EVALUATION OF TWO MAIZE ACCESSIONS FOR FORAGE YIELD, NUTRIENT COMPOSITION AND DIGESTIBILITY

BY

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DECLARATION

I declare that the work in this thesis entitled **"Evaluation of Two Maize Accessions for Forage Yield, Nutrient Composition and Digestibilty"** has been performed by me in the Department of Animal Science under the supervision of Prof. J.T. Amodu and Dr. D.D. Dung. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of the project thesis was previously presented for another degree or diploma at any University.

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CERTIFICATION

This thesis entitled **"Evaluation of Two Maize Accessions for Forage Yield, Nutrient Composition and Digestibilty"** by Akpensuen, Tersur Theophilus, meets the rules and regulations governing the award of the Masters of Science Degree of the Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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ABSTRACT

An experiment was conducted to evaluate the forage yield, nutrient composition and digestibility of two maize accessions - West Atlantic Seed Alliance 1 (WASA1) and a cultivar from Shika tagged (SHIMAZ). The maize seeds were planted in plots of 5 X 5m^2 size with four replicates for each accession. Six Red Sokoto goats (3 for each accession) were used for digestibility study in a completely randomized design. The results showed that, there was no difference (P>0.05) between the accessions for plant height and number of leaves at 4, 6, 8, and 10 weeks after sowing (WAS), but leaf area index (LAI) was higher (P<0.05) in SHIMAZ than WASA1, (1.6 vs. 1.2) and (5.2 vs. 4.8) at 6 and 10WAS respectively. The number of leaves per plant, green leaves, leaf area and forage yields harvested at 91, 105 and 112 days after sowing (DAS) were not significant (P>0.05), while leaf area and LAI were higher (P<0.05) in WASA1 than in SHIMAZ. The percentage dry matter (DM) content and cobs ratio were significantly (P<0.05) lower in WASA1, although leaf, stem and husks ratios were higher (P<0.01) at various stages of harvest. The crude protein (CP) and nitrogen free-extract (NFE) were higher (P<0.01) in WASA1 accession while crude fibre (CF) was higher (P<0.01) in SHIMAZ at various stages of harvest. Leaf ratio was higher (P<0.01) in SHIMAZ than WASA1 (37.8 vs. 29.2%) respectively, while stem ratio was higher (P<0.05) in WASA1 than SHIMAZ (33.4 vs. 24.9%) respectively at dough stage. There was no difference (P>0.05) in forage yield, husks and tassels ratios, leaf area, neutral detergent fibre (NDF) and proximate components between the two accessions at dough stage. The ash (10.8%) content in WASA1 silage was higher (P<0.01) than that of 6.8% in SHIMAZ, CP was also higher (P<0.01) in WASA1 than SHIMAZ (8.6 vs. 7.3%) respectively. The ash, EE and CP contents were significantly (P<001) higher in silage than

fresh forage of WASA1 and there was no difference (P>0.05) in EE, CF and CP for both fresh forage and silage of SHIMAZ accession. There was also no difference (P>0.05) in dry matter intake (DMI) and crude protein intake (CPI). Apparent nutrient digestibility were not significant (P>0.05) except for crude protein digestibility (CPD) which was higher (P<0.05) in WASA1 than SHIMAZ (73.4 vs. 61.7%) and (82.7 vs. 76.9%) for forage and silage respectively. It is concluded that the two maize accessions can be grown in the Northern Guinea Savanna of Nigeria for animal feeding where the experiment was carried out, but SHIMAZ accession may be preferred due to it's high biomass.

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ABBREVIATIONS

DAS = Days after sowing

DM = Dry matter

DMD=Dry matter digestibility

DMI= Dry matter intake

Ca= Calcium

CF = Crude fibre

CP = Crude protein

CPD= Crude protein digestibility

CPI= Crude protein intake

EE = Ether extract

Ha = Hectare

K = Potassium

LAI = leaf area index

LOS = Level of significance

Mg= Magnessium

ME = Metabolisable energy

MJ = Mega joules

N = Nitrogen

Na= Sodium

NAPRI = National Animal Production Research Institute

NFE = Nitrogen free extract

NS = Not significant

OMD= Organic matter digestibility

P = Phosphorus

SHIMAZ = Shika maize accession

SEM = Standard error of means

WASA1 = West Atlantic Seed Alliance accession 1

WAS = Weeks after sowing

CHAPTER 1

1.0 INTRODUCTION

In Nigeria, ruminant animal production system is characterized by low feed availability especially during the prolonged dry season in the northern part of the country Jolaosho *et al.* (2008). During this period, the natural pasture is not only low in dry matter, but also poor in quality with low crude protein content of about 3% (Nasiru and Onifade, 2008) and therefore, difficult to obtain high and quality forage for animal all year round. Olanite *et al*. (2008) noted that in the rainy season, abundant grass forages of fairly good quality become available from natural range, which supplies the bulk of the feed for grazing after which the nutritive quality of the grasses, fall rapidly, subjecting the animals to heavy nutritional stress.

There are about 15.2 million cattle, 28 million goats, 23 million sheep (FAO, 2006) and 22 million exotic poultry and 1.7 million rabbits in Nigeria (RIM, 1992). With all this number of animals, animal protein is not adequate for the present human population of about 140 million (NPC, 2006). This can be attributed to lack of feed all year round causing herdsmen and their animals to trek long distances in search of feed and water, therefore leading to loss of weight by the animals. It will therefore be an advantage to cultivate or preserve the excess green feed in the rainy season to improve animal growth, production, reproduction and maintain good health during the dry season.

Maize (*Zea mays* L) ranks after wheat (*Triticum durum*) and rice (*Oryza sativa*) as the third most important crop in the world (Bilal *et al*., 2005). Maize is widely grown in all the continents of the world and in many countries especially where annual precipitation exceeds 600mm (Akmal *et al.*, 2000). In Nigeria, it is also grown in most ecological zones

of the country, making it available to be used as livestock feed. Madamba *et al*. (2006) noted that maize grains are used for three main purposes: as a staple food, livestock feed and as raw material for industries. Maize grain is used for feeding pigs, cattle and poultry, while the plant materials, either fresh or dry are important as forage feeds (NRC, 1998). Forage maize can be utilized by animals in many ways. It can provide high quality yields of palatable forage, and if grazed, harvesting costs, storage losses and manure-hauling cost are minimized for the hectarage that is grazed (Karsten *et al*., 2003). Singh *et al*. (1986) achieved animal weight gains that were comparable to gain in feedlot when a system was developed to optimize utilization of maize at the dough-dent stage by cattle. Amodu and Abubakar (2004) stated that maize is by far the most extensively used cereal as silage in Nigeria followed by Guinea corn (*Sorghum bicolor*). Dual purpose, sweet and grain sorghums are useful alternatives to maize for silage production although they are slightly lower in digestibility and metabolisable energy content (Griffiths *et al*., 2004) but they are better adapted to a wide range of growing conditions than maize (Littimore and Griffiths, 2006). Acikgoz (1991) reported that maize is the most important plant in the world because, it has the most abundant amount of green herbage, and its silage has high nutritive value and is palatable. Maize is a premium crop, producing a large bulk of high-energy forage (Griffiths *et al*., 2004). In addition to silage maize having a high forage yield, digestible energy per hectare is by far greater than any other crop when land and climate are favourable (Staples, 2003). Whole-crop maize is one of the most ensiled crops in the world, due to its ease of cultivation, high dry matter yields, low buffering capacity and high concentration of water soluble carbohydrates and ease to ensile (McDonald *et al*., 2002). Maize silage has been proven to be an efficient feed for fattening and it is used in dairy farming especially during the dry season, when lush feeds are no longer available. Silage

produces high animal growth rates and has been an important component of many livestock enterprise (Littimore and Griffiths, 2006). Kaizer and Blackwood (2004) noted that silage can be used to successfully finish beef cattle with no adverse effects on carcass and meat quality.

Various maize varieties have been used as forage in the past for ruminant feed. However, attention is being shifted to breeding maize varieties that results in high forage yield per unit area. Differences exist in forage quality and quantity among maize varieties (Coors *et al*., 1997). Griffiths *et al*. (2004) also observed that forage quality of leaves and stems may vary between hybrids. Dairy producers however are increasingly planting forage type hybrids which have higher stover digestibility and lower grain content compared with dual purpose hybrids (Cox and Cherney, 2001).

In this regard, it has become necessary to explore maize varieties that are more beneficial as forage for ruminant animals rather than the dual purpose varieties. This will reduce the competition for grain varieties since maize seeds serve as a staple food for humans and feed for the ruminant animals especially during the dry season. Machinery can be used for cultivating large hectarage of land as it is done in developed countries. Peasant farmers can cultivate small areas and ensiled in polyethene bag to supplement dry season grazing as it is practiced in the Eastern part of Africa (Alemu, 2008). The overall benefits are to improve animal growth, reduce weight loss and increase productivity during the dry season. There is the need to conduct agronomic studies on the maize varieties and to evaluate their nutritive and digestible values so that the farmers will be able to cultivate and preserve the forage maize varieties for dry season feeding.

In this trial, two accessions of maize: West Atlantic Seed Alliance 1 (WASA1) which is an exotic variety and a local variety (SHIMAZ) were examined for their forage

yields, silage characteristics, nutrients composition and digestibilities. A study designed to examine production and preservation of forage and responses of goats to the two conserved maize accessions would provide some basic information with application to small and large-scale livestock farmers. This study was designed to investigate the following hypotheses: The Null hypothesis (Ho): There is no difference between WASA1 and SHIMAZ accessions, while the Alternative hypothesis (Ha): There is difference between WASA1 and SHIMAZ maize accessions. The objectives of the study were; (i) to determine the forage yield, silage potential and nutrient composition of the two maize accessions (WASA1 and SHIMAZ), and (ii) to determine the *in-vivo* digestibility of fresh forage and silage of the maize accessions

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 MAIZE AS A CEREAL CROP.

Maize is a tropical grass and can grow up to 4m tall (Belfied and Brown, 2008). Important forage species include grasses in the genera *Andropogon, Aristida, Paspalum* and *Cynodon* (Holechek *et al.*, 2004). Maize belongs to the tribe *Andropogonea* in the family Poaceae (USDA, 2005). Cereal crop such as maize, guinea corn and millet are all grasses. Maize was, for long time, mostly used as fresh green fodder for animal feeding during summer and, forage conservation by ensiling was first explored by Reihlen at Stuggart in the 1860s (Barrière *et al*., 2006). Maize is primarily grown for stock feed and there are also varieties available that are suitable for silage and human consumption (Belfied and Brown, 2008). DHA (2008) stated that maize has multiple uses and it is used for the preparation of food or drinks, as animal feed or industrial uses. It is the main feed for animals; the grain is used for pigs, cattle and poultry, while the plant materials, either fresh or dry are important as forage feeds (NRC, 1998).

2.2 ADAPTATION AND DISTRIBUTION

The center of origin of maize is the Mesoamerican region probably in Mexico where it spread rapidly (DHA, 2008). Rebourg *et al.* (2003) stated that maize was introduced to Europe, first by Columbus in Spain, 1494, and little later by Verrazano 1524, and Cartier 1534 in French Normandy. Within a generation, maize was grown in countries of Central and Southern Europe, along the coasts of Africa, and it reached China before the end of the 16th century, probably including the direct introduction of American germplasm

through the Mediterranean sea (Barrière *et al*., 2006). Belfied and Brown (2008) stated that maize is a tropical grass that is well adapted to many climates and hence has wide-ranging maturities from 70 days to 210 days. It is grown in all continents of the world (Akmal *et al.*, 2000) and therefore can be easily accessed. Maize is also grown in most ecological zones in Nigeria thus, making it available. Corral *et al.* (2008) stated that maize can grow from arid to humid environments and from temperate to very hot environments, basically in tropical and subtropical lands. Generally, tropical maize is grown between 30^{o}N and 30^{o}S, subtropical 30 and 34^{o} both North or South and temperate maize beyond 40^{o} latitudes and the ability of the crop to grow in wide range of environments is reflected in high diversity of morphological and physiological traits (DHA, 2008).

2.3 ENVIRONMENTAL REQUIREMENTS.

Maize is an annual crop and is grown where the rainfall can last for more than four months. It is grown in all continents of the world where annual precipitation exceeds 600mm (Akmal *et al.*, 2000). Maize is a summer crop that requires warm growing temperature of between 25-30^{o}C and cool nights (Colless, 1992). However, Belfied and Brown (2008) stated that the optimum temperature for maize growth and development is 18 to 32 °C, with temperatures of 35 °C and above considered inhibitory. Birch *et al*. (2003) stated that temperature below 8^{o}C and above 40^{o}C cause cessation of development. The optimum soil temperatures for germination and early seedling growth are 12 °C or greater, and at tasselling 21 to 30 °C is ideal (Belfied and Brown, 2008). Tropical cultivars derived from the highland regions are better adapted and grown at lower temperatures than those adapted at lowlands (DHA, 2008). Drought often affects the yield of maize and is a major limiting factor in tropical and sub-tropical regions. Maize is susceptible to water stress

especially when seed formation approaches (Srinivasan *et al*., 2004). Maize can grow and yield with as little as 300 mm rainfall (40% to 60% yield decline compared to optimal conditions), but prefers 500 to 1200 mm as the optimal range (Belfied and Brown, 2008). Plants growing for prolonged periods in waterlogged soils show stomata closure, reduce leaf area growth, chlorosis, reduced root growth and root death (Lafitte, 2000). Tropical and sub-tropical maize are most susceptible to waterlogged at early vegetative growth and during tasselling (Srinivasan *et al*., 2004). Belfied and Brown (2008) stated that maize is moderately sensitive to salinity, which reduces uptake of nutrients, decreases total dry matter production and can be grown on wide range of soils with pH 5.0 to 8.0.

2.4 LAND PREPARATION

A good seedbed should consist of 5 to 7 cm of fine firm soil that is free from weeds and to achieve this fine seedbed, traditional farmer practice is to plough the land once or twice followed by one or two harrowing (Belfied and Brown, 2008). However, it is not always necessary to cultivate the soil in order to plant maize; that is no till. Maize establishes very well under a no-tillage system is practice which requires weed control or burning before planting (Chad *et al*., 2005). The maize is then sown directly into the standing stubble without the associated costs of ploughing (Belfied and Brown, 2008).

