b]	3.19[a]	9.39[a]	LAN	12	0.04	2.96	11.72
Lablab	12	0.045[a]	2.56[b]	6.94[b]	Urea	12	0.05	3.07	9.35
Tswana cowpea	12	0.051[b]	3.52[a]	7.90[b]					
SE		0.002	0.19	2.047	SE		0.001	0.16	1.77
SL		0.06	0.003	0.07	SL		0.31	0.24	0.26

N = number; SE- Standard Error; SL= Significance level ($P < 0.05$); Mg = Magnesium; Na = Sodium; P = Phosphorous

According to the results in Table 9, the micro element concentrations of pure stand crop silages were not significantly (P > 0.05) different. However, Buffel grass silages had high and though insignificant concentration of Cu, Mn, Zn and Fe. Conversely, Lablab crop silage had low but an insignificant concentration of Cu and high concentration of Mn, Zn and Fe. The results further indicated that Tswana cowpea crop silages had the highest though statistically insignificant concentration of Fe (103.85 g/kg DM) than the rest of the pure stand crop silages. Urea or LAN (fertilizer) had no effect on pure stand crop silages micro mineral concentration as shown in Table 9.

Table 9: Effect of pure stand crops and fertilizers on mean micro elements composition (mg/kg DM) of silages.

'Pure stand crops	N	Cu	Mn	Zn	Fe	fertilizers	N	Cu	Mn	Zn	Fe
Buffel	12	0.77	0.72	66.57	79.57	Control	12	0.70	0.67	51.54	55.29
Millet	12	2.11	0.61	35.43	58.12	LAN	12	0.65	0.55	60.23	64.18
Lablab	12	0.61	1.76	48.63	44.35	Urea	12	1.81	1.14	31.22	95.17
Tswana Cowpea	12	0.72	0.47	40.05	103.85						
SE		0.68	0.61	15.99	20.01	SE		0.59	0.53	13.85	17.32
SL		0.38	0.44	0.53	0.18	SL		0.30	0.43	0.32	0.24

SE = Standard Error; N = number; Cu = Copper, Zn = Zinc; Mn= Manganese: Fe = Iron. SL =Significant level ($P < 0.05$).

Table 10: Mean chemical composition (DM %) of intercropped silages

Intercropped crops	N	Ash	NDF	ADF	ADL	CP
Lablab + Buffel	12	15.10^{a}	52.06	40.88	8.52	15.56^{a}
Lablab + Millet	12	15.9^{a}	56.34	41.17	8.79	14.21^{a}
Tswana cowpea + Buffel	12	18.1^{a}	51.34	43.36	9.06	15.15^{a}
Tswana cowpea + Millet	12	17.9^{a}	55.95	40.84	9.9	12.61^{b}
SE		0.80	2.05	1.10	0.729	0.817
SL		0.06	0.19	0.33	0.55	0.07

N =number; NDF = Neutral Detergent Fiber; ADF = Acid Detergent Fiber; ADL= Acid Detergent Lignin; DM = Dry Matter; SE = Standard Error; SL=Significance level (p, 0.05).

The mean chemical composition of intercropped silages was not significantly different between silages (Table 10). However, ash content tended to be significantly ($P \geq 0.05$) different. The ash content was similar in all intercropped silages. The crude protein (CP) content in legume intercropped with cereal silages was found to be similar. However, low CP as well as ADF content was observed in Tswana cowpea intercropped with millet silage. The results further indicated that Tswana cowpea intercropped with millet showed the lowest ADF content due to intercropping arrangements.

The effects of fertilizer on chemical composition of intercropped silages are shown in Table 11.

Table 11: Effect of fertilizer on chemical composition (DM %) of intercropped silages

Fertilizer	N	Ash	NDF	ADF	ADL	CP
Control	12	16.24	56.69^{a}	40.66	9.32	13.97
LAN	12	16.62	54.88^{a}	41.88	8.13	13.75
Urea	12	16.82	50.03^{b}	42.14	9.78	15.43
SE		0.69	1.77	0.95	0.63	0.708
SL		0.83	0.03	0.51	0.18	0.20

N = number; NDF = Neutral Detergent Fiber; ADF = Acid Detergent Fiber; ADL = Acid Detergent Lignin; DM=Dry Matter. SE = Standard Error; SL=Significance level ($P < 0.05$).

The results indicated that the chemical composition was not significantly ($P > 0.05$) different may be due to fertilizer application. The results further showed that NDF content of intercropped silages was significantly different due to fertilizer application ($P < 0.05$). However, urea treated intercropped silages had high though insignificant amounts of ash, ADF, ADL and CP than LAN treated intercropped silages.

According to the results in Table 12, Ca concentration of intercropped silages was high and significantly different ($P < 0.05$) between silages.

Table 12: Effect of intercropping and fertilizers on macro elements composition (g/kg DM) of silages

Intercropped Silages	N[1]	Ca	Mg	Na	P
Lablab + Buffel	12	6.22^{b}	1.54^{b}	0.462	0.08
Lablab+ Millet	12	5.4^{8b}	1.608^{b}	0.432	0.05
Tswana cowpea + Buffel	12	8.27^{a}	1.75^{b}	0.378	0.05
Tswana cowpea + Millet	12	7.02^{a}	2.38^{a}	0.36	0.01
SE		0.440	0.250	0.120	0.016
SL		0.006	0.08	0.9	0.4

Fertilizers	N	Ca	Mg	Na	P
Control	12	6.51	1.91	0.37	0.047
LAN	12	6.63	1.72	0.41	0.047
Urea	12	7,10	1.77	0.45	0.001
SE		0.380	0.210	0.110	0.010
SL		0.5	0.69	0.87	0.2

N = number; Ca = Calcium; Mg = Magnesium; Na = Sodium; P = Phosphorous; SE = Standard Error; SL = Significance level ($P < 0.05$).

Magnesium concentration only tended to be significantly different ($P \geq 0.05$).However, phosphorous and sodium concentration of silages was not significantly ($P > 0.05$) different may be due to intercropping. However, phosphorous and sodium concentration of silages was not significantly ($P > 0.05$) different due to the differences in intercropped forages. The results further indicated that Lablab intercropped with cereals as well as Tswana cowpea intercropped with cereals had the same amount of calcium concentration. Tswana cowpea intercropped with millet showed the highest though statistically insignificant magnesium concentration of 2.38 g/kg DM. Fertilizer had no effect on macro mineral concentration of Ca, Mg, Na and P ($P > 0.05$) as shown in Table 12.Yet urea treated intercropped silages had low and insignificant concentration of phosphorous (0.001 g/kg DM).

