FORAGE YIELD AND QUALITY OF SORGHUM (*Sorghum bicolor* L. Moench) VARIETIES AT DIFFERENT SOWING DATES, HARVEST AND UTILIZATION OF THE SILAGE BY GROWING YANKASA RAMS

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JUNE, 2021

DECLARATION

I declare that the work in this thesis entitled **"FORAGE YIELD AND QUALITY OF SORGHUM (*Sorghum bicolor* L. Moench) VARIETIES AT DIFFERENT SOWING DATES, HARVEST AND UTILIZATION OF THE SILAGE BY GROWING YANKASA RAMS"** has been carried out by me in the Department of Animal Science, under the supervision of Dr. M. R. Hassan, Dr. R. J. Tanko and Dr. S. M. Yashim. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another Degree or Diploma Certificate at any University.

Bello Mummuni MUNZA ________________________ ____________

Signature Date

CERTIFICATION

This thesis titled **"FORAGE YIELD AND QUALITY OF SORGHUM (*Sorghum bicolor* L. Moench) VARIETIES AT DIFFERENT SOWING DATES, HARVEST AND UTILIZATION OF THE SILAGE BY GROWING YANKASA RAMS"** by Bello Mummuni MUNZA meets the regulations governing the award of the Degree of Doctor of Philosophy (Ph D.) of the Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

I dedicate this work to God Almighty for giving me the grace, strength and wisdom to carry out this work successfully and my lovely wife, family and friends for their guidance, support and contribution towards the completion of this study.

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ABSTRACT

This study was conducted to evaluate the forage yield and quality of sorghum (*Sorghum bicolor* L. Moench) varieties at different sowing dates, harvest and utilization of the hay/silage by growing Yankasa rams at NAPRI, Shika. The agronomic treatment consisted of two sorghum varieties (SAMSORG-16 and SAMSORG-17), three sowing dates (15th June, 30th June and 14th July) and three stages of harvest (6, 10 and 14 weeks after sowing (WAS). The treatment were factorially combined (2 x 3 x 3) and laid down in split plot design where variety and sowing date as main plot while stage of harvest as sub-plot and completely randomized and replicated three times. Experiment II: The study evaluated the effect of feeding regime on growth, apparent nutrient digestibility, nitrogen retention, rumen indices and economics of production of Yankasa rams fed a basal diet of grain sorghum hay or silage supplemented with concentrate. Sixteen (16) growing Yankasa rams (17.0±0.2 kg) were randomly assigned to four feeding regimes consisting of T_1 = Sorghum hay + concentrate daily, T_2 = Sorghum silage + concentrate daily, T_3 = Sorghum silage + concentrate after 1-day and T_4 = Sorghum silage + concentrate after 2-days. The parameters measured were hay/silage intake, concentrate intake, total feed intake, daily feed intake, initial weight, final weight, weight gain, daily weight gain, feed conversion ratio (FCR), apparent nutrient digestibility, nitrogen retention, rumen metabolites and costs-benefit. Results showed that plant height of *Sorghum bicolor* significantly (P<0.05) differed between variety with higher values for SAMSORG-16 in 2018 and 2019 growing seasons. Plant height significantly (P<0.05) decreased from the earlier sowing of 15th June to the sowing made on 14th July in 2018, although significantly (P<0.05) higher plant height were recorded in 2019 growing season. There was no significant (P>0.05) effect of variety on number of leaves of sorghum in 2018 although in 2019 significant (P<0.05) higher number of leaves was recorded for SAMSORG-17. Number of leaves and leaf area index (LAI) decreased (P<0.05) from 15th June to 14th July sowing date in 2018, 2019 and their means. Variety had no significant (P>0.05) effect on LAI in 2018 and 2019 growing seasons. Significant (P<0.05) interactions between variety and sowing date were observed for plant height in 2018 and 2019 growing seasons. Similarly, significant (P<0.05) interactions between plant height and stage of harvest were also observed for plant height in 2019, number of leaves in 2018 and LAI in 2018 and 2019 growing seasons. Also, significant (P<0.05) interactions between variety and stage of harvest were noticed for plant height in 2018 and 2019 growing seasons, number of leaves and LAI in 2019. There was no significant (P>0.05) difference between the variety for dry forage yield in 2018 whereas in 2019, dry forage yield was significantly (P<0.05) higher with higher value obtained for SAMSORG-16. Dry forage yield significantly (P<0.05) decreased from the earlier sowing of 15th June to the sowing made on 14th July in 2018 while in 2019 higher (P<0.05) dry forage yield was obtained for sorghum sown on 14th July. Dry forage yield increased from 1.37 t/ha to 14.47 t/ha in 2018 and 0.94 t/ha to 13.21 t/ha in 2019 as stage of harvest increased from 6 to 14 WAS, respectively. Variety and sowing date significantly (P<0.05) influenced the chemical compositions of ensiled grain sorghum forage. Higher (P<0.05) dry matter, crude protein and Ca contents were obtained for ensiled SAMSORG-17 forage while higher (P<0.05) NDF, ADF and P contents were recorded for ensiled SAMSORG-16 forage. Silage made from sorghum sown on 15th June recorded higher (P<0.05) temperature, dry matter, crude protein, NDF and ADF whereas higher (P<0.05) Ca and P were observed for silage made from sorghum sown on 14th July. The results on chemical composition of sorghum forage were highly varied. However, there was no significant (P>0.05) effect of variety on dry matter, crude protein, ADF and P. Higher (P<0.05) NDF was recorded for SAMSORG-16 sorghum forage while higher (P<0.05) Ca was observed for SAMSORG-17 sorghum forage. Sowing date had no significant (P>0.05) influence on dry matter, crude protein and NDF although higher (P<0.05) Ca and P contents were recorded for sorghum forage sown on 14^{th} July while higher (P<0.05) ADF was obtained for sorghum forage sown on 30^{th} June. Stage of harvest had significant (P<0.05) effect on crude protein, NDF, ADF, Ca and P. Higher (P<0.05) crude protein and P were obtained for sorghum forage harvested at 6 WAS while higher (P<0.05) NDF and ADF were recorded for sorghum forage harvested at 14 WAS although higher Ca was obtained for sorghum forage harvested at 10 WAS. All significant interactions between the factors were reported in figures. In experiment II: The result showed that hay/silage intake (25.28 – 29.23 kg), concentrate intake (6.19 – 19.41 kg), total feed intake (35.41 – 48.47 kg), daily weight gain (43.18 – 50.76 g) and weight gain (2.85 – 3.35 kg) were significantly (P<0.05) affected by the feeding regime with rams fed silage + concentrate daily recording higher values. Better FCR was obtained in rams fed silage + concentrate after 2-days. Dry matter (79.22%), crude protein (85.59%), NDF (75.30%) and ADF (78.02%) digestibility coefficients were higher (P<0.05) for rams fed silage + concentrate after 1-day (every other day). The percentage of nitrogen absorbed and retained were higher (P<0.05) in rams fed silage + concentrate after 1-day (85.62 and 82.72%, respectively). Feeding regime had significant (P<0.05) effect on rumen indices considered with pH (5.48 – 6.20), temperature (31.41 – 34.59 ^{o}C), TVFAs (23.33 – 26.89 mmol) and NH_3-N (8.81 – 10.52 mg/dl) ranges, respectively. Sampling time significant (P<0.05) affected rumen indices with higher pH (5.93) and NH_3-N (10.74 mg/100) obtained at 0 hours before feeding. Higher (P<0.05) TVFAs (31.00 mmol) and temperature (35.53^{o}C) were recorded at 8 and 4 hours post feeding, respectively. The cost per kg gain of ₦1046.40 for rams fed hay + concentrate daily was lower than the cost per kg gain of other feeding regimes. It can be concluded that livestock farmers in Zaria should sow SAMSORG-16 variety on 15^{th} June and harvest at 14 WAS for better forage yield. For good quality silage SAMSORG-17 should be sown on 15^{th} June. It can be concluded that sorghum silage should be fed alongside concentrate daily to growing Yankasa rams for improved feed intake and weight gain. It is therefore recommended that for optimum forage yield and quality, SAMSORG-16 variety should be sown on 15^{th} June and harvested at 14 WAS. Also, for better weight gain, silage should be fed with concentrate supplement.

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CHAPTER ONE

2.0 INTRODUCTION

1.1 Background Information

Sorghum (*Sorghum bicolor* L. Moench) is the fourth most important world cereal crop in terms of food following wheat, rice, and maize (Maikasuwa and Ala, 2013). It is a staple food in the drier part of Africa, China and India. It is the most widely cultivated crop in the northern guinea savannah zone of Nigeria. The largest growers of *Sorghum bicolor* are India (16 million hectares), America (11 million hectares), Nigeria (6 million hectares) and Sudan (2.5 million hectares) (Maikasuwa and Ala, 2013). Total sorghum production in the world exceeds 50 million tonnes, a third of which is from a small area in the developed countries. Average yields are very high on the American continent (> 3.0 t/ha), while they are low (< 1.0 t/ha) in India and Africa. Africa accounts for a quarter of the world's sorghum production, to which Nigeria and Sudan contribute nearly half of the sorghum production (Maikasuwa and Ala, 2013).

About 50% of the total area devoted to cereal crops in Nigeria is occupied by sorghum. The area estimated at 6.8 million hectares extends northwards from latitude 8^0N to latitude 14^0N (Aba *et al*., 2004). In 1978; the total sorghum production in Nigeria was estimated at 4.8 million tonnes (Maikasuwa and Ala, 2013). This figure has risen to about 7.0 million tonnes annually (Ogidi and Abah, 2014). Consequently, Nigeria became the highest sorghum producer in the West African sub-region, accounting for 71% of the regional sorghum production for human consumption and has risen from its fifth position in 1995 (FAO, 1995) to the third largest producer of sorghum in the world after USA and India, where more than 90% of their sorghum harvest is used for animal feed (Ogidi and Abah, 2014).

Sorghum is used for both grain and forage; while some varieties are grown solely for grain, others have been developed for forage production, and some varieties are dual-purpose (Harada *et al*., 2000). The sorghum plant is a tall, erect annual grass, up to 5 m high, and follows the C_4 pathway. Sorghum roots are adventitious and the root system can extend from the top 90 cm soil layer to twice that depth. Culms are erect, solid, 0.6 to 5 m high and 5 to 30 mm in diameter. Leaves are broad, glabrous, very similar to maize leaves but shorter and broader. Inflorescence is a panicle, around 60 cm long, bearing up to 6000 spikelets (Balole and Legwaila, 2006). *Sorghum bicolor* is highly variable. The stem is the part of the plant that shows the greatest differences between genotypes, ranging from thin to thick, with low or multiple tillering (Rattunde *et al*., 2001). Grain sorghums mostly serve as dual-purpose varieties in Nigeria where livestock eat the stover or stubble from all varieties after the grain has been harvested.

Genotype or variety plays an important role in determining yield of sorghum. For example, late maturing cultivars are likely to have higher biomass yield than early maturing ones, since the stem components and number of leaves are higher (Taylor *et al*., 1974; Munza, 2017). Sorghum is used for both grain and forage; while some varieties are grown solely for grain, others have been developed for forage production, and some varieties are dual-purpose (Harada *et al*., 2000). SAMSORG-16 and SAMSORG-17 are grain sorghum varieties with released names SSV2 (FBL) and KSV3 (SK.5912), respectively (Aba *et al*., 2004). They are potential forage crops that are adapted to Northern and Southern Guinea Savanna zones of Nigeria. SAMSORG-16 has a maturity period of 165 – 175 days for grain whose seed colour is white with a grain potential yield of 2.5 – 3.5 ton/ha. SAMSORG-17 popularly known as Short Kaura has a maturity period of 165-175 days for grains whose seed colour is yellow with a potential grain yield of 2.5-3.5 ton/ha. SAMSORG-17 is more droughts tolerant to sustained drought (Ogbaga *et al*., 2016).

These varieties have been commonly used for malting and brewing, livestock feeding and confectionary (Aba *et al*., 2004). The agronomic and forage potential of these sorghum varieties is encouraging. For example, Munza (2017) reported a forage yield of 32.94 – 40.50 t/ha (7.39 – 9.10 t/ha DM) with dry matter (91.15 – 96.36 %), crude protein (7.62 – 8.63 %), ether extract (1.08 – 5.33 %), ash (5.12 – 7.82 %), nitrogen free extract (41.55 – 68.33 %), neutral detergent fibre (56.12 – 60.21 %) and acid detergent fibre (26.91 – 28.78 %) for SAMSORG-16 at 14 weeks after sowing in Northern Guinea Savanna, Nigeria. Munza *et al*. (2018) reported a plant height of 77.89 cm, number of leaves of 8.03, leaf area index of 2.06 and fresh and dry forage yields of 38.06 and 9.06 t/ha, respectively for SAMSORG-16 at Shika, Nigeria.

Sowing date influences seed germination in sorghum through environmental temperature and soil available (Vanderlip, 1993), vegetative and reproductive success (Prasad *et al*., 2008), as well as yield and yield components (Diawara, 2012). Jones and Johnson (1991) reported that effect of stress due to environmental factors on final yield of sorghum may depend upon genotype and growth stages in which it occurs. Deciding on early or late sowing depends on a farmer's ability to deal with the risk of poor crop establishment with early sowing or the effect of water or heat stress at reproductive stages with late sowing.

Stage of harvest plays an important role in yield determination. Generally, total dry matter increases as harvesting is delayed, especially when harvesting occurs between vegetative and booting stage (66% DM) (Munza, 2017). During early growth stages of a forage crop, leaves yields double those of stems but at later stages the situation changes and stems yields are twice those of leaves (Nelson and Moser, 1994; Munza, 2017). In a study to determine the effect of plant spacing and stage of harvest on forage yield and quality of grain sorghum, Munza *et al*. (2018) found that plant height, number of leaves and leaf area index increased significantly as the stage of harvest advanced from 6 to 12 weeks after sowing (WAS).

Water soluble carbohydrates (WSC) in ensiled crops are a source of energy for bacteria to produce lactic acid and lower pH to <4.2 for good silage quality (McDonald *et al*., 2002; Miron *et al*., 2007). Although excellent silages can be made from sorghums but crude protein (CP) concentrations decrease with increase in stage of maturity (Black *et al*., 1980; Pholsen and Higgs, 2005).

1.2 Justification for the Study

Drought is one of the major limitations on food production especially in developing countries in Africa and Asia (Ngara *et al*., 2012). There is a growing need to produce crops that can survive extreme environmental conditions such as drought in order to maximize crop production. Sorghum is one of such crops that is adapted to a wide range of environmental conditions, particularly, drought. Hence, it is widely grown in different ecological zones of Nigeria (Aba *et al*., 2004). It has a number of morphological and physiological characteristics that contribute to its adaptation to dry conditions. These include: an extensive root system, waxy bloom on the leaves that reduces water loss, ability to stop growth in periods of drought and resume when conditions are favourable as well as tolerance to waterlogging (FOA, 1995). The crop equally grows on a wide range of soils: sandy, loamy, sandy loam and a pH range of 4.0-8.5 (Aba *et al*., 2004). SAMSORG-16 and SAMSORG-17 are potential forage crops that are adapted to

Northern and Southern Guinea Savanna zones of Nigeria (Munza, 2017; Adewumi 2019). The two varieties have the same maturity period with SAMSORG-17 been more tolerant to sustained drought (Ogbaga *et al*., 2016).