2.5 FORAGE PRODUCTION

2.5.1 Forage Yields

*2.5.1.1 Fresh forage yield***.**

Producing higher forage yield from the same amount of cropping land will be of great importance to a livestock farmer for his animals. Maize can be grown as a forage crop

for grazing to reduce scarcity of feed in the dry season or for yielding silage crop (Vaughan, 2000). Premy (2002) stated that maize has both forage and cereal value that can be grown even during critical rainy season period of forage scarcity.

Hassan (2010) reported fresh forage yield of 33.6 t/ha and 28.5 t/ha for *Giza* and *Mugtama* varieties, respectively in Pakistan. *Arifiye* and *Franssico* forage maize varieties yielded 62.6 and 64.6t/ha respectively of fresh forage, followed by *P-33395* with 58.2t/ha while *P-33394* was the lowest with 52.4t/ha when yield and quality of forage maize was influenced by cultivar and nitrogen rate (Bilal *et al*., 2005). Premy (2002) obtained 24.58t/ha of fresh forage biomass at 75 days after planting, while at 45 days after planting the yield was 17.5t/ha when he compared the fresh forage yield of maize at different inter space utilization. Hassan (2011) reported the yield of 41 to 70.4t/ha in forage maize when he examined effect of different nitrogen sources on the growth, yield and quality of forage maize in Saudi Arabia. Awan *et al.* (2001) obtained the yield of 50.02, 81.48, 47.22, 54.63, 61.48 and 55.56t/ha for *Neelum, Sultan, Carlgil, Pioneer-3331, Golden* and *Akbar,* respectively for the forage varieties when they examined various maize varieties for forage yield quality. However, Ayub *et al.* (1999) reported the yield of 49.01 and 52.14 t/ha for *Neelum* and *Akbar* respectively when they examined seeding density for the two varieties in Pakistan. *Dracma, P-3223, P-3335, DK-711, DK-626* and *Arifiye* had the fresh forage yield of 69.5 62.0 59.8 55.9 and 56.5 t/ha, respectively (Yilmaz *et al.*, 2007). Turgut *et al.* (2005) obtained fresh forage yield of 79.56 t/ha for ADA-95-10 which was the highest followed by D-585 which has the lowest yield with 66.4t/ha when they examined row spacing and plant density on forage and DM yield of maize in Turkey. From all these results, it is clear that the fresh forage yield is influenced by the variety, type and quantity of fertilizer applied, planting density and location.

2.5.1.2 Forage Dry Matter Yields.

Forage dry matter (DM) yield also vary among different varieties of forage maize. Dry matter yield depend on weather factors and agronomic practices carried out in a given area. Agronomic practices such as planting density, tillage practices, type of fertilizer used, row and width spacing, defoliation etc, the stage of harvest, soil and location will affect the forage DM yields. Selection of maize varieties is one of the most important decision influencing forage maize production and subsequent milk yields (Allen *et al*., 1997).

Maize has higher potential yield (tDM/ha/cut) than all the grasses, legumes and crops used as silage materials as shown in Appendix 1. Griffiths *et al*. (2004) stated that the potential forage yields of forage maize varieties should be between 12 to 15t/ha. However many research works have shown forage DM yields above this range. Yilmaz *et al*. (2007) examined genotype and plant density on forage maize yield and reported the values of 27.0, 23.6, 21.8, 22.5, 21.6 and 22.2t/ha for *Dracma, P-3223, P-3335, DK-711, DK-626* and *Arifiye* respectively. The planting density also have effect on DM yield as reported by Carpici *et al.* (2010) who obtained forage DM yield of 18.7t/ha at a plant density of 66,000.00/ha which was the lowest, while the density of 220,000.00 plants/ha had the yield of 20.6t/ha which was the highest when examined for forage yield as influenced by plant density and nitrogen application. *Arifiye, P-3163, TTM-8119*, and *Karadiniz yildizi* forage varieties yielded 24.1, 19.9 and 22.6t/ha respectively when the four hybrids were subjected to various row spacing (Iptas and Acar, 2006).

Cox and Cherney (2001) reported the yield ranging from 17.8 to 22.7t/ha when they examined Brown midrib, leafy and transgenic hybrids for forage DM yield. Lauer *et al*. (2004) obtained the yield of 19.3t/ha forage yield while Cusicanqui and Lauer (1996) reported the yield of 19.5 and 19.3t/ha for *Cargill P-3417* hybrids respectively when they

examined hybrid influence and plant density and on maize forage yield and quality. Edoka (2006) evaluated the DM yield of fourteen early maturity silage maize varieties and reported the yield of 35t/ha for *P-3226* which was the highest while the least yield (14.8t/ha) was from *Joxxa* variety.

2.5.2 Yield Components.

2.5.2.1 Tillering.

Tillers are vegetative or reproductive shoots that grow from the base of a main stem in a grass plant. Holechek *et al*. (2004) defined tillers as the lateral vegetative shoots growing upwards within the enclosed leaf sheath while Nafziger (1998) defined tiller in maize as the branches that develop from buds on the lower five to seven stalk nodes. They are morphologically identical to the main stalk (culm) and are capable of forming their own root system, nodes, internodes, leaves, ear and tassels(Nielson, 2003). The agronomic practices and climatic conditions can influence tillering in plants. The number of tillers develop is a function of plant population, spacing, soil fertility, early season growing conditions and genetic background of the maize (Nafziger, 1998). Tillers can be of great benefits to livestock farmers due to their overall contribution to forage yields. Tillers are essentially part of wheat, barley and oat, and have some benefit in producing silage because more dry matter is produced per unit area (Nielson, 2003). Nielsen further stated that one or more tillers may be formed from the main stalk when it is injured or killed by insects, wind, tractor tires, little kid's feet, deer hooves etc, during early growing season.

Literature on maize tillering is scarce. However, Bowden *et al*.(1973) compared the nutritive value of silage from tillering variety (Stewarts Multi-T) with a non tillering variety (Idahybrid 216) and reorted that the silage made from the tillering maize was higher in

crude protein (9.8% vs. 8.1%) but lower in dry matter (DM) content (32.7% vs. 38.9%). Choe *et al*. (1991) reported 3.7, 3.3 and 3.6 tillers per plant on the average for IK1, IK2 and IK3 maize varieties, respectively. Neil (2011) stated that there is a new tillering brown midrib maize that produced 10t/ha of high energy, high protein DM in 60 days with each plant having a main stalk plus several secondary stalks, resulting in higher yields than are possible with other forages.

2.5.2.2 Number of leaves per plant.

Generally, it is expected that, the taller a maize plant is, the more the number of leaves. Turgut *et al*. (2005) reported that *C-955* forage variety with the highest height had 15.2 followed by *ADA95-10* with 14.1, while *DK-585* which was the least in height had 12.2 leaves per plant in Turkey. Number of leaves on the average was 10.7 per plant in forage maize at 90 days after planting (Hassan, 2011) in Saudi Arabia. Awan *et al*. (2001) obtained the values of 13.67, 13.00, 10.67, 12.33, 11.67 and 11.33 leaves per plant for *Neelun, Sultan, Cargil, P-3331, Golden* and *Akbar* respectively in Pakistan. Plant density influences the number of leaves per plant stand. The leaves per plant reduced as the density increases as reported by Carpici *et al*. (2010) when they reported that at 60,000 plants/ha, there was 15.01 leaves per plant and decreased to 14.16 at a density of 220,000 plants/ha. Iptas and Acar (2006) reported the values of 14.2, 13.2 11.8 and 12.3 leaves per plant for *Arifiye, P-3163, TTM 8119* and *K. Yildiz*i respectively when they examined the effects of row spacing and hybrid on forage yield and quality. In Nigeria, Hussaini (2000), Muhammad (2004) and Ubandoma (2006) obtained the values of 11.6, 8.9 and 6.2 leaves per plant respectively at 12 weeks after planting when they examined the effect of fertilizer, sowing dates and irrigation interval on pop maize while Mani (2004) obtained 12.3 and 12.4 leaves per plant *Yellow composite* and *Ashland* varieties respectively.

2.5.2.3 Height.

There are different heights in various forage maize varieties. Hassan (2010) reported the height of 118.3 and 98cm at 90 days after planting for *Giza* and *Mugtama* respectively in Saudi Arabia. With a row spacing of 75cm, the forage maize height was 218cm, which was lower than 222.8cm which was obtained at spacing of 85cm (Ramezani *et al.,* 2011) in Iran. This result implies that, spacing had an influence on the height, as the wider spacing increases, the height also increases. Furthermore Carpici *et al*. (2010) reported that at a density of 60,000 plants/ha, the height was 285.08cm, decreasing to 277.84cm at a density of 220,000plants/ha. Ayub *et al.* (1999) reported the value of 169.42 and 175.56cm in *Neelum* and *Akbar* cultivars in Pakistan at harvest stage. However, Awan *et al*. (2001) reported the value for *Neelum* and *Akbar* to be 188 and 195cm, respectively due to differences in agronomic practices. Iptas and Acar (2006) obtained the values *for Arifiye, Pioneer 3163, TTM8119* and *Karadinizi Yildizi* varieties to be 322, 298, 281 and 288cm, respectively when they examined the effect of hybrid and row spacing on forage yield and quality. The height of *Sultan, Cargil, P-3331* and *Golden* maize forage varieties were 196, 172, 172 and 194cm, respectively when these varieties were examined for forage yield (Awan *et al.,*2001). Muhammad (2004) and Ubandoma (2006) obtained the values of 188.7 and 128.2cm in pop maize varieties in Nigeria. The differences noted in height of various maize varieties may be due to differences in location, agronomic practices and variety.

2.5.2.4 Leaf: stem ratio.

The ratio of leaf percentage to stem percentage in forage plants is of great importance. Stems are less digestible than leaves because they contain more structural carbohydrates. The changing proportion of leaf, leaf sheath, stem and inflorescence account for some overall differences in cultivar nutritive value (Humphreys, 1999). MacDonald *et*

al. (1998) noted that digestibility of grasses generally is influenced by leaf: stem ratio and as the plant matures, the stem comprises an increasing proportion of the total herbage and hence has much influence in the digestibility of the whole plant than the leaf. Leaf to stem ratio may vary depending on the plant densities (Yilmaz *et al*., 2007).

Leaf: stem ratio is often reported as the percentage of leaf and stem of the whole plant. Appendix 2 shows the leaf: stem ratio in various forage maize varieties as well as cob ratio. Variety *P-3394* showed a higher leaf ratio with 25.5% than the other varieties followed by *ADA-523* with 25.2% while *P-3335* with 16.9% was the least among the varieties. The stem ratio in the various varieties ranged from 33.1% in P-3163 which was the least to 55.9% in *ADA-523* which had the highest value. The cob ratio was lower in *ADA-523* with 18.8% while *DK-626* was the highest among the varieties. Varieties that have high leaf and cob ratios and lower stem ratio are better for silage making and animal utilization. Generally, stems are less digestible than leaves and high cobs ratio will ensure adequate water soluble carbohydrates for lactic acid production that will preserve the silage material when ensiled.

2.5.2.5 Leaf area index (LAI)

Leaf area index is defined as the ratio of leaf area to unit area of land (Watson, 1945). Chen *et al*. (1997) defined LAI as one- half the total green leaf area per init area. It is projected leaf surface area per unit ground surface (Edoka, 2006). LAI of zero means there is no leaf; LAI of 1 indicates that the leaf equals the horizontal ground surface, LAI of 2 means that the leaf is double the size of the ground surface and so on. In maize under good conditions of optimal growth peak, LAI ranged from 4.8 to 7.8 (Linquist *et al*., 2005)

Leaf area index qualifies the amount of foliage per unit ground surface area (Edoka, 2006). The capacity of a crop to intercept photosynthetically active radiation and synthesize

carbohydrates is non-linear function of LAI (Elings, 2000). Water transpiration, carbondioxide absorption and oxygen emition occurs through the leaves, it is therefore an important parameter of the water balance and of the energy and mass exchange between vegetation and atmosphere (Wulder, 1998; Spanner *et al*., 1990; Cowling and Field, 2003). Leaf area index can have importance in many agronomy and crop production through the canopy, transpiration, photosynthesis, autotrophic respiration, nutrient (carbon, nitrogen, phosphorus, sulphur etc) cycles (Andres, 2004), weed control, crop weed competition, crop water use and soil erosion (Wilhelm *et al*, 2000). Cowling and Field (2003) noted that at high plant densities, self shading becomes a limiting factor, and thus increases in LAI do not directly lead to an increment in productivity.

The LAI in plant generally will be small at germination stage and as the plant grows the LAI will increase. When all the light is intercepted, photosynthesis is at maximum and this occurs when LAI is greater than one, sometimes three or five (Mannetje, 1999). Shakerami and Rafiee (2009) stated that as the density increased, LAI and light interception followed on increasing trend. Greatest LAI in tropical maize is usually reached at flowering, after which it may stabilize for several weeks, depending on growing conditions and then declines at an increasing rate as green tissues senesce (Elings, 2000). Yao *et al.* (2008) found out that the LAI of maize generally increase by 0.5 per week and they also stated that at 7 week, LAI suppose to be 3 at a maize height of 120cm. Leaf area index of *Azan, Jalal* and *S. white* varieties were 3.50, 3.60 and 3.70 respectiely in Pakistan (Akmal *et al*., 2010). Mugalkhod *et al.* (2011) reported LAI of 6.68 and 8.34 when maize was planted at a spacing of 37.5cm X 24cm (single spacing) and 25-50-25cm X 20cm respectively in baby maize in India. Edoka (2006) took measurement of LAI in various silage maize varieties and reported the values of 3.14, 3.08, 3.54, 4.58, 3.75 and 3.42 *for X*-

Probat, X-Fjord, X-romario, X- Eurostar, X- Effekt and *X- Rivaldo,* respectively. Andres (2004) obtained the values of 4.3 and 4.0 as LAI for total and green respectively when he estimated LAI and biomass in maize using remote sensing. Hassan (2011) reported LAI of 7.5 at 90 days after planting, when different nitrogen sources were used to estimate growth, yield and quality of forage maize in Pakistan. Mani (2004) and Ubandoma (2006) reported the values of 2.6 and 2.3 in pop maize varieties at 12 weeks in Nigeria.