Table 13: Effect of intercropping and fertilizers on micro elements concentration (mg/kg DM) of silages

Intercropped	N[1]	Cu	Zn	Mn	Fe	Fertilizer	N	Cu	Zn	Mn	Fe
Lablab + Buffel	12	5.07	22.43	24.38	70.47^{a}	Control	12	5.62	17.54	33.91	39.46^{b}
Lablab + Millet	12	4.02	26.67	52.51	22.64^{b}	LAN	12	4.15	23.43	39.13	53.59^{a}
Tswana cowpea + Buffel	12	5.03	24.65	39.55	26.78^{b}	Urea	12	4.68	31.79	35.93	22.40^{c}
Tswana cowpea + Millet	12	5.17	23.29	39.55	28.71^{b}						
SE		1.250	5.440	11.830	11.50	SE		1.080	4.710	10.250	9.960
SL		0.9	0.9	0.35	0.02	SL		0.6	0.9	0.4	0.001

N = number; Cu = Copper, Zn = Zinc; Mn = Manganese: Fe = Iron. SE = Standard Error; SL = significance level ($P < 0.05$).

The effects of intercropping and fertilizer on micro elements concentration are shown in Table 13.The micro elements concentration of intercropped silages was not significantly ($P > 0.05$) different. The results further showed that iron (Fe) concentration was significantly different ($P < 0.05$). The results also showed that Lablab intercropped with Buffel had the highest iron concentration of 70.47 mg/kg DM than the rest of the intercropped silages. Other intercropped silages showed similar concentration of iron (Fe) as shown in Table 13.

Effects of fertilizer (urea or LAN) on micro mineral compositions (Cu, Zn and Mn) were not significantly different between intercropped silages. However, the results showed that concentration of Fe was high and significantly different ($P < 0.05$) between the silages. The LAN treated intercropped silages obtained the highest iron (Fe) concentration of 53.59 mg/kg DM whereas urea treated intercropped silages had the lowest iron (Fe) concentration of 22.40 mg/kg DM. However, urea treated intercropped silages had high though insignificant concentration of Zn and Mn as shown in Table 13.

4.7 Discussion

4.7.1 Chemical composition of silage made from pure stands and intercropped forages

4.7.1.1 Ash content of silages made from pure stand crops

The ash content of pure stand crop silages was significantly different, ranging from 12.82- 16.22 %. Ash in forage comes from intrinsic sources of minerals calcium, magnesium, potassium and phosphorus as well as external sources such as dirt and soils (Undersander, 2010).The ash content of forage samples submitted to the University of Wisconsin Soil and Forage Analysis Laboratory indicated that the average ash content of hay silage was 12.3 % DM while that of hay was 10.3 % DM (Undersander, 2010). Typical ash content for legume silage is 8-10 % DM (Ayisi et al., 2001). In the present study, the ash contents of pure stand crop silages are higher (12.5-16.5 %DM) well the above mentioned values as shown in Table 6. The current study showed a significant difference in ash content between silage made from pure stand crops. The higher ash content than that reported in literature might be due to the following reasons: the fertility of the experimental field, as indicated in Chapter 3 under materials and methods, the experimental area was treated with basal fertilizers of super phosphate and kraal manure at a rate of 2tons/ha. The basal fertilizer applied to the experimental area might have also influenced higher level of ash content in silages from pure stand crops.

According to Undersander (2010) ash content in grass forage samples may be high due to external sources such as dirt or soil from splash of rain water. Therefore, the ash content in grass forages may be as high as about 18% (Undersander, 2010). According to Hoffman (2002), the average internal ash content of Alfalfa is about 8% DM and of grasses is about 6% DM. Additional ash in hay or silage sample is due to contamination with dirt and sand soil (Bruulsema, 2002). In the present study, the ash content on pure stand crops silages was consistent with Undersander's

(2010) values (12.8 -16 % DM). High-quality forage is free of foreign materials such as dirt, weeds, wire and straw. Livestock should be eating as much good forage as possible and consumption of other materials can fill the animals' stomach but not supply the needed nutrients (Collar and Aksland, 2001).

4.7.1.2 Ash content of intercropped silages

In the current study, the ash content of intercropped silages tended to be significantly different, suggesting that each intercropping arrangement contributed ash in different amount to the resulting silages. The current study shows that Tswana cowpea intercropped with cereals had higher ash content. As stated in the literature, intercropping legume and cereals can improve forage quality in terms of ash. In support of this theory, Anil et al., (2000) reported that ash content was increased by intercropping of maize and runner bean. A study conducted by Amole et al., (2013) on maize-Lablab mixture found a low and insignificant level of ash in the forage material (55- 86 g/kg DM). Although legumes have shown to produce high quality forage but the nutritive value is based on the selection or cultivar of legume-cereal combination (Eskandari et al., 2009). For example, in USA oats and triticale are the suitable cereals for intercropping with clover or vetch and they improve silage quality (ash content) than maize-vetch combination (Lithourgidis et al., 2006). In Botswana, maize and sorghum are the suitable cereal crops for intercropping with legumes compared to Buffel or millet to produce good quality forage (Lightfoot and Taylor, 2008). Therefore, the combination of intercropped species ensiled might have affected though insignificantly ash content in intercropped silages.

4.7.1.3 Effect of urea or LAN on ash content of silages from pure stand and intercropped forages.

The current study results showed that nitrogen fertilizer had no significant effect on the ash content of pure stand or intercropped silages. This could be attributed to the efficient utilization of fertilizer by plants as well as insufficient soil moisture (Bundick et al., 2009). Although the experimental crops were given supplementary water by drip irrigation, moisture content of the soil may not have been enough for optimal performance of the crops. Apart from that, the experimental area did not receive enough rainfall during the time when crops were planted in October 2009. In addition to that, climatic condition such as dryness might have affected the absorption of nitrogen from the soil. These could be the reasons why ash content of silages from pure stand or intercropped forages was not affected by urea or LAN as shown in Table 7 and 11, respectively.