Climate change is expected to have impact on the agricultural sector in multiple ways, among these are increased variability with regard to temperature, rain, frequency and intensity of extreme weather events, changes in rainfall patterns and in water availability and perturbations in ecosystem (Igwe *et al*., 2014). Many countries in the tropical and sub-tropical regions including Nigeria are expected to be more vulnerable to warming because of additional temperature increase that will affect their marginal water balance and harm their agricultural sector (Mendelssohn *et al*., 2000). The variability in rainfall pattern and other climatic conditions leads to the choice of the sowing dates. **Heiniger *et al*. (1997) stated that early sowing may result in unfavorable soil moisture, which may affect emergence rate, and results on poor stand establishment and possibly re-sowing. Delaying the sowing date until soil conditions are nearer the optimum for early plant growth and development may be a management strategy useful in overcoming these problems (Diawara, 2012).**

Stages of harvest affect sorghum forage yield and quality in which forages harvested at tender stage have low dry matter but high in crude protein while forages harvested at an advanced stage have high dry matter but low crude protein (Ishiaku, 2016; Munza *et al*., 2018). Optimum level must be reached in which both yield and quality should not be compromised.

Due to climate change and predictions for drier conditions (lower rainfall and less water for irrigation) in the Northern Guinea Savanna, Sudan Savanna and Sahel Savanna of Nigeria with its large livestock population, there is the need to search for alternative forages that require less water, fit the production system that integrates forage production and manure management, and maintains agricultural sustainability.

Productivity of small ruminants in many tropical areas is often poor because they are subjected to various kinds of diseases, feeding and housing management techniques. Several survey reports (Shiawoya and Tsado, 2011; Adeleke, 2015) indicated that smallholder farmers that own over 70% of the livestock population in sub-Saharan Africa offer their stocks little or no supplementary feed. Yet because of low nutrient quality, pasture alone and more specifically tropical grasses cannot provide growing animals sufficient amount of energy and protein to attain appropriate growth rate for higher slaughter weight and dressing percentage (Humphreys, 2005; Tanko, 2014). Several works had shown that young animals raised on forages alone had lower daily gains, dressing percentage and carcass quality than those supplemented with concentrate (Johson et al**., 2005; Adeleke, 2015).**

Sheep and goats are domestic animals that have been associating with humans for a very long time. In traditional setting, they serve as means of ready cash

and a reserve against economic and agricultural production hardship (Hamito, 2008). They play a significant role in the food chain and overall livelihoods of rural households, where they are largely the property of women and their children (Lebbie, 2004). They are good producers of meat for human consumption. The short gestation interval of sheep and goats and the absence of religious bias against their meat (Ozung et al**., 2011) are among the reasons why they are kept by peoples of various cultures, religions and races.**

Concentrate feeds promote rapid growth of sheep and cattle (McDonald et al**., 2002),increase propionate production and reduce ruminal methane production, thereby lowering energy losses and contributing to higher overall efficiency of utilization of dietary energy for body weight gain (Mandebvu and Galbraith, 1999). According to Mtenga and Kitalyi (1990), increase in meat output resulting from concentrate supplementation can improve access to animal protein and income to households in the traditional sector. The appropriate ratio of concentrate to roughage to be fed to ruminants had been studied (Zervas** et al**., 1999). A ratio of 40:60 concentrate to hay had been recommended (Liu** et al**., 2005). Feeding regime is used to describe a regulated system/pattern of what meals are offered, how frequently they are offered, what sequence is followed and during which particular period they are offered. Studies done by Yashim (2014) indicated that feeding every other day**

was better than feeding daily in terms of total feed intake, weight gain and decrease in methane nitrogen losses. Adeoye (2018) reported that **feeding Yankasa rams supplements containing shea-nut cake either daily or every other day resulted in similar weight gain. The author further reported that daily supplementation of Yankasa rams resulted in better digestibility of crude protein and ether extract and higher nitrogen retention than every other day supplementation.**

Consequently, recent research are geared towards the use of cheaper and readily available alternative feed resources that can possibly provide all season supplement for ruminants. Sources of cheaper alternative forages of high quality for ruminant livestock production have been a subject of research in the recent years (Alan *et al.,* 2013). Effort to reduce this problem through the introduction of drought resistant forages and forage conservation through different means of dry season feeding of ruminants has been successfully carried out by various researchers (Khampa and Wanapat, 2007; Yashim, 2014). Hence, the study on the forage yield and quality of two sorghum varieties at different sowing dates and utilization of the silage by growing Yankasa rams becomes necessary.

1.3 Objectives of the Study

The broad objective of this study was to evaluate the forage yield and quality of sorghum varieties at different sowing dates, harvest and utilization of the silage by growing Yankasa rams.

The specific objectives were to:

1. Determine the effect of variety, sowing date and stage of harvest on growth components, forage yield and chemical composition.
2. Determine the effect of variety and sowing date on chemical composition of ensiled forage.
3. Investigate the effect of feeding regime on growth, nutrient digestibility, nitrogen retention and rumen metabolites of growing Yankasa rams fed a basal diet of grain sorghum hay or silage supplemented with concentrate.
4. Determine the costs-benefit of feeding growing Yankasa rams a basal diet of grain sorghum hay or silage supplemented with concentrate at different feeding regimes.

1.4 Hypotheses

H_0: Variety, sowing date and stage of harvest have no effect on yield and quality.

H_A: Variety, sowing date and stage of harvest have effect yield and quality.

H_0: Variety and sowing date have no effect on chemical composition of ensiled forage.

H_A: Variety and sowing date have effect on chemical composition of ensiled forage.

H_0: Feeding regimes have no significant influence on growth, nutrient digestibility, nitrogen retention, rumen metabolites and costs-benefit analysis of growing Yankasa rams fed a basal diet of grain sorghum hay or silage supplemented with concentrate.

H_A: Feeding regimes have significant influence on growth, nutrient digestibility, nitrogen retention, rumen metabolites and costs-benefit analysis of growing Yankasa rams fed a basal diet of grain sorghum hay or silage supplemented with concentrate.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Sorghum

2.1.1 Origin and distribution

Sorghum (*Sorghum bicolor* (L) Moench) commonly referred to as Guinea corn in West Africa is the fourth most important cereal in the world after rice, wheat and maize (FAOSTAT, 2010). Sorghum is one of the cereal crops grown under rain fed condition over an area of 42 million hectares for grain and fodder purposes mainly in the semi-arid tropics of Africa, Asia and Latin America (FAOSTAT, 2010). Nigeria is the second largest producer of sorghum in the world, with an annual production in excess of 8 million metric tons. This energy producing plant is a basic food for mankind in regions of Africa, Asia and India. It is very hardy and can be grown in areas of the world that are too hot or too dry for other crops to be grown successfully. Grain sorghum is a small round berry which may vary in colour from yellow cream to white.

Although it is generally agreed that, the domestication of sorghum took place in Africa, there is controversy concerning its origin. Doggett (1988) specifically mentioned North-East tropical Africa where the greatest variability in both the wild and domesticated forms exists, whereas ICRISAT, (2005) reported that, the crop was first domesticated across an East-West of savannah from Lake Chad to the Sudan. Doggett (1988) regards the Ethiopian high lands as the primary center of domestication. The author further reported that, the earliest cultivated sorghums most closely resemble the current race *bicolor*. Early types of *bicolor* move west ward to the West Africa where the Guinea corn race evolved (Doggett, 1988). Sorghum reached West Africa at early date across the Sudan to the northeast toward Lake Chad. The guinea corn race either evolved in West Africa or differentiated first in East Africa and then moved to West Africa (Doggett, 1988). It also spread to the southeast tropical Africa and was taken by sea in India, Burma, Indonesia and then china. Sorghum was taken to American continent from West Africa during the slave trade, the first introduction were of guinea corn race, both Durra from northern tropical Africa, and Kafirrace, from southern tropical Africa reached America latter in the 1870s.

2.1.2 Importance of sorghum

Sorghum is the fourth most important cereal crop grown in the United States, and the fifth most important cereal crop grown in the world (Bryden *et al*., 2009). According to Murty *et al*. (1994), the crop is considered as important staple food crop in Africa, South Asia and Central America. Chantrereau and Nicous (1994) reported that, it is the principal source of nutrition for many millions of people and provide a major source of protein in human diet in Africa and much of Asia. Besides providing food for humans and feeds tor livestock, sorghum stems is used for a wide range of purposes, including: the construction of walls, fences and thatches; and production of brooms, mats, baskets, fish- traps, sun shades, etc. It is also used as fuel and as a soil additive to improve its fertility.

In Nigeria, sorghum is primarily use for human consumption and as a staple food in the diet of many people in many countries of the world especially sub-Saharan Africa. Sorghum is consumed boiled or popped, Egharevba (1979) reported the use of sorghum in local recipes like*tuwo*, *akanu* and *kunu* in Nigeria. According Chantrereau and Nicous (1994), the porridge (*Tuwo*) is considered relatively high in carbohydrate and a fair source of protein compared to most cereal crops. The local cultivars, which have large and tall stalks, are used as fuel, for fencing and roofing (Maunder, 2006). The grains and vegetative parts of the crop are used as animal feed. It serves as a major raw material in the brewing industries. Some varieties of sorghum can be “mailed” to produce nutritious food stuff for infants and use in bakery products. Malted sorghum can also be use in traditional beer production, an important income earning activity for village women in Nigeria.

Sorghum grain has high nutritive value, with 70-80% carbohydrate, 11-13% protein, 2-5% fat, 1-3% fiber, and 1-2% ash. Protein in sorghum is gluten free and, thus, it is a specialty food for people who suffer from celiac disease, as well as diabetic patients (Prasad and Staggenborg, 2009).

2.1.3 Soils and climatic requirements

Sorghum unlike other, cereals grows in both light and heavy soils, and performs very well even in waterlogged areas (Kramer and Rose, 1970). It also tolerates salinity and alkalinity fairly well. Peacock and Wilson (1984) reviewed seed dormancy inhibitions and crop establishment and reported that, sorghum seed at germination and emergence are more sensitive to low soil temperatures than maize, but less sensitive than millet (Lawnders, 1971). Field temperatures of 18°C are considered suitable for germination (Adams and Arkin, 1978). At 7.6cm soil depth, the lime of emergence is decreased by one day for each 0.9°C increase in mean soil temperature (Adams and Arkin, 1978). Soil temperatures of 40-45°C are lethal to seedling (Knapp, I966; Kailasmanthan and Shinha, 1976). The optimum temperature for seedling growth is about 33°C (Adams and Arkin, 1978). Leaf emergence increase with temperature, but tillering require relatively low temperature of about 15-20°C (Downes, I968). Net photosynthesis rates are higher in sorghum (C_4 species) than in wheat and the increase with temperature probably reaching an optimum at 30-40°C (Downes, I968). Sorghum is often referred to as "camel crop" among the cultivated plants. It is adapted to tropical as well as temperate climate, although it is best known for its good adaptation to the drought prone semi-arid and tropical regions of the world (Murty *et al.*, 1994). A long sunny dry season and rainfall of 500-1000mm is adequate for the attainment of optimum yield of sorghum. The yield may drop between 300 to 1000kgha^{-1} as moisture becomes limiting (Murty *et al.*, 1994).

2.1.4 Growth and development stages of grain sorghum

Grain sorghum has different growth stages from emergence to maturity as described by Vanderlip (1993) and the stages are these:

The first stage (Stage 0): of grain sorghum development is emergence. Emergence is the stage when the plant first breaks through the soil surface. Generally it occurs 3 to 10 days after sowing. The time required for emergence depends on soil temperature, moisture conditions, depth of sowing, and vigor of the seed. During this period growth depends on the seed for nutrients and food reserves. Cool, wet conditions during this time may favor disease organisms that seriously damage stands.

The second stage (Stage 1): is the three-leaf stage. Leaves are counted when the collar of the leaf can be seen without tearing the plant apart. At this stage, the growing point is still below the soil surface. While the plant's growth rate depends largely on temperature, this stage usually occurs about 10 days after emergence.

The third stage (Stage 2): is the five-leaf stage. This stage occurs approximately 21 days after emergence. At this stage a sorghum plant has five leaves fully expanded; its root system is developing rapidly, and roots produced at the lower nodes may push the lower leaves off the plant. This usually does not cause difficulty in identifying the five-leaf stage because the lower leaf has a rounded tip and the second leaf is pointed. The plant enters its "grand period of growth" in this stage. Dry matter accumulates at nearly a constant rate until maturity if growing conditions are satisfactory.

The fourth stage (Stage 3): is growing point differentiation. This stage occurs about 30 days after emergence. At this growth stage, the plant changes from the vegetative phase (leaf producing) to the reproductive phase (head producing). The total number of leaves has been determined, and potential head size soon will be determined. About one-third of the total leaf area has fully developed (7 to 10 leaves depending on maturity class) and the lower 1 to 3 leaves may have been lost. Culm or stalk growth increases rapidly following growing point differentiation. Nutrient uptake is rapid. Time from sowing to growing point differentiation generally is about one-third of the time from sowing to physiological maturity (maximum dry weight).

The fifth stage (Stage 4): is flag leaf visible. This stage is characterized by a visible flag leaf (final leaf) in the whorl. All except the final 3 to 4 leaves are fully expanded and about 80 percent of the total leaf area is present. Light interception is approaching maximum, and growth and nutrient uptake continue at a rapid rate. The head is developing, during this stage. The lower 2 to 5 leaves typically have been lost. Any reference to leaf number from this stage should be from the top, counting the flag leaf as leaf number 1. While only about one-fifth of the total growth has occurred, nutrient uptake is far greater with more than 40% of the potassium already taken up.

At boot stage (Stage 5): all leaves are fully expanded, providing maximum leaf area and light interception. The head has developed to nearly full size and is enclosed in the flag-leaf sheath. Except for the peduncle, culm elongation is essentially complete. Peduncle elongation is beginning and will result in the panicle exsertion from the flag-leaf sheath. Potential head size has been determined.

Half-bloom (Stage 6): follows the boot stage and is defined as when one-half of the plants in a field or area are in some stage of bloom. However, because an individual sorghum head flowers from the tip downward over 4 to 9 days, half-bloom on an individual plant is when the flowering has progressed half-way down the head. At half-bloom, approximately one half of the total dry weight of the plant has been produced. However, nutrient uptake has reached nearly 70, 60, and 80% of total for N, P, and K, respectively. Time required from sowing to half-bloom depends on the maturity of the hybrid and environmental conditions. However, it usually represents two-thirds of the time from sowing to physiological maturity.