2.6 SILAGE PRODUCTION.

2.6.1 Maize as a Silage Crop.

Silage is defined as a material that is produced as a result of a controlled anaerobic fermentation of a material high in moisture (MacDonald *et al*., 1998; Kellems and Church, 2002). Silages are fermented forages stored under anaerobic condition (Amodu and Abubakar, 2004). According to Doonan *et al.* (2004), silage is a fermented product resulting from anaerobic fermentation of water soluble carbohydrates (WSCs) in forages. Alemu (2008) defined silage as a cut green plant material that is sealed in a silo without air or water.

Almost all grasses and legumes as well as haylages can be used as silage in their high moisture content for fermentation. Griffiths *et al*. (2004) stated that some crops are more suitable for silage than others. Maize is by far the extensive used as silage followed by *Sorghum bicolor* (Amodu and Abubakar, 2004) because it has high energy concentration (Adesogan and Newman, 2008). Grant and Stock (1994) stated that forage sorghum silage has 80 to 90 percent of the energy value of corn silage per unit of dry matter. Dual purpose, sweet and grain sorghums are useful alternatives to maize for silage production although they are slightly lower in digestibility and metabolisable energy content (Griffiths *et*

al.,2004) but they are better adapted to a wide range of growing conditions than maize (Littimore and Griffiths, 2006). Maize is a premium crop producing a large bulk of high-energy forage (Griffiths *et al*., 2004). Littimore and Griffiths (2006) observed that maize is an outstanding crop for silage, producing high forage yield and easily ensiled. Whole-plant maize silage is an important fibre and energy source in diets for lactating cows (Schwab *et al*., 2002). Kellems and Church (2002) stated that maize silage is the most popular silage in the United States in cereals where maize grows very well. Maize silage popularity is due to it's high yield of very digestible, high-energy crop and the ease of adaptation to mechanized harvesting and feeding (Martin *et al*., 2004) with lower labour and machinery requirements than other forages (Roth *et al*.,1995). Maize has high ensilibility and requires no wilting (Griffiths *et al*., 2004), in addition; it has low buffering capacity (Adesogan and Newman, 2008). Acikgoz (1991) reported that maize is the most important plant in the world because, it has the most abundant amount of green herbage, and its silage has high nutritive value and is palatable. In addition to silage maize having a high forage yield, digestible energy per hectare is by far greater than any other crop when land and climate are favourable (Staples, 2003).

2.6.2 Physical Characteristics of Maize Silage.

Silage physical characteristics depend on the fermentation quality. The typical physical characteristics of maize silage are shown Appendix 3. Good quality maize silage should be leafy, soft in texture, light green to green/brown in colour and should have mild pleasant sour milk smell, as such silages are usually high in metabolizable energy and crude protein contents, while maize silages that appear stemmy, fibrous and presence of mould are low in ME and CP content (Kaiser and Piltz , 2004). Silages should not have rancid,

vinegar or alcoholic odours as such silages are associated with high level of acetic acids which result in slow feed-outs rates (Roth, 2001). Adesogan and Newmann (2008) stated that temperature in silage should be below 37^{o}C as higher temperatures could reduce the fermentation quality, enhance protein degradation and reduce rapid pH decline necessary for an efficient fermentation. Higher temperatures indicate that oxygen is penetrating into the silage and result in aerobic decomposition (Roth, 2001). Lower pH values are necessary to preserve the silage to prevent fungi and clostridia bacterial development which spoil the silage. The pH of an ensiled sample is a measure of its acidity. In general, legume silages have a higher pH than corn or other grass silages and take longer to ensile because of their higher buffering capacity (Kung and Shaver, 2001). Adesogan and Newmann (2008) stated that forages with less than 5–8% water-soluble carbohydrates in the DM may not reach a pH low enough to produce stable, high-moisture silage. Corn, sorghum, sorghum-sudan hybrids, and cool-season annual grasses usually have sugar concentrations above 5% dry matter and good, stable silage is often achieved. Kung and Shaver (2001) stated that legume and grass silages should have pH range of 4.3-4.7 while maize silages should be 3.7-4.2. Kaiser and Piltz (2004) reported the pH values of 5.7, 5.2, 4.0 and 3.9 for Lucerne, clover, rye/white clover and maize silages respectively. Knezˇevic´ *et al.* (2007) reported the value of 3.7 for maize silage. Ballard *et al*. (2001) also reported the pH values 3.75-3.78 in three maize silages.

2.6.3 Proximate and Mineral Composition

The proximate and mineral compositions depend on the stage of harvest of the silage material. Appendix 4 shows the typical value and the desired ranges of proximate and mineral composition for maize silage. Roth (2001) stated the ranges of 7.2-10.0, 23.6-

33.2 and 41-54.1% for crude protein (CP), acid detergent fibre (ADF) and neutral detergent fibre (NDF) contents, respectively in maize silages. McDonald *et al.* (1998) reported the values of 23.3, 5.7, and 10% for crude fibre (CF), ether extract (EE) and ash respectively. Phiri *et al*. (2007) reported the values of 6.9, 5.8. 49.9 and 35.0% for CP, ash, NDF and ADF respectively while Amole *et al.* (2011) obtained 9.75, 36.75, 1.14, 6.80, 45.56, 53.05 and 49.84% for CP, CF, EE, ash, NFE, NDF and ADF respectively in maize silage. Knezˇevic´ *et al.* (2007) reported the value of 6.2, 58.2 and 32.1% for CP, NDF and ADF respectively. McDonald et al. (1998) reported the metabolizable energy (ME) of 10.8MJ/kgDM in line with Griffiths *et al.* (2004) who stated that maize silages should have ME of between 10-11 MJ/kg DM.

There are different values reported for the mineral content in maize silages. Roth (2001) reported the values of 0.25, 0.23, 0.18, 0.20 and 0.13 for calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K) and sulphur (S) respectively while Ballard *et al*. (2001) stated the ranges of 0.14-0.22, 0.19-0.22, 0.10-1.15 and 1.10-1.15% for Ca, P, Mg, K and S respectively. However, Amole *et al*. (2011) reported the values of 1.12, 1.19, 1.14 and 1.13% respectively for Ca, K. P and Mg respectively.

2.6.4 Organic Acids Composition.

The pH alone is not a good indicator of knowing the quality of well preserved silage or type of fermentation process but, the end products of silage fermentation are often monitored to assess silage quality (Lemus, 2010). The various organic acids profile from legume, grass and maize silage is shown in Appendix 5. In general, pH values for maize silage should be in the range of 3.5 to 4.3, lactic acid level should be in the range of 4–6%, acetic acid 2% or less, propionic acid 0–1%, and butyric acid less than 0.1% while

ammonia-N levels should be less than 5% (Roth, 2001). Kung and Shaver (2001) stated that Lactic acid should be at least 65 to 70% of the total acids in good silage while high butyric acid (>0.05% of DM) has sometimes induced ketosis in lactating cows and because the energy value of silage is low, intake and production can suffer. They further stated that effect of high concentrations of acetic acid (>4-6% of DM) in silages fed to animals is unclear and high amounts of ammonia in silage should not have negative effects on animal performance if the total dietary nitrogen fractions are in balance however, if the high ammonia (>12 to 15% of CP) contributes to an excess of ruminally-degraded protein (RDP), this could have negative consequences on milk and reproductive performances. Legume silage has lower percentage of lactic acid (2-4%) than Grass (6-10%) and maize (4-7%) silages, Appendix 5 which can be adduced to higher amount of WSCs in grass and maize silages while legume silages have higher percentage of ammonia-N than grass and maize silages.

2.6.5 Factors Affecting Silage Quality.

Many factors may affect the fermentation process and subsequently the quality of silage. Piltz and Kaizer (2004) stated that the factors that may lead to silage losses are generally grouped into three; field and harvesting factors, storage factors and feedout losses. It is therefore important to carryout all the activities that will result in quality silage during the fermentation process. This will ensure high palatable silage to animals.

2.6.5.1 Stage of harvest

Various crops have different stages of harvest. The nutritive value of silage depends on the species and stage of growth of the harvested crop (McDonald *et al*., 1998). Griffiths and Burns (2004) stated that mature crops provide larger bulk of lower quality forages than

young vegetative crops which have more digestible energy. Harvesting silage crops at the proper stage of maturity ensures the maximum yield and nutrient content (Tyler and Emsminger, 2006). As crops mature, they become more fibrous and lignified, thus their forage quality decline rapidly. Amodu *et al.* (2008) stated that the stage of growth at which a silage crop can be harvested for silage making varies among crops and depends on the type of animals for which the silage is to be fed. Forages to be stored in horizontal silos should be harvested near 70% moisture to facilitate packing and air exclusion while upright silos should be 60-66% moisture forage to avoid seepage (Mueller *et al*., 2001). *Sorghum almun* and maize should be harvested at dough stage, rhodes grass at early flowering, elephant grass at about 2.0m tall, legume (cowpea, mucuna, soyabean, lablab etc at early fruiting (Amodu *et al*., 2008). According to Griffiths and Burns (2004) cereals such as wheat and oats should be harvested when they are young and leafy, perennial ryegrass and clover should be harvested when first head emerged, millet at 1m high, Lucerne at early stage (less than 10% flower), Kikuyu at 25-35days after planting.

Maize for silage can be harvested at the early stage prior to black layer forming (Tyler and Ensminger, 2006; Amodu *et al*., 2008). A milkline of 2.5 out of a total score of 5 is the best to harvest forage maize for silage (Griffiths *et al*., 2004). Staples (2003) noted that when the milkline moved from ½ to 2/3 down from the maize, it has maximum energy content and yield. The best livestock performance and silage fermentation usually occurs when the plant moisture is 65-70 % (Staples, 2003; Bagg, 2007). An important guideline for maize forage harvest is milkline (Lauer *et al*., 2004) and at 50% mikline, optimum yield and quality of forage is obtained (Wiersma *et al*., 1993).

2.6.5.2 Cutting height and chop length of maize

Providing a standard cutting height above the ground is difficult due to differences in varieties, climatic and growing condition and this has been controversial. Griffiths *et al.* (2006) stated that the cutting height of 15cm to 45cm above the ground is expected to reduce yield by up to 15% and increase digestibility by 2%. Nennich and Harrison (2005) stated that a cutting height between 10-15cm and cutting up to 30cm above the ground reduced yield by 10%. Increasing the cutting height of maize silage may increase digestibility due to the elimination of high fibre lower stalk (Kennington *et al*., 2005).

The length of chop varies with the crop and moisture content. Chopping length affects the packing in silo and hence the quality (Tyler and Ensminger, 2006). If harvesting is delayed and the crop DM content is more than 38%, chop length should be fine to enhance compatibility, but if forced to harvest early, when the DM content is less than 28%, adequate compaction can be achieved with a longer chop 1.5 to 2cm (Griffiths *et al*., 2004). Various theoretical lengths of chop (TLC) have been recommended for forage maize. A short TLC is however recommended because, it increases the amount of DM transported per truck load, forages are more evenly distributed and spread in bunker, more compacted, less storage space, more WSCs released resulting in more bacterial activity, well fitted to mechanical feeding and increase intake by livestock (Mickan and Piltz, 2004). However, Bal *et al.* (2001) stated that various TLC do not have effect on intake, milk production or milk composition. Staples (2003) recommended a TLC of 0.5cm. A good general recommendation for TLC for processed silages is 1.9cm with 0.1 to 0.2cm roller clearance while for unprocessed silage, an average TLC should range from 1 to 2cm (Roth and Heinrichs, 2001). Ideally, chopped material should be 4 to 10cm to enhance rapid release of sugar which assist in the compaction of stacks and make fibrous material more

palatable to animals (Morris, 2005). Meuller *et al.* (2001) recommended that silage particles should be 1.3cm long with 15 to 25% of the particles being 2.5cm in length. A chop length of 1 to 3cm is recommended as this makes easy to compact the silage and remove the air (Alemu, 2008).

2.6.5.3 Dry matter content.

The DM content of the parent material at the ensiling can affect the quality of effluent loss in the silage during storage, the growth of bacterial in the silage and the ease of compaction which in turn, affects the exclusion of air from the silo or bale (Piltz and Kaiser, 2004). The target DM content will vary with factors such as crop type, growth stage at harvest and the type of equipment and storage method used (Mickan and Piltz, 2004a) as well as the weather conditions of the place. Forages that have excess (>70%) or inadequate moisture (<45%) may not ensile well for different reasons. Higher moisture concentrations can result in greater seepage losses, possible pollution of nearby water bodies and such high-moisture silages are also more likely to undergo clostridial fermentation, which leads to high DM losses, protein degradation, high butyric acid concentrations, and reduced palatability (Adesogan and Newmann, 2008). Piltz and Kaiser (2004) stated that higher DM content increases the susceptibility of the crop to respiration losses as well as mechanical losses during various handling operations particularly as the DM content increases above 40%. Temperate perennial/forage grasses, clover, kikuyu, Lucerne, cowpea, lablab, tropical grasses, forage sorghum and millet should be wilted (Griffiths and Burns, 2004) while maize and grain/sweet sorghum do not require wilting before ensiling (Griffiths *et al.,* 2004). Mickan and Piltz (2004a) stated that the target DM for Lucerne, cereal/legumes mixtures as well as other legume crops, kikuyu grass and whole chop cereal should be 35-

40%; temperate grass/clover mixtures and forage sorghum/pennisetum should be 30-40% while maize should be 33-38%.

2.6.5.4 Sugar concentration.

Water soluble carbohydrates (WSCs) are converted to lactic acids by lactic acid bacterial (LAB) during fermentation process which aid in the preservation of the forage material as silage. Piltz and Kaiser (2004) stated that for effective silage fermentation, WSCs in the parent material should be more than 2.5% on fresh forage basis for good fermentation while parent material with less than 2.5% should be wilted. Tropical grasses are inherently low in soluble carbohydrates, with the exception of maize and sorghum species but, if the material is of adequate quality, but lacking in sugars, molasses or another source of sugar may be added (Alemu, 2008). Maize, Sorghum, Sorghum-Sudan hybrids and cool annual grasses usually have sugar concentration above 5% DM and good, stable silage is often achieved. Forage crops such as warm perennial grasses and legumes have lower sugar concentration and the high protein concentration of legumes buffers (slows) the pH decline from 5.5 to 4.5 during ensiling (Adesogan and Newman, 2008). The stage of growth is the most important factor influencing WSCs of forage species. As the plant matures, it contains hemicellulose and most LAB can not ferment hemicellulose (Piltz and Kaiser, 2004).