Nitrogen fertilizer has a significant effect on the nutritional quality of grasses (Ahmad et al, 2007). A study conducted by Khan et al., (1996) reported that nitrogen fertilizer provided from urea source had high and significant effect on forage ash percentage. A study conducted by Soleymani and Shahrajabian (2012) reported that intercropped forage treated with nitrogen especially with urea had highly significant level of ash content in forages. However, a few studies also showed that nitrogen fertilizer did not influence ash content in forages. For example, a study conducted by Hasan, et al., (2010) showed that there was no significant difference on the ash content of cowpea forage treated with nitrogen fertilizer. Another study conducted by Mohammad (1988) on the effect of nitrogen treatment and nutritional quality of Napier grass showed that nitrogen fertilizer did not influence total ash content of the forage.

4.7.2 Neutral Detergent Fiber and ADF content of silage made from pure stand and intercropped forages.

4.7.2.1Neutral Detergent Fiber (NDF) and Acid Detergent fiber (ADF) content of silage from pure stand crops.

In the present study, the NDF and ADF content of silages made from pure stand crops were significantly different between the forage crops as shown in Table 6. Silages from legumes had low fiber content than silages from cereal crops but were still higher than 27-30% recommended for normal fiber digestibility in ruminants. This could have happened due to the fact that chopped length of forage affects silage fiber quality and approximate length of forage cut for silage must be 1.5 to 2 cm (AIC, 2003). Length of cuts, packing and the amount of air present in the silo bag can affect fermentation of the carbohydrates (Takashashi, 2005). In the current study while making silage, care must be taken regarding forage cutting size at least be 2 cm (Archer and Reiciosky, 2009). In addition to that, silo management such as exclusion of air from the forages would affect fiber quality. A well fermented silage has good nutritive value with low NDF and ADF content (AIC, 2003).

A study conducted by Albayrak and Kocer (2012) on monoculture (pure stand) pea had low fiber content and significantly different. The present study results were also consistent with those of Albayrak and Kocer's study where fiber content was low in legume silages and significantly different between crop silages. Legume forages such as alfalfa and red clover at mid flowering maturity had 25% NDF (Redifearn, 1997). In this study, silages from cereal crop forages exhibited high and not significantly different due to crop silages. Dahmardeh et al., (2009) reported that maximum ADF recorded in maize was 31.85%. The ADF content of silages from pure stand cereals was not similar to the above mentioned value but it was high (44-49% DM) as shown in Table 6.

Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) are the key analysis used by nutritionists to evaluate forage quality (Robinson, 1999). NDF represent cellulose, hemicelluloses, lignin and cutin. NDF value is related to forage intake whereby low NDF results in high forage intake while high NDF in forages depress feed intake in animals (Robinson, 1999). ADF includes cellulose and lignin .ADF values are inversely related to digestibility, so forages with low ADF concentrations are usually higher in energy. Therefore, NDF and ADF are the predictors or indicators of Total Digestible Nutrient (TDN) (Rasby and Martin, 2010).

4.7.2.2 Neutral Detergent Fiber and ADF content of silages from intercropped forages

The results from the present study showed that NDF and ADF content of silages from intercropped forages were not significantly different as shown in Table 10. This is likely due to the following reasons: management factors such as packing speed which prevents air getting into the silo bag, silage pack density (thick (forage pack), chopped length of the forage, compressing of silo bag can also affect fiber content in silage (Kellems and Church, 1998). In this study, while making silages, the silo (plastic bags) management may not been handled properly including compressing and exclusion of air from forages. This could be the reasons why all silages from intercropped forages showed high NDF and ADF content than that reported in the literature. Compacting plastic bags with a hand is not ideal as it may not achieve complete compaction and therefore it is recommended that the use of mini-silo made from half cut Coke bottles or PVC pipes as better. Well-fermented silages have an average ADF of 25 - 30 % DM (Haustein, 2003). According to McDonald et al. (1991) efficient preservation of silage depends on less oxygen in the forages as well as prevention of anaerobic decomposition during ensiling which reduce NDF and ADF content compared to materials not ensiled.

Intercropping legume with cereal improves silage quality in terms of lowering NDF and ADF content, because legume provides nitrogen to grass when mixed with legume (Bingol et al., 2007). Lauriault and Kirksey (2004) reported that intercropping maize with pea resulted in a low NDF in the silages. Another study on quality of silage conducted by Javanmard et al., (2009) from legume intercropped maize showed a significant reduction of NDF content. However, another study conducted by Bao et al., (2007) showed that intercropping Bersem clover *(Trifolium alexdrainum)* with cereals did not reduce the level of NDF and ADF in the silages. Comparatively the current study results are similar to the above mentioned study by Bao et al (2007).

Dahmardeh et al., (2009) reported that maximum ADF in intercropped maize legume silage was 25-39 % meanwhile ADF content value of intercropped silages obtained in the present study was 41-43% DM which was not consistent with Dahmardeh et al., (2009). A study conducted by Yongli et al., (2013) reported that the ADF concentrations of corn-lablab bean mixture silages were significantly reduced by intercropping. The examples cited above indicated that intercropping can reduce (improve) the amount of fiber content (NDF and ADF) in forages or silages. However, these findings are not consistent with those of the current study.

4.7.2.3 Effect of Urea or LAN on NDF and ADF of silages from pure stand and intercropped forages

The study also evaluated if Urea or LAN had any effect on the NDF and ADF concentration of silage made from pure stand or intercropped silages. The results showed that nitrogen fertilizer did not influence on NDF and ADF content of silages made from pure stand or intercropped forages. However, NDF content of silage made from intercropped forages was significantly different due to fertilizer application. The following reasons could be attributed to the above finding; although the crops were given supplementary water by drip irrigation on alternative days, the moisture content of the soil might not have been enough for the crops to absorb fully and to utilize the applied fertilizer. As indicated earlier, the experimental area (site) was located at Notwane farm. Researcher's observation indicated that in 2009 October- December, the experimental area did not receive much rainfall. According to the 'Country Historical Climate Botswana' showed that the average rainfall obtained at Notwane farm of Sebele in October to December 2009 was 274.7 mm (Butcher, 2015) as shown in Appendix 2 (Rain fall data, 2009). Urea or LAN works very well in the presence of moisture (Russo, 2006). Climatic factors such as insufficient rainfall, less moisture content of the soil might have affected the utilization of Urea or LAN by pure or intercropped forages which could have resulted in insignificant level of fiber content.

Galani et al., (1991) reported that nitrogen fertilizer influences and decreases fiber content (NDF and ADF) in forages. Another study conducted by Zhao et al., (2005) showed that nitrogen treatment in sorghum-bean based intercropped silages had low NDF and ADF content. The current study results were not consistent with the above mentioned studies due to the reasons stated above. Another study conducted by Kaplan et al., (2016) showed that nitrogen fertilizer lowered NDF content in forages. In this study, the NDF content of silage made from intercropped forages was significantly different due to fertilizer application. This was consistent with Kaplan et al. (2016).