Soft-dough (Stage 7): is the stage between half-bloom and hard-dough. At this stage the grain fills rapidly, and approximately half of its dry weight is accumulated. The culm weight increases slightly following half-bloom; then, decreases as grain is forming. This loss in culm weight may account for as much as 10% of the grain weight. Lower leaves are still being lost with 8 to 12 functional leaves remaining.

In Hard-dough (Stage 8): about three-fourth of the grain dry weight has accumulated. The culm has declined to its lowest weight. Nutrient uptake is essentially complete. Additional leaves may have been lost.

Physiological maturity (Stage 9): is the last stage before harvest. Physiological maturity can be determined by the dark spot on the opposite side of the kernel from the embryo. At this stage the maximum total dry weight of the plant has occurred. The time from flowering to physiological maturity varies with hybrid and environmental conditions; however, it represents about one-third of the total time from sowing. Grain moisture content at physiological maturity usually is between 25 and 35% moisture, but varies with hybrid and growing conditions. After physiological maturity, the remaining functional leaves may stay green or die and brown rapidly. If temperature and moisture conditions are favorable, branches may start to grow from several of the upper nodes. Also, the culm or stalk weight may increase slightly near physiological maturity.

Report by Prasad and Staggenborg (2009) grouped the development stages of sorghum into three. Growth Stage 1 (GS1) represents the vegetative period from emergence to growing point differentiation; Growth Stage 2 (GS2) represents the reproductive period from growing point differentiation to flowering; Growth Stage 3 or grain filling stage (GS3) from flowering to physiological maturity (Table 2.1). The duration of each of stages and its impact of yield and yield components may depend on the environmental conditions, sowing dates, hybrids; and may change from year to year and from one location to another.

Table 2.1: Grain sorghum growth stages, approximate time interval between growth stages and identifying characteristics

Development Stage	Growth Stage	DAE	Visual Characteristics
0	GS1	0	Emergence, coleoptile visible at soil surface
1	GS1	5	Collar of 3rd leaf visible
2	GS1	10-15	Collar of 5th leaf visible
3	GS1	25-30	Growing point differentiation or panicle initiation (approximately 8th leaf visible).
4	GS2	35-50	Final leaf (flag leaf) visible in whorl; last three

			leaves may not be expanded.
5	GS2	40-55	Booting; head extended into flag leaf sheath; potential panicle size has been determined.
6	GS2	55-65	Flowering (bloom); 50% of plants flower.
7	GS3	65-80	Soft dough; grain can be easily squeezed between the fingers; 8 to 10 functional leaves; one half of the grain weight accumulated.
8	GS3	80-90	Hard dough; cannot squeeze grain between fingers; three-fourth of the grain dry weight has accumulated.
9	GS3	90-110	Physiological maturity; dark spot at the tip of the kernel; maximum total dry weight accumulated; grain has 25 to 35% moisture.

DAE = Day After Emergence. Source: Prasad and Staggenborg (2009) and Vanderlip (1993)

2.2 Varietal Response

2.2.1 Varietal response on growth components and forage yield of sorghum

Genotype or variety plays an important role in growth and development of sorghum. Plant height, number of shoots or tillers/m^2, tillering capacity, leaf/stem ratio and yielding potential are some of the most important factors that influence the choice of variety to be grown for forage, since they have a direct influence on total forage yield (Assaeed, 1994). Munza (2017) observed plant height of 119.57 cm, number of leaves of 9.61 and leaf area index of 2.29 for SAMSORG-16 at 12 week after sowing at Shika. Zakka (2019) reported taller plant height, more number of leaves and high LAI for Bush head sorghum than sweet sorghum. Adewumi (2019) reported more number of leaves and high LAI for SAMSORG-17 over indigenous sweet sorghum but higher plant height for indigenous sweet sorghum over SAMSORG-17 at Shika. Munza *et al*. (2019) reported leaf length and leaf width of 94.79 7.87 cm and 81.98 and 8.82 cm for SAMSORG-16 and SAMSORG-17 grain sorghums, respectively. Munza *et al*. (2020a) reported plant height of 239.19 and 156.14 cm for SAMSORG-16 and SAMSORG-17, respectively.

Fresh forage yield and dry forage yield varies with variety. Adewumi (2019) reported fresh forage yield and dry forage yield of 25.78 and 7.57 t/ha and 30.46 and 5.12 t/ha for indigenous sweet sorghum and SAMSORG-17 sorghum, respectively. Fresh forage yield and dry forage yield of 42.92 (4.49) t/ha and 25.73 (4.88) t/ha for Bush head sorghum and sweet sorghum were obtained by Zakka (2019).

2.2.2 Varietal response on chemical composition of sorghum forage

The forage quality of different species or cultivars of the same species may vary significantly. This is attributed to differences in anatomy, morphology and chemical compositions. Leafier genotypes have higher digestibility (Reddy *et al*., 2002). Genotypes with larger leaves may have low digestibility due to greater photosynthetic efficiency, while greater photosynthetic efficiency leads to more sunlight being converted into forage yield. The greater the rate of dry matter accumulation, the higher the lignification of the tissues and the lower the digestibility (Buxton and Fales, 1994). Hence, leaf anatomy contributes greatly to the quality of forage.

Generally, crude protein reduces as plants mature. Crude protein reduction is faster in Sudan grass than in sweet sorghum because Sudan grass makes a rapid recovery after grazing/cutting (Farhoomand and Wedin, 1986). As a result, the available N in the soil is utilized quickly and therefore there will be less available to maintain the crude protein content in the re-growths. Higher yielding cultivars have excellent nitrogen uptake ability, assimilation and efficiency of nitrogen utilization (Moyer *et al*., 2004), but they also have lowest digestibility compared to low yielding cultivars (Kalton, 1988). The highest soluble sugars (13.8%) were obtained in tall forage types.

Zakka (2019) reported dry mater (95.09 and 95.75 %), crude protein (5.07 and 4.89 %), crude fibre (34.75 and 34.52 %), ether extract (1.08 and 1.13 %), ash (4.69 and 3.12 %), NFE (49.50 and 52.12 %), ADF (33.55 and 32.72 %), NDF (46.64 and 48.88 %) and lignin (19.30 and 18.28 %) for Bush head sorghum and sweet sorghum forages, respectively. Whereas Adewumi (2019) reported 90.36 and 89.92 % dry matter, 14.33 and 14.19 % crude protein, 28.32 and 27.62 % crude fibre, 0.43 and 0.41 % ether extract, 6.28 and 5.94 % ash and 50.62 and 51.65 % NFE for Indigenous sweet sorghum and SAMSORG-17 forages, respectively. The author further reported neutral detergent fibre (49.57 and 49.64 %), acid detergent fibre (31.43 and 32.12 %) and lignin (8.42 and 7.34 %) for Indigenous sweet sorghum and SAMSORG-17 forages, respectively.

Calcium (Ca) and phosphorus (P) concentrations of sorghum forages differs with variety and genotype. Calcium (Ca) and phosphorus (P) contents ranged from 1.01 – 1.47 % and 0.24 – 0.28 % for SAMSORG-16 (Munza (2017). Adewumi (2019) reported Ca (0.44 and 0.42 %) and P (0.19 and 0.23 %) concentrations for Indigenous sweet sorghum and SAMSORG-17 forages. For Bush head sorghum and sweet sorghum the following were the Ca (0.57 and 0.31 %) and P (0.14 and 0.16 %) contents reported by Zakka (2019).

2.3 Sowing Date Response

2.3.1 Sowing date response on growth components and forage yield of sorghum

Grain sorghum growth, development, and yield depend on environmental conditions such temperatures and precipitations. The extent of the effect of these environmental conditions may vary depending on sowing date. Sowing date influences sorghum through temperature and soil available water at seed germination (Vanderlip, 1993), vegetative and reproductive success (Prasad *et al*., 2008), and hence, yield and yield components (Evans and Wardlaw, 1976). Sowing date influenced leaf length and leaf width as reported by Munza *et al*. (2019) in which leaf length and leaf width ranged from 79.64 to 95.45 cm and 7.81 to 8.74 cm, respectively. Grain sorghums sown on 15th June gave longer leaf length and broader leaf width. Munza *et al*. (2020a) reported 211.12 cm, 13.73 and 7.06 for plant height, number of leaves and LAI, respectively for grain sorghum sown on 15th June. Also, fresh forage yield and dry forage yield range of 30.72 to 54.73 t/ha and 6.11 to 10.49 t/ha when sowing date was delayed from 15th June to 14th July in Shika, Nigeria.

Jones and Johnson (1991) reported that effect of stress due to environmental factors on final yield may depend upon the growth stage in which it occurs and the genotype. Deciding on early or late sowing depends on a farmer's ability to deal with the risk of poor crop establishment with early sowing or the effect of water or heat stress at reproductive stages with late sowing.

Radiation interception and photosynthesis are of major importance in yield determination due to their role in dry matter production. Sorghum yield responses to location, time of sowing and soil water storage were associated with difference in leaf area development (Muchow *et al*., 1994). The number of leaves and leaf dimensions are functions of hybrids, growth stage, but also depend on the growing conditions. Bunck (1977) stated that as sowing was delayed from early May to early July, late maturing sorghum hybrids showed a reduction in leaf number, leaf area, and yield at Manhattan and Hutchinson. Duacan *et al*. (1981) described two hybrids as senescent (aging) and non-senescent types in relation to relative senescence of leaves after full leaf expansion. The non-senescent line had higher green leaf number and weight at maturity, leaf area index, leaf area duration, and leaf area ratio than the senescent line. Borrell *et al*. (2000) reported that stay-green hybrids produced 47% more post-anthesis biomass than their senescent counterparts (920 vs. 624 g m−2) under a terminal water deficit regime. The study also indicated that sorghum hybrids possessing the stay-green trait had a greater yield advantage under post-anthesis drought compared with hybrids not possessing this trait. Leaf senescence has been shown to increase markedly under water stress in sorghum (Kaigama *et al*., 1977; Kanangara *et al*., 1982). Leaf senescence is in general considered as a mechanism of drought avoidance in sorghum by reducing transpiration and saving soil moisture, while others think that leaf senescence during grain filling reduces photosynthesis rate and dry matter production, thus reducing final yield (Hsiao, 1973). These results indicate that appropriate crop management practices such as optimum sowing date, row spacing, and seeding rate are necessary for optimal leaves expansion of grain sorghum.

2.3.2 Sowing date response on chemical composition of sorghum forage

The environment in which forage crops are grown influences the forage quality. This causes yearly, seasonal and geographical differences in forage quality (Buxton, 1996). Environmental conditions affect quality by changing the leaf/stem ratio. In addition, environmental stresses affect senescence rates and the quality of dead plant material. The morphological development of the growing forage crop is partly controlled by the environmental conditions and hence, this determines the quantity and quality of each part of the plant (Buxton and Fales, 1994).

Stem growth is greater than leaf growth when the temperature is high. In addition, NDF and ADF concentrations are increased by high temperatures (Buxton and Fales, 1994; Nelson and Moser, 1994; Fulgueira *et al*., 2007), whereas non structural carbohydrates concentrations (soluble sugar concentration) are lowered (Ford *et al*., 1979; Wilson *et al*., 1991; Buxton and Fales, 1994). Furthermore, Wilson *et al*. (1991) suggested that temperature variation changes digestion of cell walls by changing cell thickness. A thick cell wall is likely to be digested more slowly than a thin cell wall. Cell walls deposited when temperatures are low contain less lignin and therefore higher digestibility is achieved because storage carbohydrates (total non-structural carbohydrates) accumulate in the leaf tissue (Ford *et al*., 1979). In addition, high temperatures reduce leaf/stem ratio (Lascano *et al*., 2001). Due to these changes the digestibility of the forage decreases.

Plants grown in hot and dry environments will have thick walls, thick cuticles and their tissues will be highly lignified (Levitt, 1980). In case of severe drought, leaf growth is restricted and more senescent material can be observed (Humphreys, 2005). These factors cause loss of forage quality, since the material become less digestible and less palatable to the livestock. Mild water stress improves the forage quality of a crop compared to a crop grown under normal water conditions because the leaf/stem ratio and digestibility of both leaf and stem components are increased (Wilson and Ng, 1975).

2.4 Stage of Harvest Response

2.4.1 Stage of harvest response on growth components and forage yield of sorghum

The stage at which forage is harvested plays an important role in yield determination. Generally, total dry matter increases as harvesting is delayed, especially when harvesting occurs between vegetative and boot stage (66% DM) (Worker and Marble, 1968). During the early growth stages of a forage crop, leaves yields double those of stems but at later stages the situation changes and stems yields are twice those of leaves (Nelson and Moser, 1994). In a study to determine the relative proportion of leaves, stems and heads of Sudan grass and sweet sorghum, Farhoomand and Wedin (1968) found that the dry matter content was highest in the heads and least in the stems. As the plant starts forming seeds, dry matter in leaves and stems is remobilized to the seeds.

Several studies were done on the effect of stage of harvest on growth components and forage yield of sorghum in Nigeria (Munza, 2017; Adewumi, 2019 and Zakka, 2019). Plant height, number of leaves, LAI, fresh forage yield and dry forage yield increases when stage of harvest was delayed from 6 to 12 and 14 weeks after sowing (WAS). Munza (2017) reported plant height (119.57 cm), number of leaves (9.61) and LAI (2.16) at 12 WAS. Similarly, higher plant height (223.88 cm), number of leaves (10.37) and LAI (2.43) at 14 WAS were reported by Zakka (2019). Adewumi (2019) reported plant height (191.39 cm), number of leaves (9.78) and LAI (4.03) at 9 WAS while fresh forage yield (33.68 t/ha) and dry forage yield (10.26 t/ha) were reported at 12 WAS by the same author. Leaf length and leaf width increased when cutting age was delayed from 6 to 14 WAS in a study by Munza *et al*. (2019) in Shika, Nigeria for SAMSORG-16 and SAMSORG-17 grain sorghum, respectively. Similarly, plant height, number of leaves and LAI increased as age of harvest was delayed from 6 to 14 WAS. Fresh forage yield and dry forage yield increased from 12.22 to 58.94 t/ha and 1.37 to 14.47 t/ha as age of harvest was delayed from 6 to 14 WAS (Munza *et al*., 2020a).

However, changes in forage quality also need to be considered since as the dry matter content increases, digestibility of NDF, lignin, starch, sugar content and crude protein are all reduced (Kilcer *et al*., 2003). Given that maturity affects yield and quality, forage intended for either dairy animals or fattening should be balanced between dry matter production and quality in order to achieve the intended goals, such as high productivity, lactation, calving and profit (Hodgson and Brookes, 1999).