2.6.5.5 Filling the silo and sealing

Proper filling will ensure good silage material compaction and quality. The manner in which silage is filled in the silo will greatly influence the quality of the silage. Filling and compaction should be continuous throughout the silage making process and not more than three days for a storage unit (Mickan *et al*., 2004b). Silage shrinkage (DM losses) increases as packing density decreases, and poor packing density can also reduce the

effectiveness of silage inoculants, therefore packing the silo tightly can minimize nutrient losses during filling in the silo (Adesogan and Newman, 2008). Amodu and Abubakar (2004) stated that filling should start at the close end in case of trench silo and either end of the bunker silo. If filling is delayed more than 24hours, then level and cover the top each day (Staples, 2003). Rolling with a heavy wheeled tractor (4WD) achieves better compaction than tracked vehicles (Mickan, *et al*., 2004).

Sealing is very important to ensure silage is successfully preserved to minimize losses during storing (Mickan *et al*., 2004). Sealing silage depends on the type of silo used. Poor sealing not only leads to mould but also cause losses exceeding 30% of the DM which is 100% digestible, so the remaining material will be of lower feed value (Morris, 2005). Staples (2003) stated that plastic sheets carefully placed and weighted down can help keep spoilage losses to less than 20%. Covering the ends with 20 to 30cm soil or 10cm saw dust satisfactorily seal the silo and automobile tires are usually used to weigh down the plastics sheet (Mueller *et al.,*2001).

2.6.6 Ensiling Processes and Silage Storage.

Ensiling processes are broadly divided into three (3) phases;

Phase1: Aerobic phase

This phase begins from the time of harvesting crop to the time oxygen is depleted in the sealed silo (Adesogan and Newman, 2008). Amodu and Abubakar (2004) noted that during this period, the living plant cells continue to respire, consuming the entrapped air, producing carbondioxide and water and releasing heat as energy. The heat produced by respiration raises the temperature of silage. The temperature may reach up to 46^{o}C in forages with moisture content of 50 to 70% (Barnhart, 2008). Furthermore, plant enzymes

such as proteases and carbohydrases are active during this phase, provided the pH is still within the normal range of 6.0-6.5 .Plant enzymes convert complex carbohydrates to WSCs and proteolysis also occurs (MacDonald *et al.,* 1998). Piltz and Kaiser (2004) stated that respiration is undesirable because it results in loss of DM, energy and available WSCs required by the LAB for fermentation. Harvesting at the correct plant maturity, chopping to the right particle length, packing the silo tightly and sealing properly are the key to minimizing nutrient losses during this phase (Adesogan and Newman, 2008).

Phase 2: Fermentation phase.

The fermentation phase commences once anaerobic conditions are achieved within the silo (Pitz and Kaiser, 2004). This phase starts after the oxygen is used up, when anaerobic bacteria begin to ferment plant sugars into organic acids, alcohols, carbondioxide and nitrogenous compounds (Barnhart, 2008). During this period, acids are produced, lowering the silage pH below 5 (Lemus, 2010) and preventing further microbial activity, thus preserving the silage. McDonald *et al.* (1998) stated that the LABs which are facultative anaerobic continue to increase, fermenting the WSCs in crops to organic acids mainly lactic acids which reduces the pH value. The acids produced finally reaches a point where the bacteria themselves are killed, thus completing the silage making process and at later stage, silage in good silo will remain unchanged for a period 10 to 15 years (Amodu and Abubakar, 2008). This period when silage remain unchanged for long period is also called stable phase. If the population of clostridia bacteria increases, a secondary fermentation can occur, thus fermenting the WSCs, lactic acids and protein to produce butyric, propionic and acetic acids and ammonia nitrogen plus a number of intermediate compounds releasing a strong offensive odours (Piltz and Kaiser, 2004).

Phase 3: Feedout phase

This phase begins when silage is opened for animal feeding. The silage is exposed to air where aerobic bacterial, mold and yeast can thrive and spoil the silage and can be harmful to animals. These organisms convert remaining plant sugars, lactic acid, or other energy-rich nutrients in the silage to carbon dioxide, water, and heat (Barnhart, 2008) thus, increasing the pH. The phase is also called "aerobic deterioration or aerobic spoilage". Aerobic organisms that have been dominant during the aerobic phase revive and multiply (Piltz and Kaiser, 2004). The first sign of aerobic spoilage is heating the feeding face or in the feeding trough (Martin *et al*., 2004). The silage should be fed out at a rate of at least 20.5 to 30cm per day and a straight face should be maintained with shavers (Adesogan and Newman, 2008).

Silages are usually stored to ferment in containers called silos. Tyler and Ensminger (2006) stated that silage can be stored in any container and it must exclude air from the stored material, including entrance of air into the container. The kind of silo and the choice of contraction material should be determined primarily by economics and suitability to the particular needs of the farmer or rancher (Amodu and Abubakar, 2004). The type of silo in which a farmer may choose to ferment his crops are varied, ranging from small plastic bag to large cylindrical towers built of concrete, steel or wood (McDonald, 1998). Adesogan and Newmann (2008) stated that silos used to store forage during ensiling include vertical tower silos, horizontal bunkers and drive-over piles, stacks on the ground, or long plastic bags and round bales of silage can also be stored in bags, tubes, stacks of bales under plastic, or stretch-wrapped individually or in in-line tubes.

2.6.7 *In-vivo* Digestility of Silages

Maize silage and other types of silages are fed to ruminants especially cattle, sheep and to a little extent goats. It produces high animal growth rates and has an important component in livestock enterprise (Littimore and Griffiths, 2006). The digestibility (or ME content) of a silage is the most important factor influencing live weight gain in cattle/beef production per tonne of silage consumed and has no adverse effects on meat quality (Kaiser and Blackwood, 2004).

The dry matter intake (DMI) is higher in legume silages than cereals while daily weight gain is higher in cereals silages. Jabbari *et al*. (2011) reported that steers fed maize silage had higher daily weight gain of 1.02kg/d compared to sorghum silage with 0.97g/d. The higher daily weight gain reported in steers fed maize silage may be adduced to higher ME content. Oltjen and Bolsen (1980) reported the DMI of 2.52, 2.39, 2.12 and 2.55 (% of live weight) while the live weight gain in beef steers was 1.16, 0.90, 0.48 and 1.18kg/d for barley, wheat, oats and maize silages respectively when the cereals where harvested at dough stage. Legume silages digest more quickly and have potentially higher CP than grass silages and, as a result, DMI is usually higher for legume than grass silages (Stanley *et al*., 2004). The DMI of subclover and maize silages was 3.5 and 3.0 and a daily weight gain of 108 and 122g/d respectively in lambs (Mulholland and Scott, 1992).

Maize silage has higher digestibility than sorghum and millet silages. Jabbari *et al*. (2011) reported dry matter digestibility (DMD) of 67.84 and 65.92% for maize and sorghum silages respectively fed to steers. Kaizer and Piltz (2004) reported DMD of 66.7, 66.1, 64.9, 62.9 and 69.1% for legume, grass/legume, grass, cereal/legume and maize silages compiled over several years in Australia. Sheep fed maize silage had DMD of 67.3% (Piltz, 1993). Bolsen *et al.* (1999) cited by Kaiser and Blackwood (2004) stated that

the organic matter digestibility (OMD) of maize silage in growing heifer was 76.3%. The organic matter digestibilities of maize silage at different hybrid maturity stage fed to sheep range from 66.7 to 69.3% (Kaiser and Piltz 2002 cited by Griffiths *et al*., 2004) which is higher than the values of 61.6 and 64.4 % for forage sorghum and pennisetum respectively at late dough stage reported by Kaiser (unpublished data) but lower than Lucerne silage which was 71.9% (Mulholland and Scott, 1992). Mladen *et al*. (2007) stated that the DM, OM. NDF, ADF and CP digestilities were 63.1, 65.1 59.5, 56.2 and 46.9% respectively when sheep were fed maize silage. Furthermore, Hayashi*, et al.* (2009) reported the values of 66.5, 68.2, 59.1, 70.1, 77.0 and 68.8% digestibilities for DM, OM, CP, CF, NFE and ADF respectively when maize silages were fed to dairy buffalo and cattle.

Literature reference on maize silage digestibilities in goats is scarce. This may be due to ability of goats to browse a wide of plants and can thrive in hardy environments therefore needing little supplement. However, Canizares *et al.* (2011) reported the values of 74.3% and 74.2% for DMD and OMD respectively when goats were fed maize silage. Kim *et al*. (1993) reported the values of 57.2, 58.5, 52, 54.5, and 56.6% for DM, OM, CP NDF and ADF digestibilities respectively when maize silage was fed to goats while nitrogen balance was -0.01g/d. The digestibilities of DM, CP, cellulose ADF and energy were 58.8, 56.6, 51.8 and 56.4 respectively when goats were fed high DM (33%) maize silage (Jones *et al*, 1972).

CHAPTER 3

3.0 MATERIALS AND METHODS

3.1 ENVIRONMENTAL CHARACTERISTICS OF THE STUDY AREA

3.1.1 Location

The experiment was conducted at the National Animal Production Research Institute (NAPRI), Shika, located on latitude 11°12'N, longitude 07°33'E and altitude 660m above sea level (Ovimaps, 2012). Shika is located 22km northwest of Zaria in the Northern Guinea Savanna of Nigeria.

3.1.2 Climate

Table 3.1 shows the rainfall distribution in 2011 and medium-term (2002-2010) means for Shika, while the temperature and relative humidity data for the same periods were obtained from the Institute for Agricultural Research (IAR), Samaru, Zaria. Shika has characteristics of the Northern Guinea Savanna ecological zone with well defined dry and wet seasons. The wet season starts from April or early May and ends in late September or early October. The long-term total annual rainfall ranges from 8050 to 1,580mm. Most of the rains fall between July to September. The dry season lasts from October to April and consists of the periods (November to early February) of low relative humidity, with cool and dry northeast harmattan winds and a mid-February to May hot dry period. The maximum temperature for the period (April to October) recorded at Samaru about 10km northeast of Shika showed that the highest maximum temperature occurred in April with about 37°C while August had the lowest maximum temperature of about 30°C. Also, the relative humidity recorded at Samaru was higher in the months of July and August

Table 3.1: Temperature, Relative humidity and Rainfall distribution for (2011) and Medium-term Means (2002-2012) for Shika and Samaru.

	Max. Temp(^{o}C)[a]		R.H (%)[a]		Rainfall(mm)[b]	
Months	2011	(2002-2010)	2011	(2002-2010)	2011	(2002-2010)
April	37.8	38.0	20.7	22.8	13.9	41.9
May	35.3	35.2	47.2	51.5	123.3	125.9
June	32.3	31.8	61.1	63.3	162.5	145.9
July	30.2	30.5	70.8	69.5	223.9	229.1
August.	30.3	29.6	72.2	73.9	239.9	310.9
September.	31.9	31.3	68.2	67.1	113.9	181.7
October.	34.0	32.9	64.4	51.6	54.0	68.7
Total	232.8	229.3	404.6	399.7	917.5	1104.1
Mean	33.2	32.7	57.8	57.1	131.1	157.7

Sources: [a]Samaru(Lat. 11^{o}11'N, Long. 07^{o}38'E, Altit.687m). [b]Shika (Lat.11^{o}12'N, Long.07^{o}33'E, Altit.667m)

(approximately 70%). The vegetation consists of largely woodland with tall perennial, tufted grasses that grow up to 3m beneath the scattered trees and up to 5m in open places (Crowder and Chheda 1982). According to Kallah (2004), the major forage species found in this area are; *Andropogon gayanus*, *Brachiaria spp*, *Pennisetum pedicellatum* etc. Tree species found in this area include; *Isoberlinia doka* and *I. tomentosa* which form the bulk of the scattered woodland, locust bean tree (*Parkia filicoidea*), shea butter tree (*Butyrospermum parkii*) and mangoes (*Mangifera indica*) (Aregheore, 2009).

3.1.3 Soil Texture and Chemical Properties of the Experimental Site.

Three pedons were sited on the top, middle and lower slope of the experimental plots of maize accessions and bulked soil samples were taken at four depths (0-20, 21-50, 51-80, 81-120cm) for texture and chemical analyses. Shika is classified as an area in the Northern Guinea Savanna of Nigeria, and according to Aregheore (2009), soils in this zone are sandy, friable and relatively easy to cultivate. Table 3.2 shows the characteristics of composite samples of the soil collected from the experimental field prior to the commencement of the study and analysed for physical and chemical properties.

Table 3.2: Soil Physical and Chemical Properties of the Study Area.

Properties	Value
Physical properties:	
Particle size (%)	
Clay	15.5
Silt	9.8
Sand	75.1
pH	5.4
Chemical properties:	
Total N(%)	0.1
Organic carbon (%)	0.9
Zn(ppm)	3.5
P(ppm)	95.7
Exchangeable cations (meg/100g of soil):	
Ca^{++}	2.5
Mg^{++}	0.7
K^{+}	0.3
Na^{+}	0.1

3.2 EXPERIMENT 1: AGRONOMIC EVALUATION OF TWO MAIZE ACCESSIONS FOR FORAGE YIELD.

3.2.1 Land Preparation

The area was ploughed on the 31 May, 2011 using a tractor mounted disc plough while harrowing was carried out on the 14 and 20 June, 2011 using a tractor mounted disc harrow. The field was then levelled manually using locally made hoes. All debris and weeds were removed to make a clean and flat seedbed.

3.2.2 Experimental Design and Pasture Establishment.

Two maize accessions, West Atlantic Seed Alliance (WASA1) obtained from International Livestock Research Institute (ILRI) Kano, Nigeria and a local variety from Shika tagged (SHIMAZ) obtained from the Forage and Crop Residue Research Programme of the National Animal Production Research Institute (NAPRI) were examined for various production parameters in a completely randomized design (CRD). The plot size was 5m X 5m, with four replicates for each of the maize accessions. Planting of the maize accessions was carried out at the seed rate of 15kg/ha on 20 June, 2011 when the rains were well established. Plate I shows the picture of the two maize accessions. Two seeds were planted per hole in a depth of 3cm and at a spacing of 75cm inter-row and 25cm intra-row. The total seed population planted was 106,800 per hectare. Establishment counts were determined at second and fourth weeks after planting (WAP). At each week of counting, numbers of plant per stands on each row were counted and then expressed as the percentage of the total seeds planted. Weeding of experimental plots was done manually using locally made hoes. First weeding was carried out three WAP while two additional weedings were



Plate I: Cobs of the two maize accessions.
Photograph: T. Akpensuen

carried out at 6 and 9 weeks after planting. Prior to planting, superphosphate (18% P_2O_5) fertilizer was broadcast over all plots, at the rate of 30kg/ha and the soil disc ploughed. There after, two doses of NPK (20:10:10) fertilizer was drilled into the soil at the rate of 150kg/ha; at 3 and 6 WAP.