4.7.3 Crude Protein (CP) and Acid detergent Lignin (ADL) content of silage from pure stand and intercropped forages

4.7.3.1 Crude Protein content of silages from pure stand crops

In the present study, the crude protein content of silages from pure stand crops were significantly different between silages as shown in Table 6. The result showed that legume silages had more CP than cereal silages. Alfalfa silage has a higher CP concentration than barley silage; 199 vs 124 g/ kg DM (Broderick et al., 2002). Similar to the above report, the current experimental results also showed that legume silages had higher CP content (10 % DM) than cereal silages (4. 56 -4.79 % DM). According to Van Saun (2001) legumes are inherently higher in CP protein compared to grass or cereal forages. Silages from pure stand legume forages had significantly high level of CP content may be due to types of the crops (legumes) ensiled In a study conducted by Albayrak and Kocer (2012) on pure stand (mono culture) oats and barley showed a low Crude Protein (CP) content than legume crops. The results of the current study are consistent with this report by Albayrak and Kocer, (2012).

Crude protein is needed by livestock for growth, milk production, wool production and immunity. It is also needed for rumen bacteria that digest the feed in the rumen of ruminant animals. Protein requirements for livestock usually are expressed as crude protein (CP) but for ruminant as a metabolizable protein (Buxton, 1996). The purchase of protein supplements is expensive resulting in high feed costs especially for smallholder resource limited farmers (Adgola et al., 1995). Therefore, it is necessary to provide livestock with protein supplements when forage quality is low (Hauggaard et al., 2001). Cowpea (*Vigna unguiculata*) and Lablab (*Lablab purpureus)* are the annual legumes with high level of CP protein (about twice as high) can be mixed with cereals (maize, Buffel or sorghum) to improve forage protein content and thus, the costs of provision of protein can be lowered (Anil et al., 2000).Leguminous forages can be used as source of plant protein supplements where livestock are fed on low quality feed such as roughages (Behnk and Metaferia, 2011). The most relevant and basic determination for protein-rich forages are to measure their Crude Protein (CP) content (Tolera et al, 1999).

4.7.3.2 CP content of silages from intercropped forages

The results from the current study showed that CP of silages from intercropped forages was tended to be significantly $P \geq 0.05$) different. It is higher than CP of silages from pure stand crops of Buffel and millet forages (Average CP of Legume with Buffel approximately 15.3 vs 4.6 % for Buffel and Legume with millet approximately 13.4 vs 4.8 % for Millet). The results of silages from intercropped and pure stand crops were not statistically compared but from the results. It is obvious that intercropping improve the quality of the resulting forage and hence silages (12.61-15.56 % DM vs4.56 -10.27 % DM for pure stand). The CP content of silages from intercropped forages tended to be significantly different. This was due to the fact that: the system of intercropping is an important factor which affects the quantity of N fixed by legumes. The differences in the depth of rooting lateral root (side root) spread and root densities are some of the factors that affect competition between the component crops in an intercropping system for nutrients (Rerkasem et al., 1988). The legume crops in this experiment were Lablab and Tswana cowpea which fixes nitrogen from the atmosphere. As a principle, companion cereal like Buffel and millet receives its required amount of nitrogen from the soil as well as from the legumes through biological fixation of atmospheric N. Therefore, the accompanying cereals crops in the intercropping were able to get more N that they convert into organic protein. Thus, forage quality of cereal was improved by intercropping due to more nitrogen availability for cereals (Anil et al., 2000). According to Sanginga and Woomer (2009) intercropping cereal and legume crops helps to maintain and improve soil fertility, because crops such as cowpea, mung bean, soybean and groundnuts (legumes) accumulate 80 to 350 kg nitrogen (N)/ha.(McKenzie, 1998). Thus soil fertility is improved due to legumes as well as nitrogen is an important element for synthesize of protein in plants (Wilson and Kennedy, 1996). This could be the reason why CP content of intercropped silages was higher compared to pure stand forages.

4.7.3.3 Acid Detergent Lignin (ADL) content of silages from pure stand crops

In this study, the results showed that ADL content of pure stand crop silages ranged between 6.9 to 9.3% and was not significantly different between silages from either cereals or legumes forages. The nutritive qualities of forages may vary from species to species (Jung et al., 1997). Therefore, the ADL content of silages from pure stand crops were not different regardless of different cultivar of crops ensiled. A study conducted by Sebolai et al., (2012) on silage quality of Napier grass (*Pennesitum purpureum*) found higher ADL content in Napier silage. The current study result was also similar to Sebolai et al., (2012) study.

The term fiber refers to the components of plant-derived foods and feedstuffs that are not digestible by mammalian enzyme systems (Moore and Hatfield, 1994). In the context of forages, commonly fed livestock fiber refers to the plant cell wall. Mammals do not possess the enzymes to hydrolyze (break) polysaccharides (Carbohydrate) that occur in cell walls (Azim et al., 1989). The microorganism found in the gastrointestinal tract of ruminant (rumen bacteria) is able to ferment these polysaccharides and changes them into absorbable nutrients (Van Soest, 1994). Lignin concentration of forages has been reported to be negatively correlated with digestibility of forages; the higher the lignin content, the lower the digestibility (Aman, 1993). The ADL content of grasses often appears to be greater than for legumes (Jung et al., 1997).

4.7.3.4 Acid Detergent Lignin (ADL) content of silages from intercropped forages

The current study results indicated that the ADL content of silage from intercropped forages did not differ much from ADL content of silages of pure stand forages. Because it is documented that intercropping reduces ADL content in forages. In fact, fiber components such as NDF, ADF and ADL increase with increasing maturity of the forages (Javanard et al., 2009). Plant maturation is the greatest single factor that impacts on forage or silage nutritive qualities, especially the ADL content (Basavaraj, et al., 2010). Stems contain higher proportion of thick-walled tissues called sclerenchyma, xylem fiber, and xylem vessel (Wilson and Kennedy, 1996). In general, legume has low ADL as compared to grass (Van Saun, 2001) though this was not demonstrated in the current study during comparison of pure stand cereals with legumes in Table 6. The role of legumes and their association with cereals have however the potential to decrease ADL content in silages due to extra nitrogen from legumes (Kitaba, 2003). A study conducted by Azim et al., (2000) where legume (cowpea) was intercropped with cereal (maize) showed that fiber content (ADL) was significantly low. In contrast, ADL content of silage from intercropped forages were not significantly high (Table 10) due to the fact that ADL content in legume crops vary from species to species as well as plant maturity (Linn and Martin, 1999).