2.4.2 Stage of harvest response on chemical composition of sorghum forage

Maturity of forage at harvest is the fundamental factor that affects forage quality because it plays an important role in determining the fibre content of the crop that has been harvested. As the forage crop develops, the chemical composition is modified, hence, its fundamental impact on forage quality (Buxton and Fales, 1994). With age, digestibility and crude protein content declines drastically, whilst neutral detergent fibre (NDF) and acid detergent fibre (ADF) contents increase steadily (Reid *et al*., 1964; Worker and Marble, 1968; Rachie and Majmudar, 1980; Nelson and Moser, 1994; Humphreys, 2005), and fat and ash contents reduced (Worker and Marble, 1968). The leaf/stem ratio also decreased with age (Taylor *et al*., 1974). In contrast, the total sugar percentage increased with delay in harvest (Worker and Marble, 1968). The quantity of lignin also increased with age in order to enable the plants to support their weight (McDonald *et al*., 2002). However, as discussed earlier, digestibility is reduced and hence metabolisable energy (ME) is also reduced. The reduction of nutritive value with age is a central management consideration in forage production (Humphreys, 2005).

The relative proportion of the plant parts change with age with mature plants having older tissues, more dead material and possibly a higher proportion of stem material, all of which reduce digestibility (Valentine and Kemp, 2007). For these reasons, forage sorghum is recommended to be harvested at vegetative stage (Black *et al*., 1980; Caravetta *et al*., 1990), because the reproductive process (flowering) results in a decrease in the leaf/stem ratio and hence a lower forage quality (de-Ruiter *et al*., 2007). In sorghum hybrids, the shift from vegetative to reproductive growth is fast and hence there is rapid reduction in forage quality (Bean *et al*., 2009). However, if the forage crop is harvested after grain formation, the highly digestible grain may partly offset the reduction in leaf/stem ratio and stem quality (Nelson and Moser, 1994).

Snyman and Joubert (1996) reported means of in-vitro dry matter digestibility (IVDMD) and crude protein of sorghum harvested at the pipe (just before heading stage), bloom (flowering stage) and ripe stages (at the physiological maturity stage and after maximum total dry weight has been achieved) as 67.4% and 14.5%, 61% and 9.4% and 58% and 8.4% respectively. At the booting stage, sorghum was highly digestible and had higher crude protein concentration than at flowering and ripe stages. However, there was no significant difference between bloom and ripe stages, in terms of crude protein. A range of 7.07 to 9.01% of crude protein of sorghum harvested at the soft dough stage was reported by Yosef *et al*. (2009). Cerosaletti *et al*. (2002) found that sorghum x Sudan grass cut at 86, 117, 150 and 175 cm had NDF content of 51.6, 55.5, 57.7 and 58 %; and crude protein content was 18.3, 13.5, 10.5 and 7.9 %, respectively. There was no significant difference in NDF at 117, 150 and 175 cm but at NDF was significantly lower at 86 cm than others. The crude protein concentrations were significantly different from each other.

Wedin (1970), in a study to evaluate yield and chemical composition using four cutting regimes of five cuts consecutively at 46 cm, three cuts at 92 cm, two cuts at 137 cm and one cut at the hard dough stage, concluded that there were significant differences in dry matter yields (1,950, 6,290, 7,750 and 13,460 kg DM/ha) and crude protein (18.4, 15.2, 11.6 and 5.8%) respectively. As the number of the harvests increased, IVDMD reduced in order from 70.1 to 67.7 to 65.4 and finally to 57.0%. Farhoomand and Wedin (1968) found that as the proportion of leaves decreased, the crude protein of leaves and stems reduced from 28.1 to 16% and from 12.6 to 6.1%.

In a study by Munza (2017), dry matter (96.36%), crude protein (8.63%), crude fibre (39.31), ether extract (5.33%), ADF (28.02%) and lignin (13.59%) were reported at 14 WAS while higher ash (7.83%), NFE (68.33%) and NDF (58.52%) were obtained at 9 WAS for SAMSORG-16 sorghum forage. In contrast, Zakka (2019) reported dry matter (95.58%), crude protein (5.34%), ether extract (1.20%), NFE (52.88), ADF (34.89%) and NDF (49.68%) at 9 WAS while higher crude fibre (35.70%), ash (5.19%) and lignin (22.64%) were recorded at 14 WAS for Bush head sorghum and sweet sorghum forages. Also, Adewumi (2019) reported dry matter (92.72%), crude fibre (33.47%), NDF (58.08%), ADF (41.77%) and lignin (12.04%) at 12 WAS while higher ether extract (0.46%), ash (8.60%) and NFE (53.76%) were obtained at 6 WAS and higher crude protein (17.48%) at 9 WAS for Indigenous sweet sorghum and SAMSORG-17 forages.

Calcium (Ca) and phosphorus (P) concentration of sorghum forages varies with stage of harvest in which Adewumi (2019) reported higher Ca (0.56%) at 6 WAS and higher P (0.25%) at 9 WAS. Whereas Munza (2017) reported higher Ca (1.16%) at 9 WAS and higher P (2.76%) at 14 WAS while Zakka (2019) reported higher Ca (0.52%) at 14 WAS and higher P (0.16%) at 9 WAS, vice versa.

2.5 Interaction between Variety, Sowing Date and Stage of Harvest on Growth Components, Forage Yield and Chemical Composition of Sorghum

Few experiments have studied the interaction between grain sorghum yield and hybrid maturity. Kreig and Lascano (1989) reported results from a two year study with four grain sorghum and sowing dates at Lubbock, TX, ranging from early May to late June. Their data indicated that an early May sowing reduced grain yield, with the effect being greater for shorter maturity-length hybrids. With sowing in mid to late June, yield was reduced and the effect was greater for the longer maturity hybrids. Stickler and Pauli (1961) also reported significant variety by sowing date interactions in grain yield and its components. Under non-irrigated conditions, Jones and Johnson (1991) demonstrated that the optimum sowing date, population, variety, and row spacing for grain sorghum were interdependent by showing consistent grain yield reductions by late-maturing cultivars that were sown late and at higher populations. In a three years study (1989-1991) at the USDA Conservation and Production Research Laboratory, Bushland, TX, Allen and Musick (1993) found that if early May sowing is desired under adequate irrigation, longer season medium-late maturity hybrids have additional grain yield potential compared with medium hybrids. Both medium and medium-late maturing sorghum hybrids were most productive when sown relatively early (before June 1). However, medium-maturity hybrids were better adapted if sowing is delayed until June, and are better adapted than longer season hybrids to limited irrigation. Similarly, Baumhardt and Howell (2005) suggested sowing early maturing cultivars for early June sowing under water deficit conditions, and sowing late-maturing in mid-May when plant water requirement can be met during the growing season.

Ismail and Ali (1996) found significant variety by sowing date interaction for plant height, head weight, and final grain yield in Qatar. Greater plant height, head weight, and grain yields were recorded for early and mid-September sowing compared with early and mid-October sowing for the long maturing variety. In the forest-Savanna transition zone of Nigeria, early June sowing of sorghum had greater yield compared with early or late May sowing. Delaying sowing to early June increased yield by 25 to 27 kg ha-1 compared to early or late May sowing (Bello, 1999).

Munza *et al*. (2019) reported broader leaf width was obtained for grain sorghum sown on 14th July harvested at 14 WAS. Similarly, significant interactions between variety and sowing date and sowing date and age of harvest on plant height, number of leaves and LAI, respectively (Munza *et al*., 2020a). The authors reported non-significant interaction for fresh forage yield and dry forage yield.

2.6 Conservation of Sorghum Forage as Silage

2.6.1 Sorghum as a silage crop

Sorghum is a crop similar to corn in regards to its agronomic and nutritional value. However, in terms of requirements, sorghum is an attractive alternative to corn because it is more adapted to drought and low soil fertility (Borba *et al*., 2012). Grain sorghum cultivars are usually recommended for high quality silage production because of their higher proportion of grains, whereas forage sorghum cultivars are recommended for high dry matter yield. The adaptive nature of sorghum, it’s potential to produce higher tonnage of green forage and its diverse uses make it a valued tool and one of the best choices for forage growers and dairy farmers demanding high quality feedstock. This makes sorghum one of the best fodder crops for silage making (Iqbal and Bethune 2015).

Silage is defined as a material that is produced as a result of a controlled anaerobic fermentation of a material that is high in moisture (McDonald *et al*., 1991). Silages are fermented forages stored under anaerobic condition (Amodu and Abubakar, 2004). Also, silage can be defined as a cut green plant material that is sealed in a silo without air or water. The conservation of forage as silage should be of particular interest and value to Nigerian livestock farmer since it provides ample opportunity for harnessing wet season's forage growth for later use during the dry seasons (Amodu *et al*., 2008). Hence, ensilage offers alternative means of fodder conservation during the rainy season while retaining nutrient quality of the forage without recourse to use of fuel or solar energy for artificial hay making under wet humid conditions (Kallah *et al*., 1997).

Dry matter (75.36 and 71.70 %) and crude protein (10.42 and 6.78 %) for SAMSORG-17 and SAMSORG-16 silages, respectively were reported by Munza *et al*. (2020b). Silage pH of 3.82 was reported by Munza *et al*. (2020b) for grain sorghum silage in Shika, Nigeria. Munza *et al*. (2020b) reported dry matter (73.40 – 74.70 %), crude protein (6.25 – 12.94 %), NDF (55.62 – 66.13 %), ADF (33.34 – 51.07 %), Ca (0.44 – 0.53 %) and P (0.04 – 0.06 %) for silages made from grain sorghum sown at different sowing dates. Munza *et al*. (2020b) reported significant interaction between variety and sowing date on chemical composition of silages made from SAMSORG-16 and SAMSORG-17 grain sorghum sown at different sowing dates.

2.6.2 Physical characteristics of sorghum silage

Silages should not have rancid, vinegar or alcoholic odours as such are associated with high level of acetic acids which results in slow feed outs rates (Roth and Heinrichs, 2001). Adesogan and Newmann (2008) stated that temperature in silage should be below 37°C as higher temperature 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 and Heinrichs, 2001). Forages with less than 5-8% water-soluble carbohydrates in dry matter may not reach a pH low enough to produce stable, high moisture silage (Adesogan and Newmann, 2008).

2.6.3 Organic acids composition

According to Lemus (2010), 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 access silage quality. 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 dry matter) 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 dry matter) 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 crude protein) contributes to an excess of rumen degraded protein (RDP), this could have negative consequences on milk and reproductive performances.

2.7 Factors Affecting Silage Quality

Many factors may affect the fermentation process and hence the quality of silage. These variety of factors influence silage quality and if properly managed can result in improved quality of sorghum silage.

Stage of harvest: The nutritive value of silage depends on the species and stage of growth of the harvested crop (McDonald *et al*., 1991). 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 (Tyler and Ensminger, 2006). Crops tend to become more fibrous and lignified as they become mature, 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. Grain sorghum, *Sorghum almum* 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). The best livestock performance and silage fermentation usually occurs when plant moisture is 65-70% (Staples, 2003; Bagg, 2007).

Cutting height and chop length of sorghum: Another most important factor that needs to be kept into consideration during ensiling is the chop length of sorghum because it affects the packing process in silos. It has been found that finely cut and chopped sorghum gets compacted easily than longer cut/chopped sorghum (Iqbal and Bethune, 2015). Some modern harvesters have the capacity to cut sorghum as small as 0.25 inches (Neves *et al*., 2015). Finely chopped sorghum not only makes the packing process easy but it also affects animal intake. It has been found that short chop length resulted in significantly higher intake by ruminant livestock. Some other researchers have found that a chop length of 1.25 inches of sorghum fodder as an optimum chop length. Longer chop length than 1.25 inches (Jian *et al*., 2015) results in hindrance during compaction process of chopped materials but also reduces intake by dairy animals.

Dry matter content: The dry matter (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 in turn, affects the exclusion of air from the silo or bale (Piltz and Kaiser, 2004). The target DM content will depend on factors such as crop type, growth stage at harvest and the type of equipment and storage method used as well as the weather conditions of the place (Mickan and Piltz, 2004). 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).

Sugar concentration: Sufficient plant sugars also ensure good quality of sorghum silage because these are necessary for the production of lactic acid. Deficiency of sugars results in the production of butyric acid instead of lactic acid. The harvesting stage influences sugar levels in forage sorghum, so if sorghum is harvested at the appropriate growth stage, plant sugars are not a serious problem (Iqbal and Bethune, 2015). 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 Newmann, 2008). The stage of growth is the most important factor influencing water soluble carbohydrates (WSCs) of forage species. As the plant matures, it contains hemicellulose and most lactic acid bacteria (LAB) cannot ferment hemicelluloses (Piltz and Kaiser, 2004).

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 and Piltz, 2004). Anaerobic condition develops with the rise of CO_2 level (Zegeda and Monti, 2015). Fermentation gets started when the respiration ceases. If the CO_2 is finding a way to escape or if there is too much air present, then respiration will continue to use sugars. Therefore it is important to pack and cover the chopped materials as soon as possible (Iqbal and Bethune, 2015).

Compaction removes air and without which the remaining air will cause a different type of fermentation in which there will be more respiration and resultantly over heating will deteriorate the silage quality. Therefore it is recommended that rate/speed of chopping should never be more than the speed of compaction. Adequate compaction is characterized by the factor that in case of proper compaction, chopped material should be difficult to dig out with bare hands (Iqbal and Bethune, 2015). Sealing is very important to ensure silage is successfully preserved to minimize losses during storing (Mickan and Piltz, 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).

2.8 Ensiling Process and Silage Storage

The Silage making process is commonly divided into four phases. The initial aerobic phase in the silo immediately after harvest, the fermentation phase, the stable storage phase in the silo and the feed out phase when the silo feed face is open and the material is exposed immediately before, during and after its removal from the silo (Wilkinson and Davies, 2013). The four phases are described below:

Initial Aerobic Phase: This phase begins from the time of harvesting crop to the time oxygen is depleted in the sealed silo (Adesogan and Newmann, 2008). During this period, the living plant cells continue to respire, consuming the entrapped air, producing carbon dioxide and water and releasing heat as energy. The heat produced by respiration raises the temperature of silage (Amodu and Abubarkar, 2004). Heat production is normal during the ensiling process and a rise up to 12°C in relation to silage temperature at harvesting is common even in a well-managed silo (Adesogan and Newmann, 2014). Depending on ambient temperatures when the forage was harvested, temperatures up to 40°C have been found, especially in tropical areas (Adesogan, 2009) and in crops ensiled in summer in temperate climates (Kung, 2011). Ensiling at high temperatures or in wet conditions is known to increase the rate of DM losses before silo sealing (Weinberg *et al*., 2001; Ashbell *et al*., 2002). Kim and Adesogan (2006), studying the concurrent effects of high temperatures, surface moisture due to rainfall at harvest, and delayed silo sealing, indicated the fermentation of corn silage is adversely affected by wet conditions at harvest and high ensiling temperatures.

Fermentation Phase: This phase starts after the oxygen is used up, when anaerobic bacteria begin to ferment plant sugars into organic acids, alcohols, carbon dioxide and nitrogenous compounds (Barnhart, 2008). According to Lemus (2010), acid is produce during this period lowering the silage pH below 5. As the silo becomes anaerobic, various anaerobic and facultative microorganism increase in population and ferment primarily sugars and organic acids in the crop. The principal fermentative microbial group include lactic acid bacteria (LAB), enterobacteria, clostridia and yeasts (Pahlow *et al*., 2003). 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 Abubarkar, 2008). Temperature of the crop affects both the speed of fermentation and microbial specie that dominate fermentation. Lactic acid bacteria grow most rapidly at temperature between 27 and 38 ^{o}C (Yamamoto *et al*., 2011). After fermentation is complete, the silage stabilizes and the temperature starts to slowly decrease influence by ambient temperatures and silo size.