3.2.3 Parameters Measured During Plant Growth Phase.

Three plant stands of the middle rows of each replicate were tagged and used for determining the following agronomic parameters: plant height, numbers of leaves per plant and leaf area index (LAI). These were determined at 4, 6, 8 and 10 WAP. The number of tillers was determined at 7 WAP.

Plant height: The height of the tagged plants was measured from ground level to the top of the last leaf using graduated ruler in centimeters (cm).

Number of tillers: The number of tillers per plants within each row was counted for the two maize accessions.

Leaf: The number of leaves of the tagged plants was counted for the two maize accessions.

Leaf area index (LAI): The same tagged plants were used for the measurement of leaf area index. The length and breath from the widest portion of functional (green) leaves was individually measured from each stand with a graduated ruler in centimeters. The product of length and breath was then multiplied by a factor of 0.75 from which the area of individual leaves of the tagged plants were obtained. This was added and divided by the area covered by the plant. A twine tied loosely around the stem immediately above the last measured leaf, to avoid taking measurements on the already measured leaves in subsequent measurement. Plate II shows the two maize accessions stands in the field. The leaf area



Plate II: Maize accessions stands in the field.
WASA1 accession on the left and SHIMAZ accession on the right.
Photogragh: D. Dung.

index of the dead leaves was subtracted before determining the LAI for the particular week in which the measurements were taken.

3.2.4 Harvesting of the two accessions of maize at different stages.

Each accession was harvested at 91, 105 and 112 days after sowing (DAS) as well as at dough stage (91 and 105DAS for SHIMAZ and WASA1 respectively) using the same tagged plants. The dough stage was determined by oven drying the plants for 48hrs and the target dry matter (DM) content was between 30 to 35% (Bagg, 2007). At each stage, the plants were cut at a height of 10cm above the ground. Two tagged plant stands were cut from each replicate at each harvest time to determine DM, yield components (leaves, dead leaves, green leaves, cobs, husks, stem and tassels), leaf area of green leaves, LAI, fresh forage yield and forage DM yields.

During each harvest time, the total number of leaves per plant, dead leaves and green leaves were counted. The green leaf area and LAI were obtained at each harvest time using the procedure described above. Each plant was then separated into various components viz; leaves (sheaths and blades), stems, cobs, husks and tassels. These components were immediately weighed to obtain fresh weight and then oven-dried at a temperature of 70^{o}C for 48hrs to obtain the dry weight which was used to determine DM for the various components and for a whole plant stand from where the fresh forage and forage DM yields per hectare were obtained. The plant component ratios (leaves, stem, cobs, husks and tassels) were determined as the percentage of the whole plant stand after oven drying at each stage of harvest.

3.3 ENSILING MATERIAL AND PROCEDURE

A total of six transparent polyethene bags (0.6m X 1.8m each) to containing about 60kg chopped samples maize materials (3 for each maize accession) were used as silos for silage making. The maize plant stands in each replicate that were not for measurement were cut and used for silage making and feeding as shown in plate III and IV. The two accessions of maize materials were ensiled at 98 days after sowing. The maize materials were cut at 10cm above the ground level and chopped to a length of 2cm. Forty five kilograms of the chopped maize materials were compressed in the bags and stored in a pit of about 1m deep. The ensiled materials were removed on day- 21 and fed to animals. Physical characteristics such as temperature, colour, aroma and pH were determined immediately the bags were opened. Sub-samples of the ensiled maize materials were then oven-dried and milled for proximate and mineral analyses.



PlateIII: Chopping of the maize accessions for ensiling.



PlateIV: Polyethene bags containing chopped fresh forage maize for silage. *Photograshs: T. Akpensuen*

3.4 EXPERIMENT 2: DIGESTIBILITY STUDIES ON THE MAIZE ACCESSIONS.

***In-vivo* Digestibility Trial.**

This was carried out at the Experimental Research Farm of Animal Science Department, Ahmadu Bello University, Zaria. The study lasted for twenty one days. This study was carried out using the fresh forage and ensiled forage materials of the two maize accessions. Six male Red Sokoto goats with an average weight of 11.6kg were used for the study with three animals per replicate for each accession. The animals were dewormed, carefully examined for good health and randomly housed in an individual metabolism cage before the commencement of the feeding trial. The first feeding trial was carried out with fresh maize forage materials. The same animals were used for the second feeding trial in which they were fed ensiled maize forage materials. The feeding trial for fresh forage and ensiled forage material lasted for twenty-one days in each case. A fourteen-day adjustment period was allowed followed by seven days faecal and urine collection. In both cases, feeders, waterers, faecal and urine collection trays were thoroughly washed a day before faecal and urine collection started. The animals were fed 50g dry matter per kg live weight (Osuji, *et al*., 1993). However, the quantity of feed offered per day for each animal was adjusted to 30gDM/kgLW (dry matter per kg live weight) for fresh maize forage and ensiled maize forage materials. Water was provided *ad- libitum* and dry matter (DM) intake was calculated. Each animal was fed the maize material daily between 0830 and 0900hours.

Daily urine output for each animal was collected into a plastic container containing 0.2ml of 0.1N Sulphuric acid. An aliquot sample of about 10% from each animal's urine output per day was taken and stored in a refrigerator at a temperature of about (-20^{o}C) until required for analysis. Daily faecal output was collected for each animal using a polyethene

bag. Similarly, about 10% of the faecal was also taken and stored in a refrigerator at (-20^{o}C). At the end of the collection period, the samples were bulked together and 10% was taken for nitrogen analysis.

3.5 SAMPLE PREPARATION AND CHEMICAL ANALYSES

Dried maize forage and silage samples were ground to pass through a 1-mm sieve. Proximate analysis of crude protein (CP), ash, crude fibre (CF), ether extract (EE) and nitrogen-free extract (NFE) were determined using the method of AOAC (1990), while detergent fibre analysis was determined using the method described by Van Soest *et al.* (1991). Mineral composition (Ca, P, Mg, K and S) were analyzed for maize forage and the silage material after three weeks of ensiling using the Atomic absorption spectrophotometer of AOAC, (1990). All the analyses were carried out in Central laboratory of the National Animal Production Research Institute (NAPRI), Ahmadu Bello University, Shika, Zaria. The silage physical characteristics (physical appearance, texture, pH, temperature, colour and aroma) were also observed and determined immediately after opening the polyethene bags. The texture was determined by feeling with fingers and temperature was determined using an analog thermometer which was dipped in the ensiled material from where the readings were recorded. The colour of the silage was determined by comparing with colour chart, aroma perceived and the pH determined by the use of a pH meter.

In-vivo digestibility of dry matter (DM) was calculated after feeding trial while organic matter digestibility (OMD) and metabolizable energy (ME) were determined using Prediction Equation and nitrogen retained was also calculated.

Calculations of some parameters:

(a) Moisture(%)= $\frac{\text{loss weight due to drying}}{\text{Weight of sample taken}} \times 100$

$$= \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

Where: W_1= weight of container, W_2= weight of container + sample, W_3 =weight of sample after drying.

Dry matter (%)= 100-% Moisture

(b) True dry weight=3.96 + (0.94 X oven %DM), for silage. Prediction equation by Kaiser and Piltz (2004).

(c) Dry matter digestibility (DMD) % $= \frac{\text{Feed DM consumed-faeces DM}}{\text{Feed DM consumed}} \times 100$

(d) Organic matter digestibility (OMD) = 1.017DMD + 1.90, prediction equation by MAFF (1990).

(e) Metabolisable energy (MJ/KgDM) = 0.172 X DMD - 1.707, by Agricultural and Food Research Council (AFRC) UK (1993).

(f) Metabolisable energy (MJ/KgDM) for silage = 0.171 X DOMD - 1.368, by Agricultural and Food Research Council (AFRC) UK (1993).

3.6 STATISTICAL ANALYSIS

All data generated were subjected to the *t-test* procedure using the General Linear Model of SAS (SAS Institute Inc.2001). The means of the two parameters were compared using *t-test*.

CHAPTER 4

4.0 RESULTS

4.1 AGRONOMIC PARAMETERS MEASURED DURING PLANT GROWTH

The germination of WASA1 was 24.25% while that of SHIMAZ was 50.94% at 8 days after sowing (DAS). The germination of the supplied WASA1 seeds was 74.4% similar to SHIMAZ with 74.0%. The establishment counts per plot were 163 and 184 plants in WASA1 and SHIMAZ, respectively. The number of tillers per plant was one per plant.

The number of leaves per plant, plant height and leaf area index (LAI) at various weeks after sowing (WAS) are shown in Table 4.1. There was no difference ($P>0.05$) in plant height and number of leaves between the two maize accessions for all the weeks in which the measurement were taken. The leaf area index (LAI) in SHIMAZ was higher ($P<0.05$) than that in WASA1 at 6 and 10WAS. There was no difference ($P>0.05$) in LAI at 4 and 8 weeks after sowing.

Table 4.1: Mean± S.E of Plant Height, Leaf Number and Leaf Area Index of Two Maize Accessions Measured at Various Weeks of Growth.

Parameters	Maize accession	Weeks after sowing			
		4	6	8	10
Plant height(cm)	WASA1	94.7± 4.0	177.5± 6.447	255.6± 8.5	295.3± 9.1
	SHIMAZ	97.1± 4.8	186.2± 8.2	264.9± 9.1	281.3± 8.9
		NS	NS	NS	NS
No.leaves/plant	WASA1	5.9± 0.1	7.5 ± 0.6	10.3± 0.5	15.6± 0.4
	SHMAZ	6.0± 0.1	7.9± 0.2	11.4± 0.5	14.7± 0.6
		NS	NS	NS	NS
Leaf area index	WASA1	0.3 ± 0.0	1.2± 0.1	3.2 ± 0.3	4.8± 0.2
	SHIMAZ	0.4 ± 0.1	1.6 ± 0.2	4.00± 0.5	5.2± 0.4
		NS	*	NS	*

*Significant (P<0.05), S.E=Standard error, NS= Not significant

4.2 FORAGE AND PLANT COMPONENTS YIELDS AT THREE DIFFERENT HARVEST STAGES.

The forage yield and yield components (leaves per plant, dead leaves per plant, green) at 91, 105 and 112 days after sowing (DAS) are shown in Table 4.2. There was no significant difference ($P>0.05$) between the two maize accessions in number of leaves per plant at the three stages of harvest. The number of dead leaves between the accessions was not significant ($P>0.05$) at 91DAS. However, SHIMAZ had higher ($P<0.05$) number of dead leaves than WASA1 at 105 and 112DAS. The number of green leaves was not significant ($P>0.05$) between the two maize accessions at 91 and 105DAS, but SHIMAZ accession had less ($P<0.01$) green leaves than WASA1 at 112DAS. There was a consistent increase in the number of dead leaves and a consistent decrease in the number of green leaves in the maize accessions from 91 to 112DAS.

The green leaf area was higher ($P<0.05$) in WASA1 accession in all stages of harvest. The leaf area index (LAI) was higher ($P<0.05$) in WASA1 accession at 91 and 105 DAS, while SHIMAZ was significantly ($P<0.01$) lower LAI than WASA1 at 112DAS. There was a consistent decrease in leaf area and LAI from 91 to 112DAS in the two maize accessions. There were no significance ($P>0.05$) between the two maize accessions for fresh forage and forage DM yields at all the stages of harvest. There was also a consistent decrease in fresh forage and a consistent increase forage DM yield in each maize accession as the harvest time was prolonged.

Table 4.2: Mean ± S.E of Forage yield and yield components of two maize accessions harvested at 91, 105 and 112 days after sowing.

Yield components	Maize accession	Days after sowing		
		91	105	112
No. of Leaves/plant	WASA1	15.9± 0.43	16.3 ± 0.25	14.8± 0.63
	SHIMAZ	15.2± 0.63	16.5 ± 0.29	16.0± 0.82
		NS	NS	NS
Dead leaves(no./plant)	WASA1	3.5± 0.68	4.6± 0.33	5.1 ± 0.43
	SHIMAZ	3.0± 0.41	8.6± 1.53	10.0 ± 0.41
		NS	*	**
Green leaves(no./plant)	WASA1	13.3 ± 0.32	12.3± 0.24	10.0± 1.02
	SHIMAZ	12.3 ± 0.75	9.1 ± 1.82	6.0± 0.71
		NS	NS	**
Green leaf area(m^2)	WASA1	96.1± 43.09	55.5± 3.84	45.2± 18.50
	SHIMAZ	70.7± 7.72	33.7± 6.91	18.1± 47.12
		*	*	*
Leaf area index(LAI)	WASA1	5.1± 0.27	2.9± 0.21	1.8± 0.06
	SHIMAZ	3.7± 0.43	1.8 ± 0.36	0.9± 0.25
		*	*	**
Fresh forage yield(t/ha)	WASA1	100.7± 5.25	83.3± 7.44	58.5± 3.11
	SHIMAZ	104.4± 14.32	75.45± 3.14	53.9± 8.77
		NS	NS	NS
Forage DM yield(t/ha)	WASA1	25.1± 3.34	25.5± 4.15	26.1± 1.25
	SHIMAZ	26.3± 3.99	29.3.0± 4.14	31.0± 4.14
		NS	NS	NS

*Significant (P<0.05), **Highly significant (P<0.01), Se=standard error.