4.7.3.5 Effect of Urea or LAN on silages made from pure stand and intercropped forages CP and ADL

The study also investigated if Urea or LAN had any effect on CP and ADL content of silages from pure stand or intercropped forages. The results of the present study indicated that nitrogen fertilizers (Urea or LAN) impact on pure stand or intercropped forages did result in silages with similar CP and ADL content to that of the control (not fertilized) crops. This could have been was due to the following reasons: nitrogen applied to the intercropped legumes appeared inhibitory to nitrogen fixation, both directly from increased soil nitrogen and indirectly by stimulation of cereal crops and shading of intercropped legumes (Searle et al., 1981). This could be the reason why pure or intercropped nitrogen treated pure or intercropped forages have silages with low CP and ADL contents. The significant difference between the control, urea or LAN may be because legume N fixation or residual soil nitrogen was sufficient to meet the requirements of cereals and hence no extra benefit of fertilizer application was observed. However, a slight and insignificant increase in crude protein content (CP) was observed in silages from intercropped forages treated with urea (Table 11). As indicated in the literature review, urea releases nitrates into the soil quickly than LAN which enables better absorption of nitrates (McKenzie, 1998).

A study conducted by Almodares et al., (2009) showed that forage crops treated with nitrogen had significant improvement in their chemical composition. Mohammad et al., (1998) reported that nitrogen fertilizer improved crude protein (CP of silage made from brome grass (*Bromus nermis*). Similarly Omer (1998) reported that crude protein content of silage from maize-legume increased with addition of nitrogen fertilizer. According to Sanginga and Woomer (2009) intercropping cereal and grain legume crops helps to maintain and improve soil fertility. This is so because crops such as cowpea, mung bean, soybean and groundnuts (legumes) accumulate 80 to 350 kg of nitrogen (N) /ha. Addition of nitrogen fertilizer to crops increases the amount of nitrogen content in the soil and hence improves forage nutritive qualities. (Tsubo et al., 2000).

4.8 Macro mineral composition of silages from pure stand crop silages

4.8.1 Phosphrous (P) Magnesium (Mg) and Sodium (Na).

This study showed that the average concentration of P and Mg was almost similar in both legumes and cereals silages. On average, silage made from pure stand crops contains excess P, Mg and Na (Goodlass et al., 2003). In this study, silages from pure stand crops had high Mg concentration (2.3 – 3.5 g/kg DM) than the recommended value by NRC which is enough for maintenance and production. Some crops have the capacity to absorb minerals from the soil (Matens et al., 1989). Therefore, high concentration of Mg in silages from pure stand crop may be due to the forage capacity to absorb Mg as well as the type of the crop ensiled. Phosphorus (P) content in silage from pure stand crops ranged from 0.04 % - 0.05% (Table 8). Phosphorous as well as sodium concentrations of silages from pure stand crop forages tended to be different between silages. This may be due to the fact that the cereal silage had higher concentration of Na than in legume silage (9.39 - 14.2 g/kg DM) (Bell, 1995). However, the Na content was higher (14.2 g/kg DM) in Buffel grass silages as shown in Table 8.It has been reported that grass forage has more Na content than legume forages (McDonald, et al., 1991) a result which was also observed in the present study. The silages from Buffel grass and millet in particular had higher Na than silages from Lablab and Tswana cowpea. Mineral concentration in forage depends on the crop species and soil fertility (Matens et al., 1989). High Phosphorus in diets does not improve milk production or reproduction (NRC, 1989). Risks of milk fever increase with increased dietary phosphorus (P) fed pre-calving and with increasing days of exposure to a pre-calving diet (DeGaris and Lean, 2008). This is because lactating cows fail to mobilize sufficient P during peak milk production when requirement for P for milk synthesis is high due to pre-conditioning by dietary P.

4.8.2 Effect of urea or LAN on macro mineral composition of silage from pure stand crops

The study also determined if urea or LAN would have any effect on macro elements concentration of silage made from pure stand crop forages. The macro elements concentration of silage made from pure stands crops was not different from that of control crops. Concentrations of mineral elements in forages depend on the interaction of number of factors; these are include soil, plant species, pasture management and climate (McDowell, 1996). However, studies proved that fertilizer could improve macro mineral content in forages or proved that silages. For example, a study conducted by De Rong (2010) showed that the mean contents of macro minerals (P, Mg, Na) in forage from pasture applied with $(NH_4)_2SO_4$ (Ammonium Sulphate) were significantly higher than those from unfertilized pasture. Another study conducted by (Moreira, 2009) showed that the macro mineral concentration was high in oats – vetch mixture supplied with nitrogen fertilizer.

4.9 Micro mineral Composition of silages made from pure stand crops

4.9.1 Copper and Manganese

In the current study, the concentrations of Cu and Mn, in silage made from pure stand crops were not significantly different between silages of different crops. A number of factors can influence this, e.g. environmental factors such as rainfall, soil temperature and fertility, light and ambient temperature can all influence micro minerals in plant (Pitlz, 2005). The quality of the forage is mostly affected by the plant species and soil fertility (Kaise, 2005). As mentioned earlier in the discussion, the experimental area had high temperature (32^{0}C) and low rainfall. These factors perhaps can affect absorption of minerals from the soil.

Trace minerals (micro elements) are those minerals required by dairy cattle and young livestock in very small amounts; usually at milligram level per day (Meschy, 2000).The occurrence of trace minerals in forages is largely dependent on the amount of those minerals found in the soil in which the forage is grown. Therefore, forages are an important source of trace elements for animals (Hibma, 2002). Trace minerals are needed for vitamin synthesis, hormone production, enzyme activity, collagen formation, tissue synthesis, transport oxygen, energy production, and other physiological processes related to growth, reproduction and health (Soder and Stout 2003). The requirements for trace minerals are based upon the ability of the animal to maintain a desired level of performance (Engle and Paterson, 2005). Copper plays important roles in the cattle's body systems; formation of red-blood cell (RBC), collagen development, reproduction, and immunity. Apart from these, Cu plays important roles by its own, but the combination of Cu, S, and Mo (Molybdenum) creates several important enzymes involved in nucleotide and vitamin metabolism (Harty, 2016). Cattle with Cu deficiency are characterized with lighter colored hair or faded hair coat, reduced conception rates, severe diarrhea, brittle bones and reduced immune response (Harty, 2016). Manganese plays an important role in growth and reproduction. The requirement for Mn in growing and finishing cattle is 20 ppm, while the requirement in pregnant and lactating cows is 40 ppm. If Mn requirements are not met, deficiency diseases occur like reduced conception rates, poor growth rates, low birth weights and increased abortions (Harty, 2016).