Storage Phase: Providing an effective seal on silos and silage piles is important in reducing DM losses during the storage period. Punctures in the plastic silos can occur anytime from a wide variety of sources. The sooner the punctures are found and sealed, the less time silage is exposed to oxygen to oxygen and less deterioration will occur (Green *et al*., 2011).

Feed out Phase: According to Barnhart (2008), this phase begins when silage is opened for animal feeding. Aerobic bacterial, mold and yeast can thrive and spoil the silage due to exposure of the silage to air, thus 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. This phase is also called aerobic deterioration or aerobic spoilage. The general pattern of aerobic deterioration has been known for approximately three decades (Wilkinson and Davies, 2013).

Aerobic deterioration of silages during the feed out phase is a significant problem for farm productivity and feed quality worldwide (Berger and Bolsen, 2006; Borreani and Tabacco, 2008).

In contrast to surface losses occurring during storage, air exerts a stronger effect during the feed out phase because exposure of the silage to oxygen is inevitable once the silo is opened and air can penetrate through the silage face up to distances of 4m especially in the periphery of the silo (Pahlow *et al*., 2003; Borreani *et al*., 2007; Vissers *et al*., 2007). The greater penetration in the periphery is due to the higher porosity of the silage in these areas, and movement of oxygen is proportional to porosity (Pitt and Muck, 1993).

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).

2.9 Silage Utilization by Ruminants

Generally, research data show that sorghum appears to be inferior to corn in total DM digestibility. The mean average daily gain (ADG) for sheep fed corn silage (65.2 g) was more than three times higher than the ADG for sheep fed sorghum silage (18.1 g). The poor performance of sheep on sorghum silage was attributed to the presence of compounds such as tannins or HCN (Fisk, 1980 as cited in Getachew *et al.*, 2016) that may negatively have affected the utilization of nutrients in the sorghum silage. Significantly ($P<0.05$) lower in-vitro DM digestibility (52%) for sorghum silage compared with corn silage (65%) was reported by

Abdelhadi and Santini (2006). The in-vivo DM digestibility of a corn silage based diet (71%) was also higher than sorghum based diet (65%) in cattle (Abdelhadi and Santini, 2006). Forage intake was influenced by the DM content of silages. Intake of sorghum silage increased when DM content of the silage increases. Increasing DM content from 20% to 40% resulted in increased intake from 1.8 to 2.9 kg/100kg (Ward *et al.*, 1966 as cited in Getachew *et al.*, 2016). These researchers attributed the lower DM intake of the high moisture sorghums to higher concentration of volatile organic acids that once consumed might reduce DM intake. Dry matter intake of a sorghum silage based diet was similar with corn silage, although in-vitro DM digestibility was higher for the corn based diet (Miron *et al.*, 2007). When sweet sorghum silage based total mixed ration (TMR) was compared with alfalfa silage based TMR for lactating dairy cows, sweet sorghum silage decreased milk yield, which the authors attributed to the increased NDF content of the TMR. However 4% fat-corrected milk yield (35.0 kg/d for alfalfa silage and 35.3 kg/d for sweet Sorghum silage) was not affected by silage type (Amer *et al.*, 2012). Research results has shown that sorghum, although inferior in forage yield and quality to corn when growing conditions are optimum, has potential for areas of low precipitation or limited irrigation water supply (Getachew *et al.*, 2016). According to Adewumi (2019), diets containing SAMSORG-17 silage improved growth performance of Red Sokoto bucks in Zaria, Nigeria.

2.10 Feeding Regimes in Small Ruminant Production

In ruminant production, feeding regime is used to describe a regulated system/pattern of what meals are been offered, how frequently they are offered, what sequence is followed, and during which particular period they are offered. In Nigeria, small ruminants’ management system may be extensive, intensive or semi-intensive. According to Oludimu (1992) and Lakpini (2002), under the extensive management system, goats and sheep graze on large expanse of land or scavenge all day to feed themselves. At best, they are offered feed supplements such as kitchen refuse, cassava/yam/ banana peelings, bean husks and maize chaff. The animals raised under this system are very destructive to crops, and are prone to diseases, risk of theft and parasites infestation which result in low productivity (Weaver, 2005). In intensive type of management system, animals are completely confined and provided feed using the cut-and-carry (zero-grazing) method in which leguminous trees sown in alley farms or intensive feed gardens provide a high-protein diet to small ruminants. Intensive system of management ensures higher growth rate, carcass yield, milk yield, litter sizes and survival rates. But, it is not advised for the rural poor due to the level of input on feeding and health care (Gefu, 2002; Lakpini, 2002).

Huijsman (1987) remarked that there is a substantial increase in reproductive performance of dwarf goats when the animals are kept under intensive management. The author recorded productivity of 10.9 kg live weight/doe/year under extensive management compared to 24.2 kg live weight/doe/year in the intensive management system. Semi-intensive system of management involves allowing the animals to graze for 6 to 8 hours and supplementing them with concentrates after returning to the pens in the evening. Growth and survival rates of animals are high under this system, though it can only be practiced where grazing land is available or during the dry season when crops have been harvested (Lakpini, 2002; Ugwu, 2007). For instance, Osinowo *et al*. (1992) reported that sheep managed under semi-intensive system are allowed to graze on improved and sown pasture for 6-8 hours daily, with 0.3-0.5 kg/day of 15-20% CP concentrate supplement throughout the year, depending on the animal’s physiological status. In addition, changing the frequency of concentrate supplementation such as feeding the supplement in alternate days or every third day (e.g. Tellier *et al*., 2004) is another feeding regime being employed in ruminant animals' production. Supplementation in most areas where domestic ruminants graze is a major factor to consider when making management decisions. Providing nutrients to offset deficiencies or to meet production demands is more often practiced during the dry season in the tropics and in the periods of summer dormancy or in the fall and winter months in temperate regions (Caton and Dhuyvetter, 1997; Detmann *et al*., 2009). In situations where optimum sward conditions cannot be maintained, and the nutrient intake of animals falls below the required level, one option available is to provide supplementary feeding. Supplements are usually offered in the morning, when the animals have just completed the first grazing season (Carro *et al*., 1994). However, irrespective of the management system, it is important to increase the proportion of forage in the diet to reduce or minimize cost (Bouwman *et al*., 2005) bearing in mind the production objective. Feeding regime, like the number of meals and the sequence of feeding roughage and concentrates during feeding is important to prevent sub-acute ruminal acidosis (Nordlund *et al*., 1995). The levels of rumen metabolites (VFAs, NH3-N) and pH are closely related with feeding regime (Steger *et al*., 1970).

2.11 Response of Ruminants to Sequence and Feeding Interval of Supplement and Roughages

Schilcher *et al*. (2013) investigated the rumen health of different wild ruminant species in relation to feeding managements. In the morning, the test animals were offered with a mixture of concentrates, vegetables and fruits, and at the same time hay. They observed severe lesions on the rumen mucosa of the animals which are fundamental characteristics of sub-acute ruminal acidosis (Krause and Oetzel, 2006). This is because of initial low hay intake as the animals usually eat the concentrate mixture in preference before hay. The authors, therefore, suggested that roughage be offered in the morning before the concentrate meal. Earlier, Morita and Nishino

(1991) offered diets to steers separately by feeding hay before concentrate and observed greater dry matter intake in steers fed hay before concentrate compared to their counterparts fed concentrate before hay. Similar results were obtained when this sequence of feeding (concentrate supplement fed 40 min before or after feeding hay) was compared with feeding mixed diet of hay and concentrate (Morita and Nishino, 1993). However, Nocek *et al*. (1986) observed that the amount of DM intake increased when the mixed ration was offered. On the other hand, some reports pointed out that offering the mixed ration had no effect on DM intake (Holter *et al*., 1977). Voight *et al*. (1978) cited by Morita and Nishino (1993) reported that cellulose digestibility in the fore stomach increased when chopped ryegrass was fed before feeding barley or corn. Beauchemin (1992) recommended to dairy producers that forages should be fed before starch-rich concentrates, particularly in the morning, in order to increase rumen buffering capacity. And alternately, less rapidly fermentable starch sources, such as corn, should be substituted to reduce the rate of production of volatile fatty acids and lactic acids. Both of these practices have been reported (Robinson, 1989; Beauchemin, 1992) to result in higher intake of forage and increased overall animal productivity. Furthermore, Carro *et al*. (1994) studied the effect of time of supplementary feeding on performance of sheep. The authors offered cereal-based concentrate supplement 1 hour after feeding hay in the morning and 30 minutes before feeding hay in the afternoon, at the rate of 700 g/sheep/d, and observed a higher total OM intake when concentrates were given after rather than before a period of ingestion of hay. This suggests that feeding supplement after rather than before a major grazing may be an effective means of minimizing reduction in forage intake as a consequence of feeding concentrate. Manipulating rumen fermentation through strategic supplementation with concentrate and forages could improve rumen efficiency by maintaining higher pH and optimum rumen ammonia-nitrogen

(NH_3-N) concentration, thus reducing methane (CH_4) production and increasing microbial protein synthesis and essential volatile fatty acid (VFAs), for enhanced ruminant production in the tropics (Yashim *et al*., 2015).

2.12 Rumen Metabolites of Sheep

Rumen pH: Rumen pH is the acidity or alkalinity of the rumen and is determined by the concentration of the produced volatile fatty acids in the rumen. Normal pH differs according to type of feed eaten and ranges between 6.0 – 7.0 in animals on a mostly forage diet but is lower at 5.5 – 6.5 in animals fed mostly grain and the type and time of sampling (immediately after feeding acidic and after certain period alkaline). High pH 8.0 – 10.0 (rumen alkalosis) indicates simple indigestion, urea indigestion and putrefaction of rumen ingesta. Lower pH of 5.0 – 5.5 (rumenacidosis) signifies engorgement with readily digestible carbohydrates, chronic rumenacidosis and abomasal reflux from abomasal disease, vagal indigestion and intestinal obstruction (Gozar et al., 2001).

Volatile fatty acids (TFAs): The VFAs, also known as short-chain fatty acids, are produced in the gastrointestinal tract by microbial fermentation of carbohydrates and endogenous substrates, such as mucus. This can be of great advantage to the animal, since no digestive enzymes exist for breaking down cellulose or other complex carbohydrates (Bergman, 1990).Volatile fatty acids (VFAs) are produced in large amounts through ruminal fermentation and are of paramount importance in that they provide greater than 70.0% of the ruminant's energy supply. The principal VFA in either the rumen or large intestine are acetate, propionate, and butyrate and are produced in a ratio varying from approximately 75:15:10 to 40:40:20. Virtually all of the acetic, proprionic and butyric acids formed in the rumen are absorbed across the ruminal epithelium, from which they are carried by ruminal veins to the portal vein and hence through the liver. Bergman (1990) observed that continuous removal of VFA from the rumen is important not only for distribution, but to prevent excessive and damaging drops in pH of rumen fluid.

The rumen is lined with stratified squamous epithelium similar to skin, which is generally noted for efficient absorption. Nonetheless, this squamous epithelium has a structure which functions similarly to the columnar epithelium in the small gut and performs efficient absorption of VFA, as well as lactic acid, electrolytes and water. Animals that have been on a high plane of nutrition, with abundant VFA production, have long, luxuriant papillae well suited to promote absorption. In contrast, animals which have been under nutritional deprivation have small, blunted papillae, and require time on a high quality diet to allow for development of their papillae and absorptive capacity (Bergman, 1990). All the VFA appear to be absorbed by the same mechanism, which is diffusion through the epithelium, down a concentration gradient. As they pass through the epithelium, the different VFA undergo different degrees of metabolism. Acetate and propionate pass through the epithelium largely unchanged, but almost all of the butyric acid is metabolized in the epithelium to beta-hydroxybutyric acid, a type of ketone body. The three major VFA absorbed from the rumen have somewhat distinctive metabolic fates:

Acetic acid is utilized minimally in the liver, and is oxidized throughout most of the body in the peripheral blood to generate ATP. Another important use of acetate is as the major source of acetyl CoA for synthesis of lipids.

Proprionic acid is almost completely removed from portal blood by the liver. Within the liver, proprionate serves as a major substrate for gluconeogenesis, which is absolutely critical to the ruminant because almost no glucose reaches the small intestine for absorption.

Butyric acid, most of which comes out of the rumen as the ketone beta-hydroxybutyric acid, is oxidized in many tissues for energy production.

Ammonia nitrogen (NH_3-N): The quantity of ammonia in rumen digesta appears to be determined chiefly by the nature and quantity of the diet the sheep is offered. The main sources of the ammonia are nitrogen (N) from the diet, N transferred from the blood to the rumen via saliva or the rumen epithelium and N released during the autolysis of micro-organisms. The important avenues of disposal of ammonia are incorporation into microbial protoplasm, absorption, and passage in digesta to the omasum. The level of ammonia in rumen liquor is of particular nutritional significance as many types of rumen micro-organisms utilize ammonia as a source of N. Thus at very low levels of rumen ammonia, it is to be expected that microbial activity in the rumen will be reduced and accordingly protein and carbohydrate digestion will be impaired; associated with this impairment, feed consumption will probably decline (McDonald et al., 2002).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experiment I: Forage Yield and Quality of Two Grain Sorghum Varieties at Different Sowing Dates and Stage of Harvest

3.1.1 Experimental site and location

The study was carried out during 2018 and 2019 raining season at the Experimental Farm of the Feeds and Nutrition Research Programme, National Animal Production Research Institute, Shika. The farm is located on latitude 11^0 12' N and longitude 07^0 33' E at an altitude of 660m above sea level, along Zaria-Funtua Road in the Northern Guinea Savannah Zone of Nigeria (Ovimap, 2016). The climate was characterized by a defined wet and dry season. Wet season starts from April to early-May and ends in late September to early-October, while the dry season lasts from October to April. The total annual rainfall ranged from 748.6 – 1156.7 mm with a long-term average of 1058.60 mm. Maximum air temperature of 35.16^0C was recorded in May and minimum air temperature of 11.5^0C recorded in December/January with relative humidity of approximately 70% during the rainy season (IAR, 2017).Weather observations taken at IAR meteorological station is shown in Table 3.1.The soil of the experimental site consists of 60% sand, 14% clay and 26% silt giving rise to sandy loam while the organic carbon was 0.94%. The pH value recorded was 5.20 and 4.20 for H_2O and 0.01M $CaCl_2$, respectively which showed that the soil was slightly acidic in nature. Typically with tropical soils, the soil of the experimental site was low in both total nitrogen (0.140%) and available phosphorus (21.53 ppm). The exchangeable cations were Ca^{2+}, Mg^{2+}, K^+ and Na^+ which are needed for growth and development in plants. Also the soil had cation exchange capacity, exchangeable acidity and electrical conductivity of 8.20, 0.80 cmol/kg and 0.030 dsm, respectively (Munza, 2017).