4.3 DRY MATTER CONTENT AND YIELD COMPONENTS RATIO AT THREE DIFFERENT HARVEST STAGES.

Table 4.3 shows the dry matter (DM) content and plant components ratio of the two maize accessions at various stages of harvest. The DM of WASA1 accession with 24.2% was significantly ($P<0.01$) lower than SHIMAZ accession with 29.7% at 91DAS. However, there was no difference ($P>0.05$) between the accessions in dry matter content at 105DAS, but SHIMAZ accession had higher ($P<0.05$) value than WASA1 accession at 112DAS. There was a consistent increase in the DM content from 91 to 112DAS of the two maize accessions. The leaf ratio was not significant ($P>0.05$) between the two maize accessions at 91DAS. However, WASA1 accession was higher ($P<0.01$) in leaf ratio at 105DAS and 112DAS than SHIMAZ. There was a consistent decrease in leaf ratio in the two maize accessions from 91 to 112DAS. The stem ratio was higher ($P<0.01$) in WASA1 accession at 91 and 105 DAS, while there was no difference ($P>0.05$) between the two accessions at 112DAS. The cob ratio was significantly ($P<0.01$) lower in WASA1 accession at all the three stages of harvest. The husk ratio was significantly ($P<0.05$) higher in SHIMAZ at 91DAS while WASA1 was higher ($P<0.05$ and $P<0.01$) than SHIMAZ at 105 and 112DAS, respectively. There was a consistent decrease in husk ratio of SHIMAZ, from 91DAS to 105DAS. On the other hand, the husk ratio of WASA1 accession increased from 9.8 to 13.1% and decreased to 11.8% at 91 to 112DAS respectively.

Table 4.3: Mean ± S.E of Dry Matter Content and Plant Components Ratios of Two Maize Accessions Harvested at 91, 105 and 112 days after sowing.

Parameters (%)	Maize accession	Days after sowing		
		91	105	112
Dry matter	WASA1	24.2± 0.34	30.9± 2.88	32.5± 1.09
	SHIMAZ	29.7± 0.44	36.5± 3.77	40.2± 3.28
		**	NS	*
Leaf ratio	WASA1	39.3± 4.08	29.2± 0.51	25.8± 1.06
	SHIMAZ	37.8± 4.66	22.7± 0.54	20.9± 0.48
		NS	**	**
Stem ratio	WASA1	32.5± 0.89	33.4± 3.41	38.4± 2.59
	SHIMAZ	24.9± 1.41	27.3± 3.64	33.2± 1.11
		**	**	NS
Cobs ratio	WASA1	15.8± 3.89	21.9± 1.4	26.1± 1.5
	SHIMAZ	24.2± 2.58	38.6± 1.10	40.4± 1.26
		**	**	**
Husk ratio	WASA1	9.8± 1.69	13.1± 0.27	8.8± 0.39
	SHIMAZ	11.0± 1.9	9.8± 1.18	5.2± 1.53
		*	*	**
Tassels ratio	WASA1	2.8± 0.19	1.9± 0.26	0.9± 0.16
	SHIMAZ	2.2 ± 0.18	1.3± 0.26	1.0± 0.05
		NS	NS	NS

*Significant (P<0.05), **Highly Significant (P<0.01), Se=Standard error, NS=Not Significant (P>0.05).

4.4 FORAGE YIELD, YIELD COMPONENTS AND PLANT COMPONENTS RATIO AT DOUGH STAGE.

Forage yield, yield components and plant components ratio of WASA1 and SHIMAZ at dough stage are shown in Table 4.4. There was no significant ($P>0.05$) difference in DM content between the two maize accessions. West Atlantic Seed Alliance1 attained dough stage at 105DAS, while SHIMAZ was at 91DAS. There was no significant difference ($P>0.05$) between the fresh forage and forage DM yields. The fresh forage yield was 83.3 and 104.4t/ha in WASA1 and SHIMAZ respectively, while the forage DM yields was 25.5 and 31.0 t/ha in WASA1 and SHIMAZ accessions respectively.

The leaf ratio was lower ($P<0.01$) in WASA1 compared to SHIMAZ with 37.8%. Stem ratio was higher ($P<0.05$) in WASA1 than SHIMAZ. The cob ratio was lower ($P<0.05$) in WASA1 compared to SHIMAZ which. There was no difference ($P>0.05$) in tassels ratio, DM, number of leaves, green leaves per plant, leaf area and leaf area index of the maize accessions. The number of dead leaves was lower ($P<0.01$) in SHIMAZ than WASA1.

Table 4.4: Forage Yield, Yield Components and Plant Component Ratios at Dough Stage.

	Maize accessions		
Parameters	WASA1 mean± se	SHIMAZ mean± se	LOS
Fresh fodder yield(t/ha)	83.3± 7.45	104.4 ± 14.32	NS
Forage DM yield(t/ha)	25.5± 4.14	26.3 ± 3.98	NS
Leaf ratio(%)	27.22± 0.82	37.8 ± 0.41	**
Stem ratio (%)	33.4± 3.01	24.9 ± 0.45	*
Cods ratio(%)	21.9± 1.67	24.3± 2.58	**
Husk ratio(%)	13.1± 0.65	11.1± 0.77	NS
Tassels ratio(%)	1.9± 0.26	2.2 ± 0.18	NS
Dry matter(%)	30.9± 2.88	29.7± 0.45	NS
Leaf(No./plant)	16.3± 0.25	15.3± 0.63	NS
Green(No./plant)	12.3± 0.77	12.3± 0.75	NS
Dead leaf(No./plant)	4.6 ± 0.24	3.0± 0.41	**
Leaf area(m^2)	55.4± 3.50	70.7± 7.22	NS
Leaf area index (LAI)	2.9 ± 0.21	3.7± 0.40	NS

**Highly significant (P<0.01), *Significant (P<0.05), NS=Not significant, Se=standard error, LOS= Level of significant.

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4.5 PROXIMATE COMPOSITION OF FORAGE AT DIFFERENT HARVEST STAGES.

Table 4.5 shows the proximate analysis of the maize accessions harvested at three stages of harvest. The result showed that there was no difference ($P>0.05$) in ash content between the accessions at 91 and 105DAS. However, the content in WASA1 was higher ($P<0.05$) at 112DAS. There was a consistent decrease in each accession from 91 to 112DAS. There was no significance ($P>0.05$) for ether-extract (EE) between the maize accessions at various harvest stages and there was also a consistent decrease in EE from 91 to 112DAS in the two accessions. There was also no difference ($P>0.05$) for crude fibre (CF) content at 91DAS between the two maize accessions but WASA1 was higher ($P<0.01$) at 91 and 112DAS. Similar trend was observed for crude protein (CP). Crude fiber (CF) increased from 23.0 to 31.1% and 27.8 to 36.6% from 91 to 112DAS in WASA1 and SHIMAZ respectively, while CP decreased from 7.8 to 6.5% and 6.6 to 53.6% for the same periods of harvest in WASA1 and SHIMAZ respectively. The nitrogen free-extract (NFE) was higher ($P<0.05$) in WASA1 at 91 and 112DAS, and higher ($P<0.01$) than SHIMAZ at 112DAS.

Table 4.5: Mean ± S.E of Proximate Composition of the Two Maize Accessions at Various Stages of Harvest.

Parameters (%)	Maize accession	Days after sowing		
		91	105	112
Ash	WASA1	4.9± 0.15	4.5± 0.10	4.5± 3.28
	SHIMAZ	5.1± 0.54	4.7± 0.51	4.0± 4.66
		NS	NS	*
Ether-extract	WASA1	7.6± 0.06	7.2± 0.33	6.2± 0.50
	SHIMAZ	6.8± 0.20	6.6± 0.21	6.0± 0.21
		NS	NS	NS
Crude fibre	WASA1	23.0± 0.61	28.5± 0.73	31.0± 0.98
	SHIMAZ	27.8± 0.89	33.2± 0.62	36.5± 0.21
		NS	**	**
Crude protein	WASA1	7.8± 0.41	7.4± 0.41	6.5± 0.43
	SHIMAZ	6.6± 0.99	6.1± 0.15	5.2± 0.12
		NS	*	*
Nitrogen free-extract	WASA1	56.6± 0.70	52.1± 1.42	51.7± 0.11
	SHIMAZ	53.6± 1.29	49.1± 0.44	48.1± 0.55
		*	*	**

*Significant (P<0.05), **Highly significant (P<0.01), NS=Not siginificant, Se=standard error, WASA1= West Atlantic Seed Alliance, SHIMAZ= Shika maize

Figure 1 shows the proximate and detergent fibre analyses of the two maize accessions at dough stage. There were no differences ($P>0.05$) in the proximate components and ME of the two maize accessions. There was also no difference ($P>0.05$) between the accessions in neutral detergent fibre (NDF), but WASA1 with 30.8% ADF was higher ($P<0.01$) than SHIMAZ with 24.5%.

Table 4.6 shows the mineral composition of WASA1 and SHIMAZ at dough stage and ensiled forage materials. The content of phosphorus (P) was a significantly ($P>0.05$) lower in SHIMAZ than in WASA1 for both the silage and at dough stage, WASA1 was better ($P<0.01$) in calcium (Ca) and magnesium (Mg) contents than SHIMAZ. On the other hand, potassium (K) was higher ($P<0.05$) in SHIMAZ than WASA1 at dough stage. There was also no difference ($P>0.05$) in P, K and Na of silage of the maize accessions.

4. 6 PHYSICAL CHARACTERISTICS, PROXIMATE AND DETERGENT FIBRE COMPOSITION OF SILAGE.

The physical characteristics of silage for the two maize accessions observed at 21 days after ensiling are shown in Table 4.7. The physical appearance was leafy while the texture was soft for the two maize accessions. The silage colour of the two maize accessions was light greenish brown as shown in Plate V. The pH value and the temperature of the silage material in WASA1 accession was slightly lower than that of SHIMAZ.

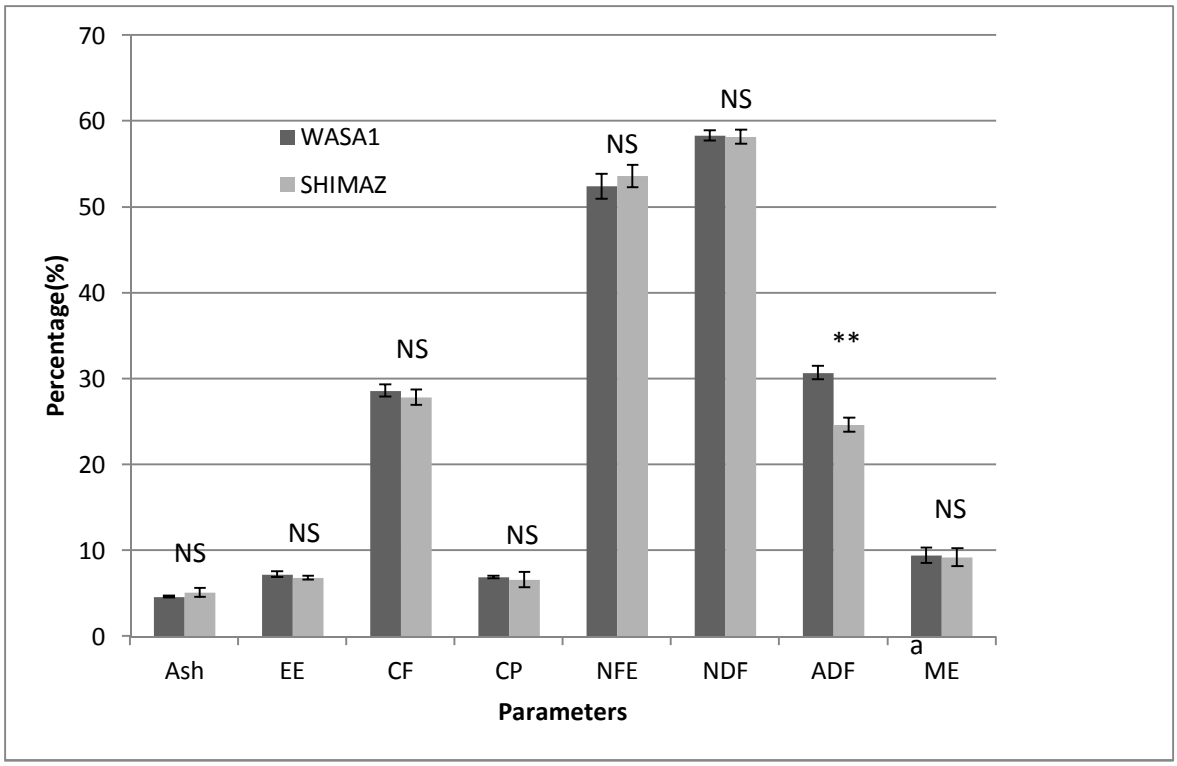


Fig.1: Proximate and detergent fibre analyses of WASA1 and SHIMAZ at dough stage. NS=Not Significant, I= Error bars, **= Highly Significant (P<0.01). a=MJ/kgDM.

Table 4.6: Mineral Composition (%DM) of the Two Maize Accessions at Dough Stage and Silage,

	Dough stage			Silage		
Parameters	WASA1 mean± se	SHIMAZ mean± se	LOS	WASA1 mean± se	SHIMAZ mean± se	LOS
Phosphorus	0.1± 0.04	0.07 ± 0.02	*	0.2± 0.04	0.3± 0.21	NS
Calcium	0.4± 0.04	0.05± 0.02	**	1.0± 0.05	0.9± 0.02	**
Magnesium	0.7± 0.15	0.37± 0.05	**	1.1± 0.03	0.7± 0.03	**
Potassium	1.0± 0.05	1.42± 0.71	*	1.2± 0.04	1.1± 0.01	NS
Sodium	0.5 ± 0.06	0.39± 0.02	NS	0.4± 0.04	0.5± 0.06	NS

**Highly significant (P<0.01), *Significant different (P<0.05), NS=Not significant, Se=standard error, LOS= Level of significance.

Table 4.7: Physical Characteristics of Silage of Two Maize Accessions at 21 Days after Ensiling.

Parameter	Maize accessions	
	WASA1	SHIMAZ
Appearance	leafy	leafy
Texture	soft	soft
Colour	light yellowish brown	light yellowish brown
Aroma	mild pleasant sour milk smell	mild pleasant sour milk smell
pH	3.9	4.1
Temperature (^{o}C)	29 .0	31.0



Plate V: Colour of the SHIMAZ maize silage material at 21 days of ensiling.
Photogragh: T. Akpensuen

Figure 2 shows the proximate and detergent fibre of silage for the two maize accessions. There was no difference ($P>0.05$) in DM and CF contents of the two maize accessions. The ash and EE contents were significantly ($P<0.01$) higher in WASA1. The ash contents in WASA1 and SHIMAZ were (10.8% vs. 6.8% respectively). The CP content was higher ($P<0.05$) in WASA1 with 8.6% than SHIMAZ with 7.3%. On the other hand, NFE was higher ($P<0.01$) in SHIMAZ than WASA1 and there was no significant ($P>0.05$) difference in metabolizable energy (ME) values of the two accessions. The NDF was higher ($P<0.01$) in WASA1 than SHIMAZ while, the difference in ADF of SHIMAZ was significantly ($P<0.05$) lower.