4.9.2 Zinc and Iron

The results indicated that silages from pure stand forage such as zinc and iron concentration was not significantly different due to crop variety. The study further indicated that silage from pure stand crop had higher iron (Fe) concentration ranging from 44.35 to103.85 mg/kg DM (Table 9). Tswana cowpea silage had the highest iron concentration of 103.85 mg/kg DM than the rest of the silages from pure stand crops. Tswana cowpea may be able to absorb Fe more efficiently from the soil than the rest of the other experimental crops. This could be the reason why silage from Tswana cowpea had higher Fe concentration as compared to silage from other pure stand crops. A study conducted by Fardous et al., (2011) showed that a significantly higher level of Fe in forage than other microelements something which was also obtained in the current study. The Fe concentrations in silage from pure stand crops were higher than Cu, Zn and Mn concentration.

Zinc plays a role in immune response, enzyme systems and hoof health (Harty, 2016). The requirement of Zn is 30 ppm in forages; grains and proteins are all sources of Zn (Engle and Paterson, 2005). In forages average concentration of Zn is 20 ppm, grains have approximately 35 ppm Zn, and in protein sources it averages between 60 to 70 ppm Zn. Therefore, if cattle are fed forage based diets, additional Zn supplementation may be necessary (Harty, 2016). Signs of Zn deficiencies are reduced feed intake and weight gain, excessive salivation, rough hair coat and eventually swelling of the feet and legs (Khan, 2006).

4.9.3 Effect of urea or LAN on Micro mineral Composition of silage from pure stand crops

The micro mineral composition of silage made from pure stand forages was not significantly different between treatments. This happened due to the fact that: as for a slow-release product, nitrogen fertilizer such as Nitroform, about 2/3 of the Nitroform is required for microbial activity to release N (Clapp, 2001). Release of N can also be controlled by the types of fertilizer used. Some nitrogen fertilizers have coating granules with a polymer or sulfur (Trenkel, 2010). Polymers or sulphur coated nitrogen fertilizer allows more N to diffuse through the coating during warmer weather. Sulfur coatings must breakdown first, followed by soil microorganism that act on it and breakdown to release N (Bundick et al., 2009). The structure of nitrogen fertilizer used in this experiment may not have a polymer coating. According to Kabata and Pendias (1992), the changing soil conditions like pH, climate as well as physiological state of plants also affects micro mineral absorption of the plants.

The poor absorption of nitrogen due to pH variation or moisture content of the soil could affect mineral content in forages (Rebole et al., 1996). These might ultimately result in low micro mineral content in silages made from pure stand crops even though they have been fertilized with urea or LAN. Nitrogen fertilizer significantly affects the nutritional quality of forages. During the mineralization process elements are released and plants can assimilate them easily (Meschy, 2000). Plant nutrition is one of the most important factors that increase plant production, as well as nutritive qualities (Khan, 2006). Nitrogen (N) is one of the most important nutrients affecting the growth, development, yield and quality of plants (Gerendas et al., 1997). A study investigating the effects of input of N fertilizer on the composition of mineral elements (Mn, Fe, Cu, Zn,), in corn grain showed that these mineral concentration were low compared to control crops (Zhang, 2010). Similar result was obtained in this study. Nitrogen release can be limited by temperature or moisture content that affects forage quality (Butzen, 2010).

4.10 Macro elements concentration of silages from intercropped forages

4.10.1 Calcium and Magnesium

Although the results of the current study indicated that the macro mineral composition was similar between intercropped silages, however, calcium concentration was high and significantly different between silages. The results further indicated that magnesium content tended to be different between silages. Tswana cowpea intercropped with Buffel grass had higher calcium concentration of 8.27 g/kg DM while Tswana cowpea intercropped with millet had higher magnesium (Mg) concentration of 2.38 g/kg DM as compared to Lablab intercropped with cereals (Buffel grass/millet as shown in Table 12. This may be implying that Tswana cowpea is capable of absorbing calcium and magnesium than Lablab. Legumes contain adequate amounts of minerals such as calcium and magnesium which are necessary for animal growth (Matens et al., 1989).

Minerals are essential nutrients for all animals, especially in ruminants; they play a key role in growth, production and the maintenance of health. Without minerals, the nutrients of protein, carbohydrate and fat would be worthless (Minson, 1990). A study conducted by Amole et al., (2013) on intercropped maize-Lablab silage revealed a significant effect on macro mineral concentration. Studies conducted by Azim et al., (2000) with intercropped silages of maize-cowpea and mille-cowpea at different seed ratio of 75: 25; 70: 30; 50:50 observed higher content of calcium and phosphorous.

According to the nutrition facts reported by FAO (2014) Lablab has higher concentration of calcium (Ca ≈ 4 %) and magnesium (Mg≈ 20 %) whereas Cowpea has low calcium (2 %) and magnesium of 13 %. Mineral concentrations of cowpeas also vary due to the type of cowpea ensiled. High yielding, short season, multiple disease-resistant varieties of cowpeas has high mineral content (Luther, 1987).Though Tswana cowpea's nutritive value may be different from other cowpeas however it has high calcium and magnesium concentration as compared to Lablab intercropped with cereal.

4.10.2 Sodium and Phosphorous

Sodium and Phosphorus concentration of silages from intercropped forages were not significantly different between silages as shown in Table 12. However, a slightly higher phosphorus concentration was observed in silages from Lablab intercropped with Buffel grass. This could be so because mineral concentration of legumes is influenced by soil fertility and age of the crop ensiled (Cox et al., 2003). Age and cutting height of the forage can also influence their phosphorus and sodium concentration (Antos, 2002). An experiment conducted by Ogedegbe et al., (2012) reported that cutting height of 10mm in Lablab forages destined for making silage had more mineral concentration than Lablab cut at 20mm. Generally, crops should be harvested at bud or booting stage for quality silage (Mickan, 2008). In the current study, forages were harvested beyond the anticipated time (a week late) due to the lack of manpower, which affected the crop maturity. Therefore, the concentration of macro elements, (Calcium, magnesium, sodium and phosphorus) were low than expected probably due to age and cutting height of the crop ensiled.