Table 3.1: **Meteorological distribution of the experimental location in 2018 and 2019 growing seasons**

	Max Air Temp (°C)		Min Air Temp (°C)		Relative Humidity (%)		Rainfall (mm)	
Month	2018	2019	2018	2019	2018	2019	2018	2019
January	39.48	31.58	15.35	15.19	15.7	15.06	0	0
February	34.48	32.57	18.00	16.07	12.74	16.95	0	3.50
March	34.71	36.77	24.06	22.26	28.19	18.47	25.30	0
April	39.47	38.77	25.80	25.63	40.67	30.30	2.20	0
May	35.16	35.81	24.16	24.48	56.10	58.12	81.30	146.70
June	31.40	30.40	23.20	23.10	70.47	75.50	133.30	110.30
July	30.84	28.81	22.94	22.84	75.94	78.10	218.40	314.20
August	30.55	28.29	21.90	22.19	78.12	81.18	268.80	243.40
September	31.62	30.40	25.45	22.96	71.19	73.37	229.20	237.40
October	33.23	29.81	18.23	22.52	55.68	76.39	61.60	217.40
November	33.83	32.33	12.80	17.93	21.93	33.07	0	0
December	32.10	29.77	14.58	14.81	19.39	19.52	0	0
Total	406.87	385.31	246.47	249.98	546.12	576.03	1020.10	1272.90
Mean	33.91	32.11	20.54	20.83	45.51	48.00	85.01	106.08

Source: IAR, 2020

3.1.2 Treatment and experimental design

The treatment consisted of two sorghum varieties (SAMSORG-16 and SAMSORG-17), three sowing dates (15th June, 30th June and 14th July) and three stages of harvest (6, 10 and 14 weeks after sowing (WAS). They are factorially combined and laid down in split plot design with variety and sowing date assigned in the main plot while stage of harvest was assigned to the sub-plot and replicated three times. The plot size is 5m x 5m with 1m between the plots and 0.5m within plots totaling 35m x 18m (0.063ha).

3.1.3 Source of experimental materials

Grain sorghum seeds were obtained from the Institute for Agricultural Research (IAR), Zaria. SAMSORG-16 and SAMSORG-17 varieties were preferred to other varieties, because of their adaptability to the environment of the study (Aba *et al*., 2004) and forage yield potentials (Munza, 2017). SAMSORG-16 and SAMSORG-17 are grain sorghum varieties with released names SSV2 (FBL) and KSV3 (SK.5912), respectively, adapted to Northern and Southern Guinea Savanna zones of Nigeria (Aba *et al*., 2004). SAMSORG-16 has a maturity period of 165 – 175 days for grain whose seed colour is white with a grain potential yield of 2.5 – 3.5 ton/ha. SAMSORG-17 popularly known as Short Kaura has a maturity period of 165-175 days for grains whose seed colour is yellow with a potential grain yield of 2.5-3.5 ton/ha. SAMSORG-17 is more droughts tolerant to sustained drought (Ogbaga *et al*., 2016).

3.1.4 Basic agronomic practice

The land was ploughed and harrowed with tractor drawn implements and ridged with two work bulls to provide a clean seedbed and to enhance early seed germination. Five (5) seeds were sown on ridges at 2 cm depth at a plant spacing of 15 x 85 cm for each of the three sowing dates.

The tillers were thinned to two (2) plants/ stand after twelve (12) days, so as to have a uniform plant population of (13,333 stands/ha). A uniform dose of 120 kg/ha NPK (20:10:10) was applied at 2 and 5 weeks after sowing (WAS) as first and second doses, respectively. Weeding of the experimental plots was carried out during the growing periods as the need arises.

3.1.5 Data collection on plant growth parameters and yield components

Seedling emergence was monitored at 4 days after sowing. Germination counts were carried out at 12 days after sowing. Data on crop growth components and yield were measured at 6, 10 and 14 weeks after sowing (WAS) on primary growth. Five (5) plants were randomly sampled per plot and tagged for measurements of various agronomic parameters using the standard procedure as reported by Tarawali *et al.* (1995).

Plant height:

The plant height of grain sorghum was determined by measuring from the base of the plant to the top with the aid of a 200cm ruler on 5 randomly selected stands per plot and later averaged out as plant height.

Number of leaves per plant:

The number of leaves on the 5 randomly selected and tagged plants per plot was counted and the mean number of leaves per plant was determined from each plot at 6, 10 and 14 WAS and recorded.

Leaf area index (LAI):

Leaf area was measured using the method described by Stickler *et al*. (1961), i.e LA = length of the lamina x the largest width x a factor (0.747). The means were later recorded. The leaf area index was determined from the ratio of leaf per plant to the unit area of land covered by each plant (Watson, 1952).

$$\text{LAI} = \frac{Leaf\ Area\ per\ Plant}{Area\ of\ Ground\ per\ Plant}$$

Forage yield:

This was determined at 6, 10 and 14 WAS by harvesting the fresh forage within each in a 1m^2 quadrat at 15cm above the ground using a hand sickle. The fresh forage was weighed in the field using a sensitive weighing scale and sub-samples were oven dried at 65^0C for 48 hours and reweighed to estimate dry matter yield.

Dry matter production was calculated as: (Total FW x (DWss/FWss)) x 10 = Dry matter kg/ha. (Tarawali *et al.*, 1995) where:

Total FW = Total fresh weight from 1 m^2 in (g)

DWss = Dry weight of the sub-sample in (g)

FWss = Fresh weight of the sub-sample in (g)

3.1.6 Silage preparation and sampling

In 2018, the two sorghum varieties were harvested at 14 weeks after sowing, when they were at booting stage of development and the forage chopped to 2 cm with a forage chopper. The chopped forage materials were allowed to wilt for 24 hours and ensiled in glass jars labeled A, B, C, D, E and F representing the two varieties and three sowing dates. The silos (1 kg each) were opened at twenty-one (21) days after ensiling for chemical evaluation. The pH of the silage was measured with pH meter. Composite sample (600g) was obtained by sampling and then bulked immediately and mixed thoroughly before being stored in the refrigerator at (-5^oC) until required for chemical analysis.

3.2 Experiment II: Effect of Feeding Regime on Performance of Growing Yankasa Rams Fed Basal Diet of Sorghum Hay or Silage Supplemented with Concentrate

3.2.1 Experimental site

The experiment was conducted at the Sheep Unit of the Teaching and Research Farm, Department of Animal Science, Ahmadu Bello University Zaria, Kaduna State. **Zaria is located between two latitude of 11° 14' 14"N and two Longitude 7° 38' 65"E at an altitude of 610m above sea level (Ovimap, 2016), within the Northern Guinea Savanna Zone of Nigeria.**

3.2.2 Silage preparation

The choice of SAMSORG-17variety and 15th June sowing date was based on the high dry matter and crude protein contents of the silage made in 2018. SAMSORG-17 grain sorghum sown on the 15th June, 2019 was conserved as silage. The forage was harvested at soft dough stage with the aid of forage harvester and chopper. The chopped forage was conveyed in tractor trailer to the Seed Production Unit of the Feed and Nutrition Research Programme, NAPRI, Shika. The chopped forages were inserted and compressed in PICS (Purdue Improved Crop Storage) bags having extra two polythene inside and then properly tied to enable anaerobic fermentation process (Amodu and Abubakar, 2004). The bags were stored until required for feeding.

3.2.3 Experimental animals and their management

Sixteen (16) growing Yankasa rams aged between 12 and 15 months and weighing 17.0±0.20 kg were used for the study. The animals were purchased from Anchau market, Kaduna State. The animals were given prophylactic treatment against internal and external parasites. All animals received intramuscularly 0.1 mg/kg body weight of *Tetranor* (*Oxytetracycline Dehydrate*, 20%

weight/volume injectable solution) as long active antibiotics. Deworming against intestinal parasites using *Albendazole*® 10% solution was administered orally. *Amitics*® solution was sprayed on the animals using Knapsack sprayer against external parasites prior to the commencement of the study. The animals were pen-housed individually. The pen was cleaned daily.

3.2.4 Experimental design, treatments and feeding

The rams were balanced for their weights and allotted to four (4) dietary treatments with four (4) rams per treatment in a Complete Randomized Design (CRD). Grain sorghum hay and silage supplemented with concentrate were used in a 60:40 hay/concentrate ratio. The composition of the concentrate supplemented is shown in Table 3.2. The rams were pen-fed individually at 4 % of their body weight for a period of 70 days. Feeding regime was used as the treatment consisting of T_1 = Sorghum hay + concentrate supplemented daily, T_2 = Sorghum silage + concentrate supplemented daily, T_3 = Sorghum silage + concentrate supplemented after one day and T_4 = Sorghum silage + concentrate supplemented after two days. Feed was offered once in the morning at 8:00 am. Daily records of feed offered and left-over were recorded to determine the voluntary feed intake. Water was provided *ad-libitum* to the rams. During the experiment the rams were weighed fortnightly to determine their live weight changes and for adjusting feed offered accordingly.

3.2.5 Metabolism study

At the end of the growth study, three (3) rams from each of the treatment groups were randomly selected and housed in individual metabolism crates ideal for easy collection of urine and faeces as described by Osuji *et al*. (1993)**.** The rams were maintained on the same treatment diets in the feeding trial. The animals were allowed 14 days adjustment period to the feed and crates while 7 days was used as collection period for urine and faeces. The orts of previous day's feed was collected and weighed each morning at 8:00 am.

The total faecal output from individual animals were collected daily in the morning, weighed, mixed thoroughly and 10% sub sample was taken for dry matter determination. The total faecal sample was collected over the 7 days period, bulked and sub sampled for laboratory analysis after treating with 20% formaldehyde to prevent further bacterial activity. The total urine output for 24 hours was collected from individual animal for a period of 7 days. This was done using graduated plastic containers containing 10ml of 0.1M H_2SO_4 which was placed under the metabolism crates. An aliquot (10%) of the daily urine output was taken from each ram, bulked and stored in a freezer at (0^oC) until required for analyses as described by Osuji *et al*. (1993).

3.2.6 Rumen fluid sampling

At the end of the metabolism study, three of the experimental animals were used for rumen fluid collection to evaluate the effect of treatment diets and sampling time on some rumen metabolites. Three (3) rams were allotted to four (4) dietary treatments (T_1 = Sorghum hay + concentrate supplemented daily, T_2 = Sorghum silage + concentrate supplemented daily, T_3 = Sorghum silage + concentrate supplemented after one day and T_4 = Sorghum silage + concentrate supplemented after two days) and three (3) sampling time (0, 4 and 8 hours post-feeding) in a factorial Complete Randomized Design (CRD). Rumen fluid samples were collected using stomach tube at 0 hour before morning feeding and subsequently at 4 and 8 hours post feeding, respectively. The stomach tube was carefully inserted into the rumen of the rams through the oesophagus, after restraining the animals. The pump was pressured to collect the rumen liquor into a stainless container. A clinical thermometer and digital pH meter were used immediately to

Table 3.2: Composition of concentrate supplement fed to growing Yankasa rams

Ingredients	Percentage (%)
Maize offal	40.0
Wheat offal	31.5
Cotton seed cake	25.0
Bone meal	2.5
Salt	1.0
Total	100
Calculated analysis (%)	
Crude Protein	13.63
Metabolizable energy (kcal/kg)	2679.0
Cost/kg diet (₦)	93.40

determine the temperature and pH of the rumen fluid, respectively. The samples were strained through a double layer cheese cloth to remove extraneous materials. Ten (10) ml of the rumen fluid was measured into well-labeled plastic bottles containing equal volume (10 ml) of 0.1 normal Sulphuric acid (H_2SO_4) solutions to trap the ammonia nitrogen (NH_3-N). The rumen fluid samples were immediately stored in a freezer at a temperature of -4^oC pending laboratory analysis.

3.2.7 Costs-benefit analysis

Costs-analysis was carried out to determine the profitability of feeding growing Yankasa rams basal diet of grain sorghum hay and silage supplemented with concentrate at different feeding regime. Parameters considered included cost of concentrate, total concentrate intake, cost of hay, total hay intake, total feed cost consumed per ram, live weight gain and cost per gain. All calculations of feed cost and output were based on averages per head, and at the prevailing prices.

3.3 Chemical Analyses

In both experiments, samples of the forage material harvested, silage, feed offered, orts and faeces were analyzed for dry matter and crude protein according to AOAC, (2005) in the Biochemical Laboratory, Department of Animal Science, A. B. U., Zaria. Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined by the method of van-Soest *et al.* (1991). Calcium and Phosphorus were determined according to AOAC (2005) using Atomic Absorption Spectrophotometer at Soil Science Laboratory, Department of Soil Science, A. B. U, Zaria.

Rumen ammonia-nitrogen (NH_3-N) and total volatile fatty acids (TVFAs) were determined by steam distillation (**AOAC, 2005)** in the Central Laboratory of NAPRI, Shika, Zaria, Nigeria.

3.4 Statistical Analyses and Models

Data collected from experiment I on growth components were analyzed using Repeated Measure Analysis of Variance (ANOVA). Data on chemical composition, forage yield and chemical characteristics of hay, silage, daily feed intake, average daily gain, final weight, coefficient of nutrient digestibility, nitrogen retention and rumen metabolites were analyzed using the General Linear Model Procedure of SAS (2005). Significant means were compared using the Duncan's Multiple Range Test (Duncan, 1955).

Growth and yield components model:

$$Y_{ijkl} = \mu + A_i + B_j + C_k + (A*B)_{ij} + (B*C)_{jk} + (A*C)_{ik} + (A*B*C)_{ijk} + E_{ilkl}$$

Where: Y_{ijkl} = is the record of observations for dependent variables

μ= is the population mean

A_i = effect of variety (i = 1 and 2);

B_j = effect of sowing date (j = 15th June, 30th June and 14th July);

C_k = effect of stage of harvest (k = 6, 10 and 14 WAS);

$(A*B)_{ij}$= effect of interaction between variety and sowing date;

$(B*C)_{jk}$ = effect of interaction between sowing date and stage of harvest;

$(A*C)_{ik}$ = effect of interaction between variety and stage of harvest;

$(A*B*C)_{ijk}$ = effect of interaction between variety and sowing date and stage of harvest;

E_{ijkl}= random error assumed to be normally and independently distributed with zero means and standard variation.

Silage model:

$Y_{ijk} = \mu + A_i + B_j + (A*B)_{ij} + E_{ilk}$

Where: Y_{ijk} = is the record of observations for dependent variables

μ= is the population mean

A_i = effect of variety (i = 1 and 2);

B_j = effect of sowing date (j = 15th June, 30th June and 14th July);

$(A*B)_{ij}$= effect of interaction between variety and sowing date;

E_{ijk} = random error assumed to be normally and independently distributed with zero means and standard variation.