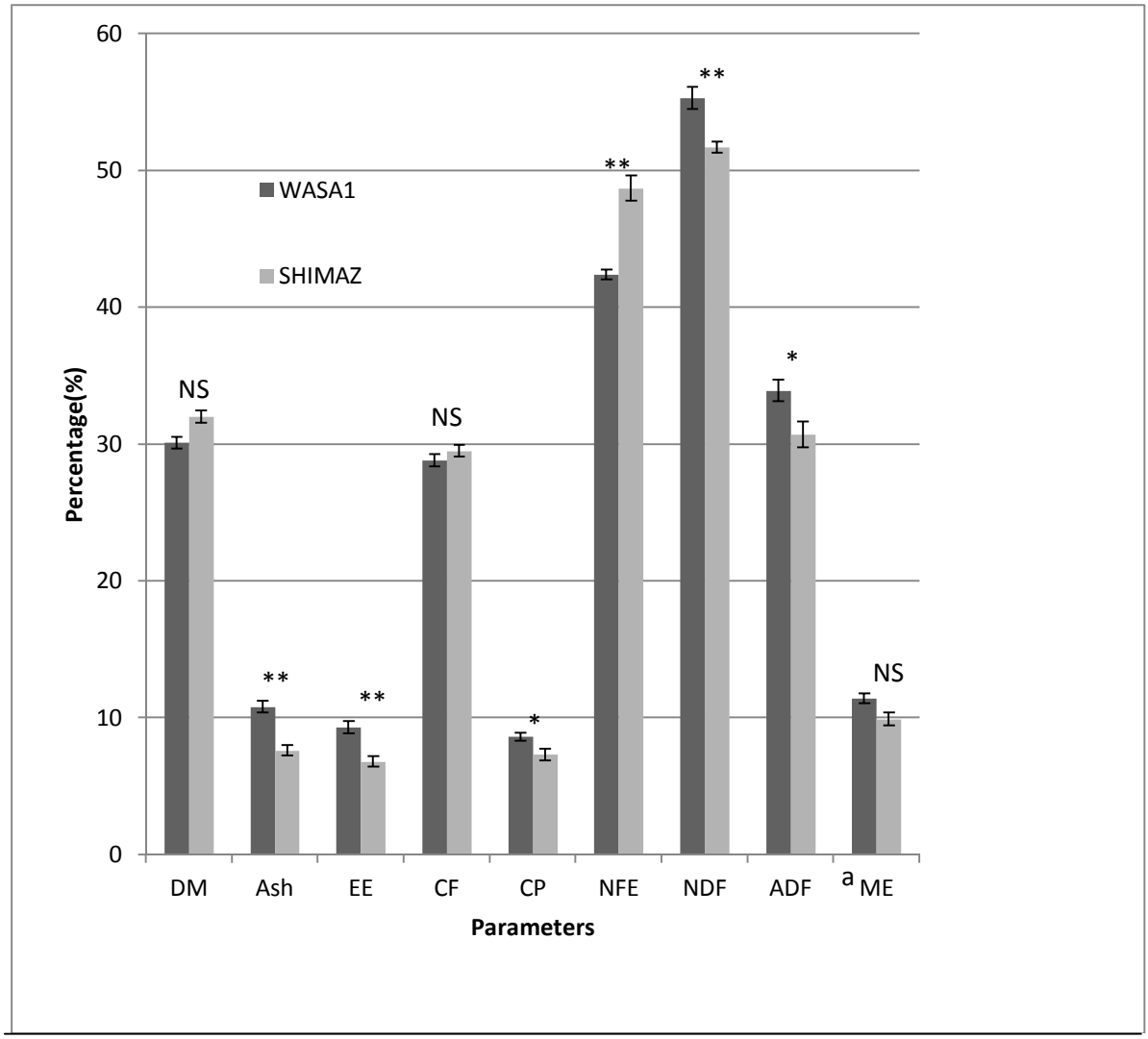


Fig. 3: Silage proximate and detergent fibre analyses at 21 days of ensiling.
NS=Not Significant, I= Error bars, **Highly Significant (P<0.01), *Significant (P<0.05).
a=MJ/kgDM

4.7 PROXIMATE, DETERGENT FIBRE AND MINERAL COMPOSITION OF FRESH FORAGE AND SILAGE FOR TWO MAIZE ACCESSIONS.

Table 4.8 shows the proximate, detergent fibre and mineral composition in forage and silage of the two maize accessions before and after ensiling. The ash content was higher ($P<0.01$) in silage for both maize accessions. The EE (9.4%) in silage was higher ($P<0.01$) than in forage with 7.2% of WASA1, but there was no difference ($P>0.05$) between forage and silage of SHIMAZ. There was no difference ($P<0.05$) in CF contents of silage and forage for both maize accessions. The CP content was higher ($P<0.01$) in silage than the forage of WASA1 accession, while there was no significance ($P>0.05$) between the forage and silage in SHIMAZ. The NFE was higher ($P<0.05$) in silage of the two maize accessions. There was also no difference ($P>0.05$) between forage and silage in NDF of WASA1 accession. However, silage value (58.3%) was higher ($P<0.01$) than in forage with 51.5% of SHIMAZ. Silage was higher ($P<0.05$) and ($P<0.01$) in ADF than forage in WASA1 and SHIMAZ accessions respectively.

There were no differences ($P>O.05$) in the phosphorus content of the forage and silage of WASA1 and SHIMAZ accessions. The silage of WASA1 was higher ($P<0.01$) in Ca, but there was no difference ($P>0.05$) between forage and silage of SHIMAZ. Similarly, there was no difference ($P>0.05$) in Mg between the forage and silage of both maize accessions. There was also no difference ($P>0.05$) between forage and silage in K and Na of WASA1. However, there was a difference ($P<0.05$) between forage and silage in K and Na of SHIMAZ.

Table 4.8: Proximate, Detergent Fibre and Mineral Composition of Forage and Silage of the two Maize Accessions (%DM).

	WASA1			SHIMAZ		
Parameters	Forage mean± se	Silage mean± se	LOS	Forage mean± se	Silage mean± se	LOS
Ash	4.5± 0.10	10.8± 0.41	**	5.1± 0.54	7.6± 0.37	**
EE	7.2± 0.33	9.4± 0.43	**	6.8± 0.20	6.8± 0.38	NS
CF	28.6± 0.72	28.8 ± 0.44	NS	27.8± 0.89	29.5± 0.43	NS
CP	6.9± 0.17	8.6± 0.32	**	6.6± 0.89	7.5± 0.43	NS
NFE	52.4 ± 1.38	42.4± 1.41	*	53.6± 1.29	48.7± 0.94	*
NDF	58.3± 0.69	55.3± 0.8	NS	58.2± 0.80	51.5± 0.41	**
ADF	30.8± 0.80	33.9± 0.79	*	24.7± 0.82	30.6± 0.96	**
P	0.1± 0.01	0.12 ± 0.04	NS	0.1± 0.02	0.3± 0.21	NS
Ca	0.4± 0.04	1.1± 0.05	**	0.6± 0.02	0.6± 0.02	NS
Mg	0.7± 0.16	1.05± 0.03	NS	0.4± 0.04	0.4± 0.03	NS
K	1.0± 0.05	1.2± 0.41	NS	1.5± 0.77	1.1± 0.01	*
Na	0.5 ± 0.06	0.3± 0.10	NS	0.4± 0.02	0.5± 0.04	*
ME(MJ/kgDM)	9.2± 0.43	11.32± 0.39	**	9.2± 0.39	9.9± 0.49	NS

**Highly significant (P<0.01), *Significant different (P<0.05), NS=Not significant, Se=standard error, LOS= Level of significance.

The ME was higher (P<0.01) in silage of WASA1 while there was no difference (P>0.05) between silage and forage of SHIMAZ.

4.7 NUTRIENTS INTAKE AND DIGESTIBILITY OF FORAGE AND SILAGE MATERIALS FED TO RED SOKOTO GOATS.

Table 4.9 shows the nutrient intake, digestibility and nitrogen balance of WASA1 and SHIMAZ accessions of maize for forage and silage. The dry matter intake (DMI) and crude protein intake (CPI) between the two accessions were not different (P>0.05) in both forage and silage. Apparent nutrient digestibility was not significant (P>0.05) except for crude protein digestibility (CPD), which was higher in WASA1 accession in both fresh forage and silage materials. The nitrogen intake, faecal-N, urinary-N and nitrogen were not similar (P>0.05) in WASA1 and SHIMAZ accessions of the forage and silage.

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Table 4.9: Nutrient Intake and Digestibilty of Forage and Silage of Two Maize Accessions Fed to Red Sokoto goats.

	Forage			Silage		
Parameters	WASA1 mean± se	SHIMAZ mean± se	LOS	WASA1 mean± se	SHIMAZ mean± se	LOS
DMI(g/d)	298.7± 33.80	285.5± 33.31	NS	290.0± 33.80	270.7± 28.81	NS
CPI(g/d)	22.8± 3.44	20.1± 2.09	NS	24.5± 2.95	20.0± 2.26	NS
Apparent nutrients digestibilties(%)						
DMD	64.6± 5.11	63.4 ± 5.99	NS	75.2± 1.19	67.6± 2.86	NS
CPD	73.4± 2.69	61.7± 4.51	*	82.7± 1.08	76.9± 1.93	*
OMD	67.5 ± 5.1	66.5± 6.1	NS	78.4± 2.0	70.4± 2.8	NS
Nitrogen balance(g/d)						
Total N-intake	3.7± 1.22	3.2± 1.18	NS	3.9± 1.15	3.2± 0.17	NS
Urinary N	1.1± 0.51	0.7± 0.42	NS	1.2± 0.60	0.8± 0.42	NS
Faecal N	I.0± 0.06	1.0 ± 0.16	NS	0.52± 0.09	0.7± 0.13	NS
N- retained	1.6± 1.27	1.5± 1.58	NS	2.2± 1.27	1.7± 1.58	NS

*Significant (P<0.05), NS=Not significant, Se=standard error, LOS= Level of significance, DMI=Dry matter intake, CPI=Crude protein intake, DMD= dry matter digestibility, CPD= crude protein digestibility, OMD= Organic matter digestibility, N= Nitrogen.

CHAPTER 5

5.0 DISCUSSION

5.1 AGRONOMIC PARAMETERS MEASURED DURING CROP GROWTH.

Germination and establishment: The first germination counts of both accessions were poor because, there was drought for eight days after planting. WASA1 was most affected indicating that, it has low resistance to drought compared to SHIMAZ accession. Maize has been reported to have low tolerance to water stress (DHA, 2008). However, the germination of the supplied seeds was good because of adequate moisture as a result of good rainfall intervals. The number of established plants stands was less than the number of seeds planted due to pest attack. The tillers of the two accessions were lower than the results obtained by Choe *et al*. (1991), who reported 3.7, 3.3 and 3.6 tillers per plant on the average for IK1, IK2 and IK3 maize varieties, respectively probably due to in-breds variety and environmental differences.

Plant height: The height of the two maize accessions as shown in Table 4.1 were similar to the result obtained by Carpici *et al.* (2010). However, the height of the two maize accessions were higher those (98 to 222.8cm) obtained by Hassan (2010) and Ramezami *et al* (2011) in Pakistan for forage maize varieties.

Leaf number: The number of leaves of the two maize accessions were similar to the results obtained by Turgut *et al.* (2005) and Carpici *et al.* (2010) but, higher than the result obtained by Awal *et al.* (2001) and Hassan (2011).

Leaf area index: The significant difference in LAI of the two accessions of maize indicates that, SHIMAZ accession will grow and cover more land area, and has the tendency to produce more forage dry matter (DM) yield. The capacity of a crop to intercept

photosynthetically active radiation and synthesis of carbohydrates is a non-linear function of LAI (Elings, 2000) and as the LAI increases, so does photosynthesis (Mannetje, 1999). The LAI obtained in this study at 8 weeks after sowing is in line with the result of Yao *et al*. (2008), who obtained similar value at 7 weeks after sowing in forage maize varieties. The differences in the agronomic parameters can be adduced to variety, environmental and cultural practices.

5.2 DRY MATTER CONTENT, FORAGE AND PLANT COMPONENTS YIELDS.

The result obtained for number of leaves at different stages of harvest in the two maize accessions was higher than the result obtained by Hassan (2010) for Giza-2 (12.6 leaves per plant) and Mugtama (11.3 leaves per plant) forage varieties at 90DAS. The number of dead leaves was significant between the two accessions at 105 and 112DAS because, WASA1 had fewer numbers of dead leaves and more green leaves than SHIMAZ. The accession WASA1 with higher number of green leaves at 112DAS matured so late, compared to SHIMAZ. The differences in the leaf area at different stages of harvest was due to the differences in number of green leaves between the two accessions which WASA1 had higher number and this was responsible for the significant difference in LAI of the two accessions at the same stages of harvest. The yield difference in fresh forage and forage DM was also due to differences in maturity periods as SHIMAZ matured earlier and tends to dry faster than WASA1. The fresh forage yield and forage DM yields obtained in this trial at 91 DAS were higher than the results obtained by Hassan (2010) for *Giza-2* and *Mugtama-45* at 90DAS probably due to variety, agronomic practices and environmental differences of the location of the trial.

The DM content of the two accessions at various stages of harvest indicated that WASA1 accession can be harvested for silage at 105 to 112 post-planting while SHIMAZ can be harvested earlier at 91 to 98 post-planting when using DM as the basis for harvesting, in line with Staples (2003) and Bagg (2007). Mickan and Piltz (2004a) also confirmed that stage of harvest affects both the dry matter content and dry matter yield of maize crop.

The significant difference observed in plant component ratios at different stages of harvest was likely due to genetic difference and maturity date of the two accessions. Yilmaz *et al*. (2007) and Tang *et al*. (2008) also reported differences in yield component ratios in forage maize varieties. There was a consistent decrease in leaf ratio of each of the maize accessions which agreed with Humphreys (1999), who reported that as the plant matures, there is decrease in ratio of leaf to stem and the changing proportion of the plant components accounts for the overall differences in cultivar nutritive value. The increases in stem ratio obtained in this trial also agreed with McDonald *et al*. (1998) that as the plants mature, the stem proportion of the total biomass increased. Furthermore, Russell (1986) reported that as the stem proportion increased, the proportion of leaves decreased with the increasing maturity stage in maize. The increment noticed in cob ratio for each of the accession at 91 to 112DAS was due to the accumulation of water soluble carbohydrates (WSCs) for seed development.