4.10.3 Effect of urea or LAN on macro mineral composition of silages from intercropped forages

The study also tested if nitrogen fertilizer (Urea or LAN) application had any effect on macro mineral concentration of silages from intercropped forages. The results in Table 12 showed that the macro mineral concentration of silages made from intercropped forages fertilized with urea or LAN was not different from control silage. The above results could be linked to the following factors and explanations: the ability of a plant to take up phosphorus is largely due to its root distribution relative to phosphorus location in the soil (Beegle, 2007). Because phosphorus molecule is very immobile in the soil, it does not move very far from the soil to the roots (Beegle, 2007). Thus, the roots must grow through the soil and absorb phosphorus from soil. Any factor that affects poor root growth will affect the ability of a plant to establish in the soil and fail to absorb phosphorus (Ganskopp and Bohnert, 2003). Muna et al., (2011) reported that maize - Lablab crop treated with nitrogen fertilizer had high level of phosphorus concentration in its silage something which the current study did not support (Mune et al,2011).

Soil compaction, herbicide content in the soil, root injury, and insects feeding on roots can all dramatically result in poor root growth and reduce the ability of the plant to get adequate phosphorus (Beegle, 2007). In addition to that, rainfall is also an important factor for root growth and development (Etana et al., 2013). As indicated earlier, the experimental field did not receive much rainfall; therefore, the root system of the experimental forages might not have been well developed. If the root systems of the crops are poorly developed, the crops cannot efficiently absorb enough nutrients from the soil. This could result in low concentration of macro elements in silages from urea or LAN treated intercropped forages. It was also reported that macro mineral concentration depends on the quantity of nitrogen fertilizer applied to the soil as well as maturity of the crops ensiled (Whitehead, 1996). The above mentioned factors could have affected the forages quality in the same manner and hence there was no difference between the treatments. Another possibility is that the soil through applying kraal manure had met the forage requirements for these plants.

4.11 Micro elements concentration of silages from intercropped forages

4.11.1 Copper and Zinc

In the present study, Cu and Zn contents of silages from intercropped forages were not significantly different from control forages. However, as light variation was observed whereby silages from Lablab intercropped with millet had high concentration of Zn as compared to other silages (Table13). The above results could be attributed to a number of reasons: Plant species have different abilities to accumulate mineral elements, as indicated in a study conducted by Grytsyuk et al., (2006). In this study Ukraine clover had Cu content of 4.3mg/kg DM; Zn 12.4 mg/kg DM while a mixture of Fescue and perennial Ryegrass contained 1.7–3.4 mg/kg DM of Cu and 8.5–11 mg/kg DM of Zn. Therefore, the species capability in absorbing micro minerals from the soil also might have affected the rate at which Cu and Zn in silages differ within each intercropped group.

Grass forages are important source of minerals in the diet of ruminants. In the case of grazing ruminants, they may be the only source of both macro and micro elements available to meet animals' requirements (NRC, 1989). From the ecological point of view, plant and animal production is elevated by the optimal content of macro and microelements present in forages (Juknevicius and Sabient , 2007). Some species of fodder plants contain or absorb excess of some elements (e .g. Fe) than others. Grass forages usually lackcopper and Zinc (McDowell, 1996). Accumulation of mineral elements also depends on soil properties, cultivars or plant type (Bengtsson et al., 2003).

4. 11. 2 Manganese and Iron

Effects of intercropping on iron concentrations of silages were significantly different in the present study. Similar result was observed in another study that intercropping legume with cereal (*Leucanea leucocephalia* and *Giricid asepium respectively*) and the resulting silage had significantly (20.72 -25 mg/kg DM) high level of iron content (Glowacka, 2013). Although Fe is the least toxic of all the essential trace minerals for livestock, its maximum tolerable level in the forage/diet is about 1000 mg /kg DM ((McDowell, 2005). In the present investigation it is clear that Fe concentration is far below the threshold for tolerable concentration for ruminants and it is line with McDowell and Arthington (2005) findings. Another study conducted by Gunes et al., (2007) also reported that silages from maize and peanut intercropped forage had high iron content than maize silage alone. Mineral levels vary from area to area depending on the type of soil. Acidic soils can increase the uptake of iron into the crop (Bretherton, 2012). A study on mineral profile in grass silages indicated that acidic soil had high level of iron concentration than Cu in the forage (Adetuyi and Akambang, 2006). Therefore, the experimental soil's pH (4.5-5.5) might not have negatively affected level of iron content in the intercropped forages shown in Table 13.

The present study also indicated that manganese concentration of silages from intercropped forages was not significantly different as shown in Table 13. This could be attributed to the following reasons: high temperature (32°C - 35°C) of the experimental site at Notwane farm in the year 2009. Species difference of the ensiled forages' mineral concentration was very low and hence there was no significant difference in manganese concentration of silages from intercropped crops. These results are also lined with a study conducted by Glowacka (2013) where the Mn content in peanut and maize intercropped forage was similar to control. Glowacka (2013) reported that lower level of Mn in silages from maize–peanut was affected by poor weather conditions like lowest rainfall and high temperature. In West Africa (Ghana or Nigeria), as in the rest of tropical Africa, forages still serve largely as a source of essential elements for grazing animals (Underwood and Suttle, 1999).Manganese in animals activates several enzymes involved in the metabolism of proteins, carbohydrates and lipids (Losak et al., 2011).

4.11 3 Effect of urea or LAN on micro mineral composition of silages from intercropped forages

The present study also determined the effect of nitrogen fertilizers (Urea or LAN) on microelement concentration of silages from intercropped forages. The results indicated that iron concentration was highly significant due to fertilizer application. This could be due to the fact that: the soil texture, intercropping type and the cultivar of the species ensiled might have also contributed to the variation in the level of iron (Fe) in silages made from intercropped forages. The results further indicated that copper, Zinc and Mn concentration were not significantly different due to fertilizer (Urea/LAN) application. According to Coolong et al., (2004) nitrogen fertilization also reduces zinc content; however, has no effect on copper content in forages. During fertilization, the amount of macro and micro elements taken by plants may differ significantly (Anonymus, 2006). This could be reasons why low and insignificant levels of Cu, Zn and Mn was found in silages from urea or LAN fertilized intercropped forages. Nitrogen fertilizer and intercropping increases iron

(Fe) concentration in forages (Cakmak, (2004). A study conducted by Glowacka (2013) on star grass indicated that iron (Fe) concentration (122.2 mg/kg DM) was greatly increased with nitrogen fertilizer. Similar to Cakmak's (2004) and Glowacka (2013)'s studies, the present study also indicated that Fe concentration of silage from intercropped forages is likely to have been was affected by the application of Urea or LAN. A study conducted by Albayrak and Yükse (2010) reported that nitrogen fertilizer and harvest time significantly affected forage micro mineral content. Similarly, a study on nutritive value of Panar forage in terms of crude protein and mineral concentrations found that these were affected by the fertilizer and intercropping treatments (Abusuwar and Solimani, 2013).