Growth model:

$Y_{ij} = \mu + T_i + E_{ij}$

Where: Y_{ij} = Dependent variables

μ= overall mean

T_i = Effect of i^{th} treatment diets (i= 1, 2, 3 and 4);

E_{ij} = Random error assumed to be normally and independently distributed with zero means and standard variation.

Rumen fluid model:

$Y_{ijk} = \mu + A_i + B_j + (A*B)_{ij} + E_{ilk}$

Where: Y_{ijk} = is the record of observations for dependent variables

μ= is the population mean

A_i = effect of feeding regime (i = 1, 2, 3 and 4);

B_j = effect of time of sampling time (j = 0, 4 and 8 hours post-feeding);

$(A*B)_{ij}$= effect of interaction between feeding regime and sampling time;

E_{ijk} = random error assumed to be normally and independently distributed with zero means and standard variation.

CHAPTER FOUR

4.0 RESULTS

4.1 Plant Height of Grain Sorghum as Influenced by Variety, Sowing Date and Stage of Harvest in 2018 and 2019 Growing Seasons

Plant height of grain sorghum as influenced by variety, sowing date and stage of harvest in 2018 and 2019 growing season is presented in Table 4.1. There was significant (P<0.05) effect of variety on the plant height of grain sorghum in 2018, 2019 and mean. Plant height was taller for SAMSORG-16 compared to SAMSORG-17 in 2018 and 2019 growing seasons and the mean.

Plant height significantly (P<0.05) varied with different sowing dates (Table 4.1). In 2018 growing season, taller plant height was obtained in sorghum sown on 15th June which was at par with sorghum sown on 30th June and shorter in sorghum sown on 14th July. Different trend was observed in 2019 growing season, in which sorghum sown on 30th June recorded taller plant height, followed by 14th July and shorter in sorghum sown on 15th June. Taller plant height was obtained in sorghum sown on 30th June, followed by sorghum sown on the 15th June which was similar with those sown on 14th July. The values obtained in 2019 growing season and the mean were lower than the values recorded in 2018 growing season.

Plant height significantly (P<0.05) increased as stage of harvest was delayed from 6 to 14 WAS (Table 4.1). In 2018, 2019 growing seasons and the mean, plant height was taller at 14 WAS, followed by 10 WAS and least at 6 WAS.

Significant (P<0.05) interaction effect was obtained for variety and sowing date in 2018 and 2019 growing seasons and mean; sowing date and stage of harvest in 2019 growing season and mean; and variety and stage of harvest in 2018 and 2019 growing seasons and mean (Table 4.1).

Table 4.1: Plant height of grain sorghum as influenced by variety, sowing date and stage of harvest in 2018 and 2019 growing seasons

	Plant height (cm)		
Treatment	2018	2019	Mean
Variety			
SAMSORG-16	239.19^{a}	175.22^{a}	207.20^{a}
SAMSORG-17	156.14^{b}	115.86^{b}	136.00^{b}
SEM	11.69*	9.12*	8.44*
Sowing date			
15th June	211.12^{a}	125.73^{c}	168.43^{b}
30th June	199.08^{a}	163.43^{a}	181.26^{a}
14th July	182.79^{b}	147.44^{b}	165.12^{b}
SEM	7.79*	6.08*	5.63*
Stage of harvest (WAS)			
6	79.99^{c}	69.84^{c}	74.92^{c}
10	205.98^{b}	153.48^{b}	179.73^{b}
14	307.02^{a}	213.29^{a}	260.16^{a}
SEM	7.79*	6.08*	5.63*
Interactions			

V x S	0.019	0.006	0.012
S x W	0.248	0.001	0.036
V x W	<0.001	<0.001	<0.001
V x S x W	0.288	0.195	0.450

[abc]Means with different superscripts within columns differed significantly (P<0.05), SEM = Standard error of mean, WAS = Weeks after sowing, V = Variety, S = Sowing date, W = Stage of harvest

4.1.1 Interaction between variety and sowing date on mean plant height (cm) of grain sorghum

Interaction between variety and sowing date on mean plant height (cm) of grain sorghum is presented in Figure 1. Significantly (P<0.05) taller plant height was obtained for SAMSORG-16 sown on 30th June, followed by SAMSORG-16 sown on 14th July which was similar with that of SAMSORG-16 sown on 15th June. Shorter plant height was recorded for SAMSORG-17 sown on 14th July which was at par with SAMSORG-17 sown on 30th June.

4.1.2 Interaction between sowing date and stage of harvest on mean plant height (cm) of grain sorghum

The significant (P<0.05) interaction between sowing date and stage of harvest on mean plant height of grain sorghum is shown in Figure 2, significant (P<0.05) mean plant height of grain sorghum in sorghum sown on 30th June, and harvested at 14 WAS had taller plant height but at par with sorghum sown on 14th July and harvested at 14 WAS. It was followed by sorghum sown on 15th June, harvested at 14 WAS, also similar with sorghum sown on 14th July harvested at 14 WAS. Shorter plant height was obtained for sorghum sown on 14th July harvested at 6 WAS again similar with sorghum sown on 15th June and 30th June harvested at 6 WAS, respectively.

4.1.3 Interaction between variety and stage of harvest on mean plant height (cm) of grain sorghum

Significant (P<0.05) interaction effect between variety and stage of harvest on mean plant height of grain sorghum (Figure 3) revealed that SAMSORG-16 harvested at 14 WAS recorded taller plant height which was followed by SAMSORG-16 harvested at 10 WAS. Shorter plant height was obtained for SAMSORG-17 harvested at 6 WAS which recorded similar plant height at 6 WAS for SAMSORG-16.

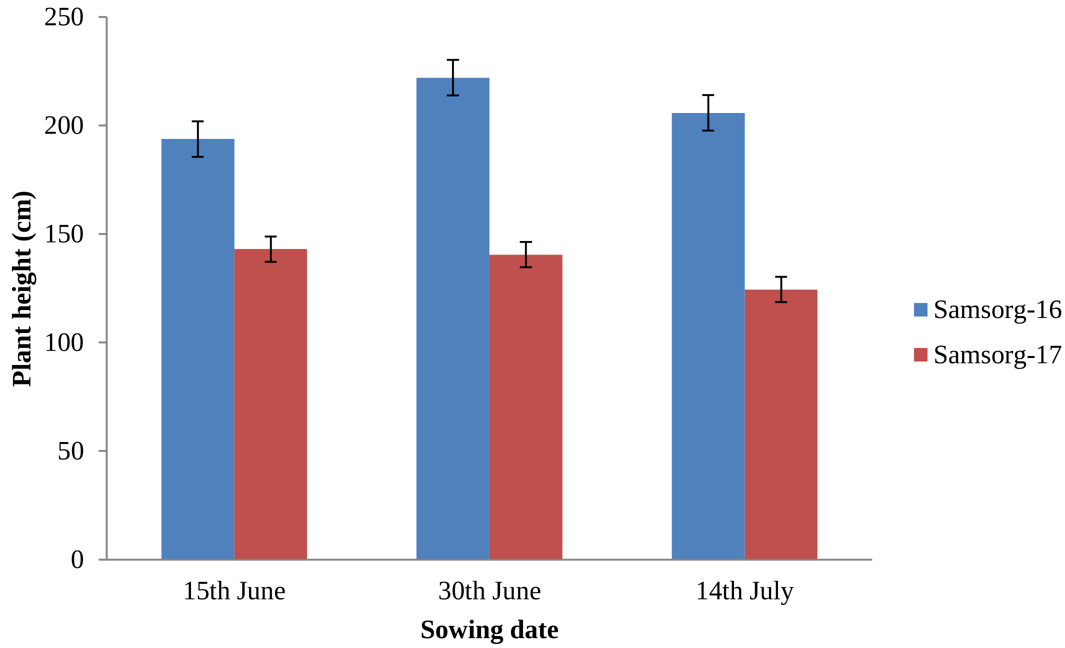

Figure 1: Interaction between variety and sowing date on mean plant height (cm) of grain sorghum

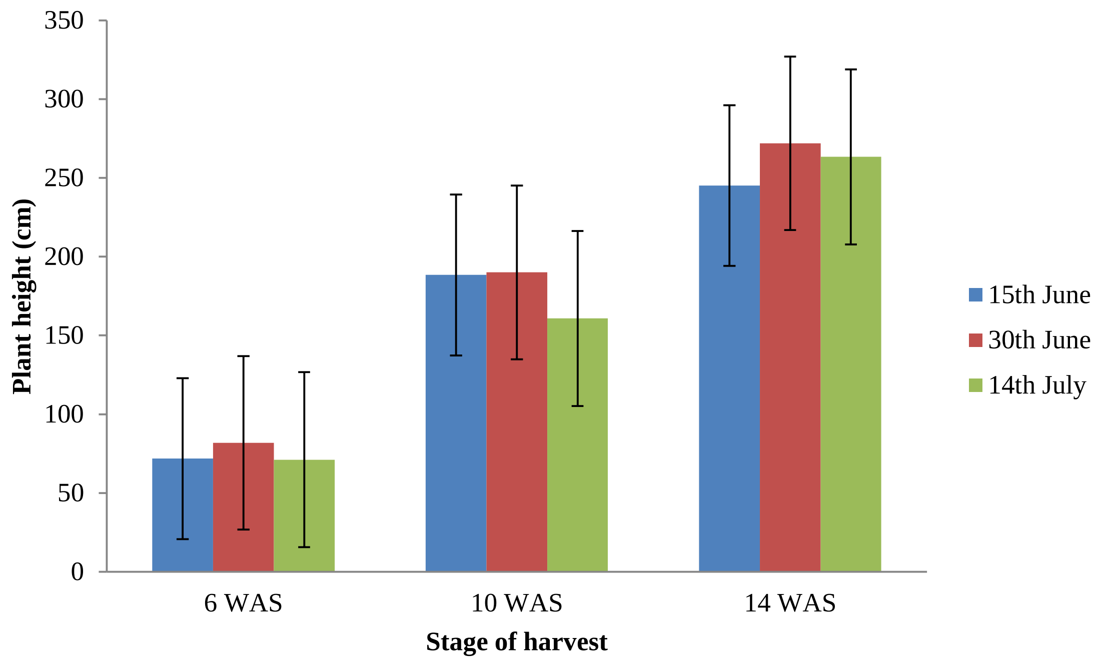

Figure 2: Interaction between sowing date and stage of harvest on mean plant height (cm) of grain sorghum

4.2 Number of Leaves of Grain Sorghum as Influenced by Variety, Sowing Date and Stage of Harvest in 2018 and 2019 Growing Seasons

The number leaves of grain sorghum as influenced by variety, sowing date and stage of harvest in 2018 and 2019 growing seasons is shown in Table 4.2. There was non-significant (P>0.05) effect of variety on number of leaves in 2018 and the mean. In 2019 growing season, number of leaves was significantly (P<0.05) higher for SAMSORG-17 while lower number of leaves was obtained for SAMSORG-16 variety.

Sowing date had significant (P<0.05) effect on number of leaves in 2018 and 2019 growing season and the mean (Table 4.2). Grain sorghum sown on 15th June recorded higher number of leaves in 2018 growing season, followed by sorghum sown on 14th July which was similar with sorghum sown on 30th June. In 2019 growing season and the mean, the higher number of leaves obtained for sorghum sown on 30th June was at par with sorghum sown on 15th June. While lower number of leaves was observed for sorghum sown on 14th July in 2019 growing season and the mean.

There was significant (P<0.05) stage of harvest effect on number of leaves of grain sorghum in 2018 and 2019 growing seasons and the mean (Table 4.2). Number of leaves was increasing as stage of harvest was delayed from 6 to 14 WAS. Higher number of leaves was obtained for grain sorghum harvested at 14 WAS, followed by sorghum harvested at 10 WAS while lower number of leaves was recorded for sorghum harvested at 6 WAS.

Interaction was significant (P<0.05) for number leaves between sowing date and stage of harvest in 2018 growing season and the mean and between variety and stage of harvest in 2019 growing season (Table 4.2).

Table 4.2: Number of leaves of grain sorghum as influenced by variety, sowing date and stage of harvest in 2018 and 2019 growing seasons

	Number of leaves		
Treatment	2018	2019	Mean
Variety			
SAMSORG-16	13.06	11.34[b]	12.20
SAMSORG-17	13.09	12.61[a]	12.85
SEM	0.48[NS]	0.62*	0.42[NS]
Sowing date			
15th June	13.73[a]	12.38[a]	13.06[a]
30th June	12.69[b]	12.68[a]	12.68[a]
14th July	12.80[b]	10.87[b]	11.83[b]

SEM	0.32*	0.41*	0.28*
Stage of harvest (WAS)			
6	9.63^{c}	8.52^{c}	9.08^{c}
10	12.26^{b}	11.99^{b}	12.12^{b}
14	17.33^{a}	15.41^{a}	16.37^{a}
SEM	0.32*	0.41*	0.28*
Interactions			
V x S	0.070	0.336	0.657
S x W	<0.001	0.095	0.022
V x W	0.688	0.028	0.053
V x S x W	0.568	0.571	0.496

^{abc}Means with different superscripts within columns differed significantly (P<0.05), SEM = Standard error of mean, WAS = Weeks after sowing, V = Variety, S = Sowing date, W = Stage of harvest

4.2.1 Interaction between sowing date and stage of harvest on mean number of leaves of grain sorghum

There was significant (P<0.05) interaction effect between sowing date and stage of harvest on mean number of leaves of grain sorghum (Figure 4). Higher number of leaves was recorded for sorghum sown on 15th June harvested at 14 WAS, followed by sorghum sown on 30th June harvested at 14 WAS which was followed by sorghum sown on 14th July harvested at 14 WAS. While lower number of leaves was obtained for sorghum sown on 14th July harvested at 6 WAS which was similar with sorghums sown on 15th and 30th June harvested at 6 WAS.

4.3 Leaf Area Index (LAI) of Grain Sorghum as Influenced by Variety, Sowing Date and Stage of Harvest in 2018 and 2019 Growing Seasons

Result for leaf area index (LAI) of grain sorghum as influenced by variety, sowing date and stage of harvest in 2018 and 2019 growing season is shown in Table 4.3. There was non-significant (P>0.05) effect of variety on LAI of grain sorghum in 2018 and 2019 growing seasons and the mean.

Sowing date had significant (P<0.05) effect on LAI of grain sorghum in 2018 and 2019 growing seasons and the mean. Leaf area index (LAI) was higher for sorghum sown on 15th June in 2019 growing season and the mean. Higher LAI in 2018 growing season observed was followed by that of sorghum sown on 14th July which was at par with sorghum sown on 30th June. In 2019 growing season, higher LAI recorded in sorghum sown on 30th June was similar with sorghum sown on 15th June. While lower LAI was obtained for sorghum sown on 14th July in 2019 growing season and the mean.