The attainment of dough stage at 105 days in WASA1 is in line with the growing period of 100 to 150 days for silage varieties stated by Griffiths *et al*. (2004), while Chad *et al.* (2005) recommended a maturity period of between 113 to 120 days. SHIMAZ accession which attained dough stage at 91 days for silage is in contrast to the recommended days by the previous authors due to difference in cultuvar. The fresh forage yield of 83.3 and

104.4t/ha at dough stage in WASA1 and SHIMAZ accessions, respectively were higher than the results obtained by Yilmaz *et al.* (2007), Hassan (2010) and Hassan (2011) who obtained between 28.5 to 70.4t/ha in various forage maize varieties. Similarly, the forage DM yield of 25.5 and 31.0 t/ha obtained in WASA1 and SHIMAZ accessions, respectively were higher than the range (12 to 25.0t/ha) obtained by Griffiths *et al.* (2004), and Lauer *et al.* (2004), Yilmaz *et al*. (2007), Iptas and Acar (2008) and Carpici *et al.* (2010) for various forage maize varieties. However, the yield of WASA1, was less than variety *C- 955* as reported by Turgut *et al*. (2005) who obtained 28.5t/ha. The differences in fresh forage and dry forage DM yields between the accessions can be adduced to differences in population density (67,600 and 93,200 plants per hectare) for WASA1 and SHIMAZ respectively, and variety. SHIMAZ had more established plants and was also more robust than WASA1 accession. Higher forage yield in SHIMAZ suggests that there will be more biomass and quantity of feed available for the animal.

The leaf ratios of the two accessions were higher than the results obtained by Iptas and Acar (2008) and Carpici *et al*. (2010) who reported the values of 16.7 to 25.5% in various forage maize varieties. The results obtained for stem ratio in this trial were lower than the values (34 to 56%) in maize varieties as reported by the previous authors, but higher than 25.8% as obtained by Tang *at al*. (2008). The cobs ratios in the two maize accessions were similar to the result obtained by Tang *et al*. (2008). The significant differences in plant component ratio of the two accessions can be adduced to genetic variation. The numbers of leaves (16.3 and 15.3) per plant for WASA1 and SHIMAZ, respectively obtained in this trial was higher than 15 leaves per plant reported by Hassan (2010), Carpici *et al.* (2010) and Hassan (2011) for different forage maize varieties. The leaf area of the two accessions were higher than the result obtained by Edoka (2006) who

examined leaf area in four early and six mid-early maturing forage maize varieties. The LAI for the two accessions were quite in line with the results obtained by Alkmal *et al*. (2010) and Edoka (2006), but lower than the result obtained Mugalkhod *et al*. (2010) which may be due to differences in variety.

5.3 FORAGE PROXIMATE COMPOSITION.

The decrease in contents of ash and EE of the accessions agrees with McDonald *et al.*, (1998) and Kellems and Church, (2002) who reported that as the plant matures, both ash and EE contents decreased. The decrease in CP also agreed with Holechek *at al*. (2004) and Tang *et al*. (2011) that as the plant matures, the CP decreases; and structural carbohydrates increased due to accumulation of cellulose and lignin (McDonald *et al*., 1998). The difference in proximate composition of the two accessions may be due to the changing proportion in leaf: stem ratio at various harvest stages (Humphreys, 1999). Higher NFE in WASA1 at each harvest stage was likely due to lower content of CF at each stage of harvest and the decline in NFE in each accession as maturity advanced, can be adduced to increase in CF and decrease in ash, EE and CP. The values obtained in this trial for the two maize accessions for CP, ash, ADF and NDF at dough stage were similar to those reported by Ballard *et al*. (2001).

The Ca, Mg and P contents obtained in this trial at dough stage were higher than the result obtained by Ballard *et al*. (2001). The mineral contents in silage for the two maize accessions were lower than the contents obtained by Kaiser *et al.* (2004) and Amole, *et al*. (2011). The P contents in the two accessions experimented was lower, but the K content was higher than result obtained by Staples (2003). Animals fed WASA1 silage will be able to utilize crop by-products more effectively than SHIMAZ silage due to higher mineral

content. The mineral contents of the two maize accessions for forage and silage can satisfy small ruminants for growth, maintenance and production as the contents are above their mineral requirements (Humphreys, 1999; and Freer, 2007).

5.4 PHYSICAL CHARACTERISTICS AND NUTRIENTS COMPOSITION OF SILAGE.

Kaiser and Piltz (2004) stated that the good fermented maize silage should be leafy, soft to touch, yellowish-brown, mild pleasant and sour smell, and in addition the silage must be high in CP and ME contents. The pH values obtained in this study is within the recommended range of 3.7 to 4.2 stated by Kung and Shaver (2001) and Kaiser and Piltz (2004) for maize silage. The results also agreed with Roth and Heinrichs, (2001) who stated that maize silages having a DM content of less than 30% should have pH value of 3.9 while those having the DM content between 30 to 35% should have a pH of 4.0. The temperature values of the two maize accessions agreed with Adesogan and Newmann, (2008) that silage temperatures should not be more than 37.7^{o}C which encourages good silage fermentation because higher temperatures reduce quality, enhance protein degradation and reduce rapid pH decline for an efficient degradation.

The ash and EE contents of silage obtained in this trial were similar to the result reported by Amole *et al*. (2011). The ash contents in both maize accessions experimented were higher than the result obtained by Ballard *et al.* (2001) and Hayashi *et al*. (2009) who reported 2.3 to 3.7% in maize silage varieties. The contents of CF and NFE in the two maize accessions were similar to the result obtained by Hayashi *et al.* (2009) who reported 27.7% and 57.3% for CF and NFE respectively, but lower than the value obtained by Amole *et al*. (2011) who reported the value (36.7%) for CF. However, the NFE in the

accessions was within the range of 23.6 to 33.2% as reported by (Roth and Heinrichs, 2001). The CP content of WASA1 was slightly higher than the range of 4.5 to 8.5% stated by Griffiths *et al.* (2004), while those SHIMAZ were within the range. The two maize accessions can not be used as a sole feed to supply protein for beef and dairy cattle as their CP contents are lower than 10% and 11.6% respectively (Humphreys, 1999). The metabolizable energy (ME) values for the two accessions were in line with the range of 10-11MJ/KgDM stated by (Griffiths *et al.,* 2004) for maize silage. The ME of the silages in these maize accessions will satisfy the energy requirements of sheep and goats for growth, maintenance and pregnancy but lower than 14.2 to 22.0 MJ required for lactating sheep (McDonald *et al.,* 1998). The ME can not also satisfy the energy requirements of all groups of cattle as stated by the same authors. The values obtained in this trial for NDF and ADF are similar to those reported by Knezˇevic´ *et al*. (2007). The NDF of the two maize accessions was higher but the ADF lower than the value obtained Amole *et al*. (2011) who reported 53.5 and 49.8% for NDF and ADF, respectively. The differences in proximate components can be adduced to varietal differences. Ballard *et al.* (2001) also reported differences in proximate components of silages made from three different maize varieties.

5.5 EFFECT OF FERMENTATION ON NUTRIENT COMPOSITION.

Ballard *et al*. (2001) reported increase in ash, EE and CP in fermented maize with a decrease in NDF after fermentation. However, the increment in ash and CP were contrary to Phiri *et al.* (2007) who reported a decrease in CP and ash while a decrease in NDF was quite in line with their results. The CP increment after fermentation can be attributed to microbial synthesis of protein from the substrate during their growth cycle (Mohiedeen *et al*., 2010) and also loss in carbohydrates. The decrease in NFE could be attributed to partial

hydrolysis of WSCs that provided additional sugar for lactic acid production during fermentation (Muck, 1989; Muck and kung, 1997). Derby and Lauer (2002) reported a decrease NDF after ensiling which was similar to the report in this study. The increase in ADF after fermentation contrast those of Phiri *et al.* (2007) and Ozkose *et al*. (2009) who reported that ensiling had no effect on ADF. On the other hand, Nkosi *et al.* (2011) reported that ensiling decrease both NDF and ADF contents.

5.6 DIGESTIBILITY OF FORAGE AND SILAGE MAIZE ACCESSIONS FED TO RED SOKOTO GOATS.

The dry matter digestibility (DMD) obtained in the silage of WASA1 was similar to the value obtained by Canizares *et al.* (2011). The organic matter digestibility (OMD) in WASA1 and SHIMAZ silage accessions were higher than values obtained by Kim *et al*., (1993) and Canizares *et al*., (2011) when maize silage was fed to goats. The OMD of forage and silage in both maize accessions were 3% higher than DMD, which agreed with Humphreys (1999) who stated that the OMD is always 2 to 3% higher than DMD. The nitrogen retained in two accessions of both forage and silage were higher than the value obtained by Kim *et al*. (1993), but lower than the result obtained by Amole *et al*. (2011). The advantage of the high nitrogen retained in the animals implies that there will be more nitrogen available for digestion, absorption and metabolism.

CHAPTER 6

6.0 SUMMARY, CONCLUSION AND RECOMMENDATION.

6.1 SUMMARY AND CONCLUSION.

In summary, differences between accessions were relatively small, especially in plant height, number of leaves and leaf area index. Forage yields were similar for both accessions. Chemical analysis indicated higher calcium and magnesium contents for WASA1 accession at dough stage of harvest. Crude protein contents in the silages of both accessions were above 7%. The content of ash in silage was higher than in the forage for the two maize accessions. Crude protein digestibilities were higher in the forage and silage of WASA1 than SHIMAZ while nutrients intake and nitrogen retained for the forage and silage were similar.

It is concluded that the two accessions can be grown successfully in the Northern Guinea Savanna of Nigeria where the experiment was carried out, but SHIMAZ accession may be preferred due to it's high biomass. The mineral contents in fresh forage and silage can satisfy small ruminant requirements. Silages made from the two accessions will supply the protein requirements of small ruminants (sheep and goats) for maintenance, growth and production but can not be used as sole feed for beef and dairy cattle.

6.2 RECOMMENDATIONS.

From the current study, it was observed that the two accessions of maize can be produced without heavy inputs, but how this can be accomplished has to be determined and quantified. Finally, animal studies involving feeding trials are needed to define the limits of maize forage and silage as a supplement to other fodder in ruminant feeding systems in Nigeria.

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List of appendices

Appendix 1: Potential Forage Dry Matter Yields of Grasses, Legumes and Crops used for Silage.

Silage material	Yield (t DM/ha/cut)	Sources
Forage ryegrass	2.4-4.5	Griffiths and Burns (2004)
Other temperate graases	2-4	,,
Kikuyu/tropical grasses	2.3-5	,,
Clover	2.5-4	,,
Lucerne	1.5-3.2	,,
Cowpea/lablab	1.5-6	,,
Forage sorghum/pennisetum	2-5	,,
Oats/wheat/barley	5-15	Griffiths *et al*. (2004)
Grain sorghum	4-10	,,
Sweet sorghum	10-25	,,
Soyabeans	4-10	,,
Maize	12-25	,,

Appendix 2: Leaf, Stem and Ear Ratio in Various Forage Maize Varieties

Variety	Leaf ratio (%)	Stem ratio (%)	Ear ratio (%)	Sources
P-3394	25.5	34.0	40.7	Bilal *et al*. (2005)
Arifiye	24.3	44.9	30.6	,,
Frassico	24.8	37.0	30.6	,,
Dracm	15.4	42.4	41.7	Yilmaz *et at.* (2007)
P-3223	15.9	44.3	42.2	,,
P-3335	16.7	39.8	43.2	,,
DK-711	15.4	42.7	41.9	,,
DK-626	14.8	40.5	44.8	,,
Aritiye	15.7	49.4	34.8	,,
Arifiye	22.0	44.6	34.1	Iptas and Acar (2008)
P-3163	18.7	33.1	48.0	,,
TM-8119	16.9	38.2	44.3	,,
K. Yildizi	18.8	35.8	45.3	,,
ADA-523	25.2	55.9	18.8	Carpici *et al*. (2010)

Appendix 3: Physical Characteristics of Maize Silage and Interpretation

Parameter	Characteristics and interpretation
Physical appearance[a]	Leafy. Have high CP and ME contents.
Texture[a]	Soft. Have high CP and ME contents,
Colour[a]	Light green to green/brown- normal colour range for grass, cereals And maize silage.
Aroma[a]	Mild, pleasantly acid, sour milk or natural yoghurt smell- normal lactic Acid fermentation- desirable
pH[b]	3.7-4.2 Normal value range.
Temperature(^{o}C)[c]	Below 37^{o}C

Sources; [a]Kaiser and Piltz (2004). [b]Kung and Shaver (2001). [c]Adesogan and Newman(2008)

Appendix 4: Typical Chemical Composition of Maize Silage

Nutrients (%)	Concentration	Desired range	Sources
Dry matter	33	30-40	Roth(2001)
Crude protein	8.8	7.2-10.0	,,
Crude fibre	23.3	-	McDonald (1998)
Ether-extract	5.7	-	,,
Ash	10.0	-	,,
Acid detergent fibre	28.9	23.6-33.20	Roth(2001)
Neutral detergent fibre	49.0	41-54.1	,,
Metabolizable energy (MJ/kgDM)	10.8	-	McDonald(1998)
Total digestible nutrients	68.0	66.8-70.9	Roth(2001)
Calcium	0.25	-	,,
Phosphorus	0.23	-	,,
Magnesium	0.18	-	,,
Potassium	0.20	-	,,
Sulphur	0.13	-	,,

Appendix 5: Fermentation Acids Profile Collected from Numerous Maize Silage Sample

End product(%)	Grass silage 30-40%DM	Legume silage 45-55%DM	Maize silage 30-40%DM
pH	4.3-4.7	4.7-5.0	3.7-4.2
Lactic acid	6-10	2-4	4-7
Acetic acid	1-3	0.5-2.0	1-3
Propionic acid	<0.1	<0.1	<0.1
Butyric acid	0.5-1.0	0.0	0.0
Ethanol	0.5-1.0	0.5	1-3
Ammonia-N(% of CP)	8-12	<12	5-7

Source: Kung and Shaver, 2001.