Application of organic manure (kraal and chicken manure) as well as inorganic manure like Urea or LAN enriches forage quality such as mineral content and decreased fiber content in forages (Mcdonald et al., 1983). Organic fertilizers can provide an extra source of mineral elements to the soil. As indicated in chapter 3under materials and methods, before planting forage seeds, the experimental field was treated with basal fertilizers (Super phosphate, lime.), and kraal manure at rate of 2tons/ha. Organic fertilizer supplements soil with micro elements of Cu and Zn (Brazauskienė et al., 2005). As mentioned earlier, Urea and LAN was applied to the crops two weeks after sowing the forage seeds. Since the crops are mature enough to absorb the minerals from the soil. Soil is an important source of nutrients including Fe, Mn, Cu and Zn for plant growth (San, 2006). In some African countries such as Ghana, Nigeria and in Botswana, legumes and grass/cereals have been used as components of cereal-legume mixtures. This reduces to reinforce cereal quality in arable agriculture (McDowell, 2003). However, this strategy can be used in animal agriculture to improve pasture quality.

Conclusion

This study investigated chemical and mineral composition of silages made from pure stand and intercropped forage crops of Lablab, Tswana cowpea, Buffel and millet fertilized with either Urea or LAN. The following conclusion can be drawn from this study:

- The result indicated that chemical composition of silages made from pure stand forages were significantly different except for ADL content.
- The chemical compositions of silages intercropped forages were also not significantly different.
- Macro and micro mineral composition of silages from pure stand pure stand or intercropped forages were also not significantly different.
- Magnesium concentrations of silages from pure stand crop were significant.
- Calcium concentrations of silages from intercropped forages were high and significantly different from crop varieties.
- The fertilizers (Urea or LAN) had no effect on both silages' chemical and mineral compositions. Yet the results indicated that fertilizer (Urea or LAN) had effect on intercropped silages in terms of iron concentration.

Recommendation

The following recommendation can therefore be drawn from this study:

- That intercropped silages are better feed for livestock since they contain high crude protein, ash content, iron, calcium and less fiber
- In vitro digestibility and gas production should be conducted on these silages since these can give better indication of forage quality
- Intercropping is a better strategy for improving quality forage production.

- Furthermore, feeding studies should be carried out to test the dry matter, nutrient digestibility and animal performance of livestock fed by these silages.

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Appendix 2

SEBELE RAINFALL DATA 2009

	Jan;09	Feb;09	Mar;09	Apr;09	May;09	Jun;09	Jul;09	Aug;09	Sep;09	Oct;09	Nov;09	Dec;09
Days												
1			14.0					18.0				
2		28.0	4.0		1.5			3.0				
3					16.0							3.0
4		18.0								15.0		5.0
5							1.5			9.5	5.5	
6		3.0			5.5							
7											8.0	
8				1.8								
9						70.0						
10						30.0						
11						12.0		10.0				3.0
12			3.0			5.5						
13			4.0								5.0	
14											1.6	40.0
15			12.0									
16			0.5									
17												

19		6.0	34.0								50.0		
20			0.5								26.0	3.0	
21			7.5								65.0		
22													
23	15.0	3.5							0.5				
24	0.5	1.0											
25									8.0				
26									0.5	0.2			
27		7.0											
28	30.0	0.8											
29	44.0								7.0			32.0	
30	42.0									1.0			
31										2.0			
TOTAL	131.5	67.3	82.5	1.8	23.0	117.5	1.5	31.0	16.0	27.7	161.1	86.0	746.9

CHAPTER 5

General Conclusion

The study was conducted to examine biomass yield and silage chemical composition including macro and micro minerals of pure stands and intercropped fodder crops of Lablab (*Lablab purpureus*), Tswana cowpea(*Vigna unguiculata*), millet (*Panicum miliaceum*) and Buffel grass (*Cenchrus ciliaris*) fertilized with either Urea or LAN (Lime Stone Ammonium Nitrate). Percentage dry matter (DM %), fresh yield mass and dry matter yield (biomass yield) were high and significantly different among pure stand crops as well as among intercropped forages. Fresh yield and biomass yield of pure stand Lablab was higher than that of Buffel grass, millet and Tswana cowpea. The results of the first study proved that fertilizer Urea or LAN did not influence biomass yield of pure stand or intercropped forages. However, LAN treated pure stand and intercropped forages showed a slight increase in their fresh yield mass.

The second study examined the chemical composition including macro and micro mineral composition of silage made from either pure stand or intercropped forages as mentioned above. Ash, NDF, ADF and CP content were high and significantly different in silage made from pure stand crop forages. On the contrary, the chemical compositions of silage made from intercropped forages were not high and significant except for ash ($P = 0.06$) and CP ($P = 0.07$) tended to be different between silages. As stated in the literature, intercropping could reduce fiber content and improve crude protein content in terms of nutritive quality. This study also proved that forage quality was increased and the Neutral Detergent Fiber (NDF) was reduced due to intercropping. Magnesium (Mg) concentration of silage made from pure stand crop forages was significantly different whereas the micro element concentration such as Cu, Zn and Mn was similar between crop varieties. However, higher iron concentration was observed in Tswana cowpea silage and no explanation can be advanced for high value. In this study, silages did not exhibit high concentration of macro and micro elements concentration due to intercropping except for calcium. The second study was to determine if Urea or LAN could influence silage qualities. According to other research, it is stated that intercropping and nitrogen fertilizer would improve silage quality. In contrast, the present study results showed that Urea or LAN had no effect on the chemical composition of the silage made from either pure stand or intercropped forages. However, the Urea fertilizer reduced NDF content as well as decrease iron concentration of silage made from intercropped forages.

According to this study it could be concluded that intercropping was a better method for farmers to adopt in order to produce high forage yield as well as improving nutritive quality in silage. In general, there is no need to apply fertilizer if intercropping crops includes a legume. Fertilizer can therefore only be used for biomass increase. Further research is needed regarding the effects of these silages and forage yield.