There was significant (P<0.05) effect of stage of harvest in 2018 and 2019 growing seasons and the mean (Table 4.3). Leaf area index (LAI) was increasing when stage of harvest was delayed

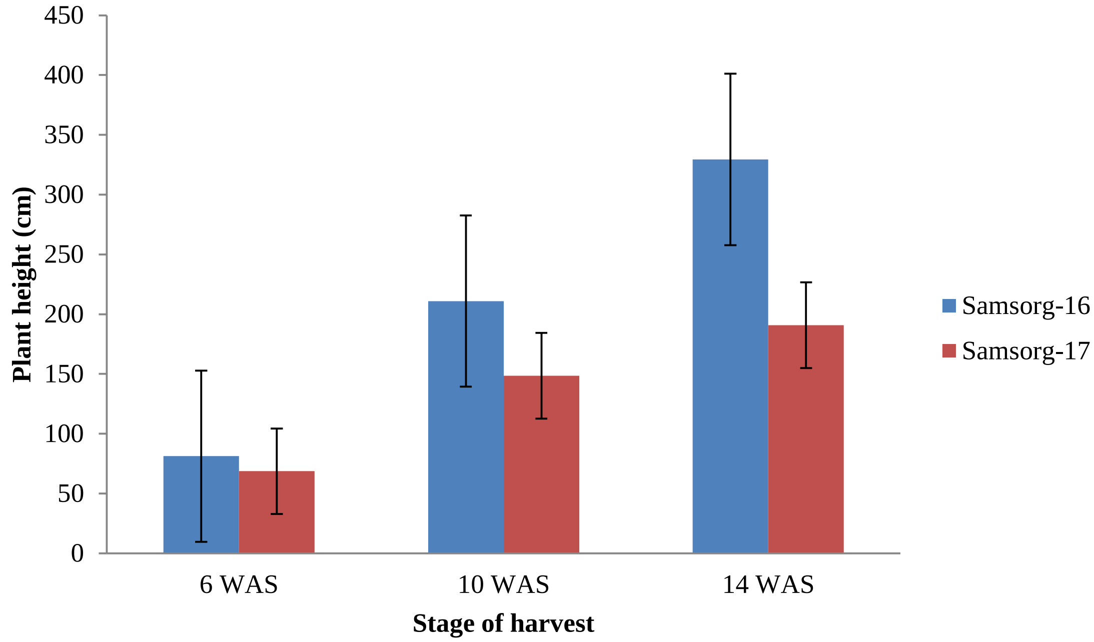

Figure 3: Interaction between variety and stage of harvest on mean plant height (cm) of grain sorghum

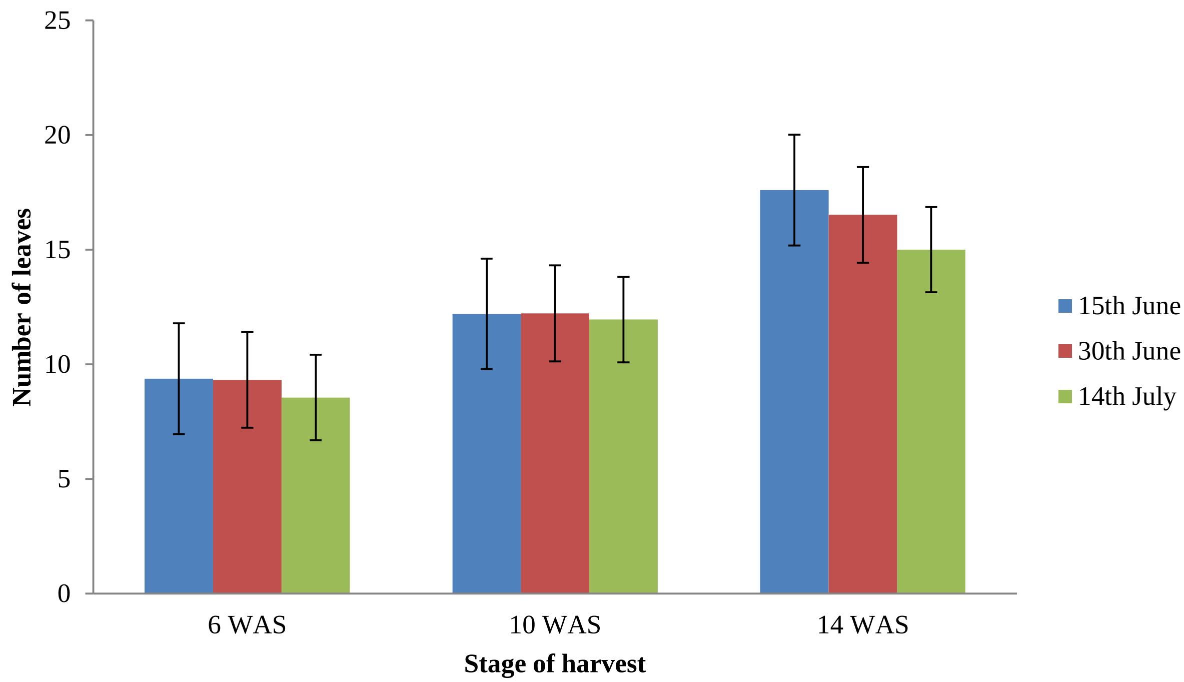

Figure 4: Interaction between sowing date and stage of harvest on mean number of leaves of grain sorghum

from 6 to 14 WAS. Higher LAI was obtained for sorghum harvested at 14 WAS, followed by sorghum harvested at 10 WAS while lower LAI was recorded at 6 WAS in 2018 and 2019 growing seasons and the mean.

Significant (P<0.05) interaction effect was observed between sowing date and stage of harvest in 2018 and 2019 growing seasons and the mean and between variety and stage of harvest in 2019 growing season (Table 4.3).

4.3.1 Interaction between sowing date and stage of harvest on mean LAI of grain sorghum

Significantly (P<0.05) higher LAI was recorded for sorghum sown on 15th June harvested at 14 WAS, which was followed by sorghum sown on 30th June harvested at 14 WAS (Figure 5). This was then followed by sorghum sown on 14th July harvested at 14 WAS but was statistically similar (P>0.05) with sorghums sown on 15th and 30th June harvested at 10 WAS. While lower LAI was obtained for sorghum sown on 14th July harvested at 6 WAS which was at par with sorghum sown on 30th June harvested at 6 WAS.

4.4 Dry Forage Yield of Grain Sorghum as Influenced by Variety, Sowing Date and Stage of Harvest in 2018 and 2019 Growing Seasons

The result for dry forage yield of grain sorghum as influenced by variety, sowing date and stage of harvest in 2018 and 2019 growing seasons is shown in Table 4.4. There was non-significant (P>0.5) effect of variety in 2018 growing season, while in 2019 growing season and the mean, significant (P<0.05) varietal effect was observed. Dry forage yield was higher for SAMSORG-16 sorghum and lower for SAMSORG-17.

The effect of sowing date on the dry forage yield in both 2018 and 2019 growing seasons and the mean was significantly (P<0.05) varied among the sowing dates evaluated. In 2018 growing

Table 4.3: Leaf area index (LAI) of grain sorghum as influenced by variety, sowing date and stage of harvest in 2018 and 2019 growing seasons

	Leaf area index (LAI)		
Treatment	2018	2019	Mean
Variety			
SAMSORG-16	6.14	4.28	5.21
SAMSORG-17	6.02	5.14	5.58
SEM	0.57^{NS}	0.45^{NS}	0.33^{NS}
Sowing date			
15th June	7.06^{a}	5.18^{a}	6.12^{a}
30th June	5.46^{b}	5.44^{a}	5.45^{b}
14th July	5.71^{b}	3.51^{b}	4.61^{c}
SEM	0.38*	0.30*	0.22*
Stage of harvest (WAS)			
6	3.16^{c}	1.64^{c}	2.40^{c}
10	6.10^{b}	5.52^{b}	5.81^{b}
14	8.97^{a}	6.97^{a}	7.97^{a}
SEM	0.38*	0.30*	0.22*
Interactions			
V x S	0.084	0.243	0.529
S x W	0.007	0.001	0.001
V x W	0.976	0.011	0.115
V x S x W	0.962	0.808	0.895

^{abc}Means with different superscripts within columns differed significantly (P<0.05), SEM = Standard error of mean, WAS = Weeks after sowing, V = Variety, S = Sowing date, W = Stage of harvest

season, higher dry forage yield was recorded for sorghum sown on 15th June which was similar with sorghum sown on 30th June. While lower dry forage yield was observed for sorghum sown on 14th July which was at par with sorghum sown on 30th June. In 2019 growing season, dry forage yield was higher for sorghum sown on 14th July, followed by sorghum sown on 15th June and lower for sorghum sown on 30th June. The result for the mean revealed higher dry forage yield for sorghum sown on 15th June, followed by sorghum sown on 14th July which had similar dry forage yield with sorghum sown on 30th June.

There was significant ($P<0.05$) stage of harvest effect on the dry forage yield of grain sorghum in 2018 and 2019 growing seasons and the mean. Dry forage yield rises when stage of harvest was delayed from 6 to 14 WAS. Higher dry forage yield was obtained for sorghum harvested at 14 WAS in 2018 and 2019 growing seasons and the mean. This was followed by sorghum harvested at 10 WAS while lower dry forage yield was recorded for sorghum harvested at 6 WAS for both 2018 and 2019 growing seasons and the mean, respectively.

Interaction was significant ($P<0.05$) for dry forage yield of grain sorghum between variety and sowing date in 2019 growing season and the mean, between sowing date and stage of harvest in 2019 growing season and the mean, between variety and stage of harvest in 2019 growing season and the mean and between variety, sowing date and stage of harvest in 2019 growing season (Table 4.4).

4.4.1 Interaction between variety and sowing date on mean dry forage yield (t/ha) of grain sorghum

Interaction between variety and sowing date on mean dry forage yield of grain sorghum is shown in Figure 6. Higher dry forage yield was recorded for SAMSORG-16 sown on 14th July which was similar with SAMSORG-16 and SAMSORG-17 sown on 15th June, respectively.

Table 4.4: Dry forage yield of grain sorghum as influenced by variety, sowing date and stage of harvest in 2018 and 2019 growing seasons

	Dry forage yield (t/ha)		
Treatment	2018	2019	Mean
Variety			
SAMSORG-16	9.13	7.90^{a}	8.52^{a}
SAMSORG-17	7.66	5.46^{b}	6.56^{b}
SEM	1.88^{NS}	0.71*	0.90*
Sowing date			
15^{th} June	10.49^{a}	7.21^{b}	8.85^{a}
30^{th} June	8.59^{ab}	4.43^{c}	6.51^{b}
14^{th} July	6.11^{b}	8.40^{a}	7.26^{b}
SEM	1.25*	0.48*	0.60*
Stage of harvest (WAS)			
6	1.37^{c}	0.94^{c}	1.15^{c}
10	9.36^{b}	5.88^{b}	7.62^{b}
14	14.47^{a}	13.21^{a}	13.84^{a}
SEM	1.25*	0.48*	0.60*
Interactions			
V x S	0.664	<0.001	0.015
S x W	0.308	<0.001	0.001
V x W	0.411	<0.001	0.006
V x S x W	0.965	0.001	0.103

^{abc}Means with different superscripts within columns differed significantly (P<0.05), SEM = Standard error of mean, WAS = Weeks after sowing, V = Variety, S = Sowing date, W = Stage of harvest

It was followed by SAMSORG-16 sown on 30th June which was at par with SAMSORG-17 sown on 15th June while lower dry forage yield was observed for SAMSORG-17 sown on 14th July which had similar dry forage yield with Samsorg-17 and SAMSORG-16 sown on 30th June, respectively.

4.4.2 Interaction between sowing date and stage of harvest on mean dry forage yield (t/ha) of grain sorghum

The sowing date and stage of harvest interaction on mean dry forage yield of grain sorghum (Figure 7) indicated that higher dry forage yield was obtained for sorghum sown on 15th June harvested at 14 WAS. This was followed by dry forage yield for sorghum sown on 14th July harvested at 14 WAS which was then followed by sorghum sown on 30th June harvested at 14 WAS. While lower dry forage yield was recorded for sorghum sown on 14th July harvested at 6 WAS which had similar dry forage yield with sorghums sown on 15th and 30th June harvested at 6 WAS, respectively.

4.4.3 Interaction between variety and stage of harvest on mean dry forage yield (t/ha) of grain sorghum

The interaction between variety and stage of harvest on mean dry forage yield of grain sorghum (Figure 8) revealed that SAMSORG-16 harvested at 14 WAS had higher dry forage yield, followed by SAMSORG-17 harvested at 14 WAS. These were followed by mean dry forage yield recorded for SAMSORG-16 harvested at 10 WAS which was at par with that of SAMSORG-17 harvested at 10 WAS. While lower dry forage yield was observed for SAMSORG-17 harvested at 6 WAS which had similar dry forage yield with SAMSORG-16 harvested at 6 WAS.

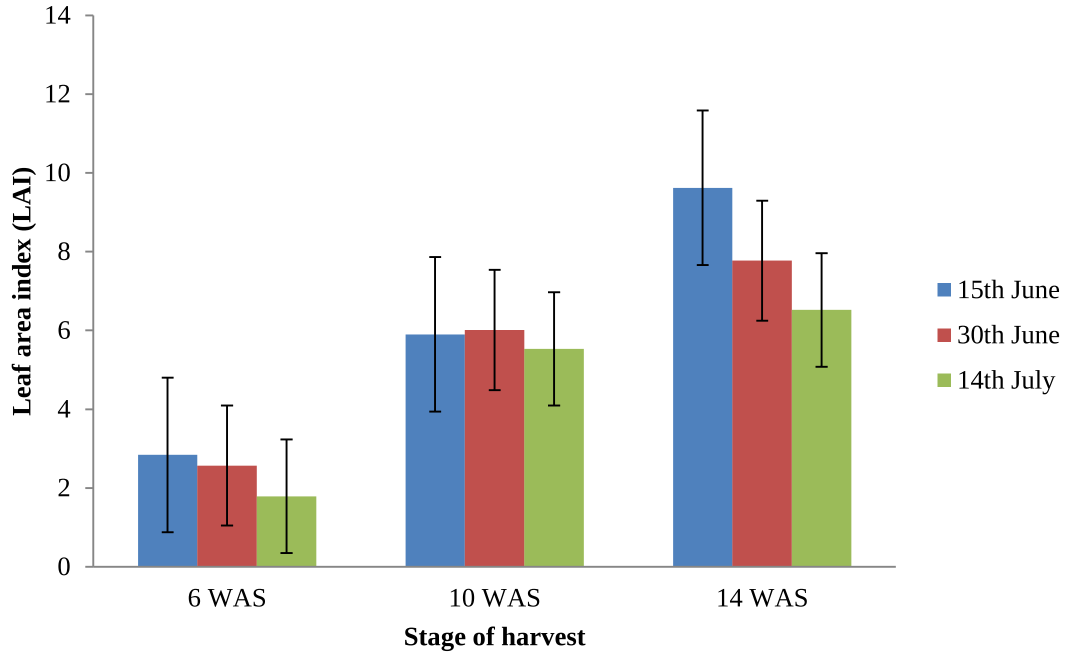

Figure 5: Interaction between sowing date and stage of harvest on mean LAI of grain sorghum

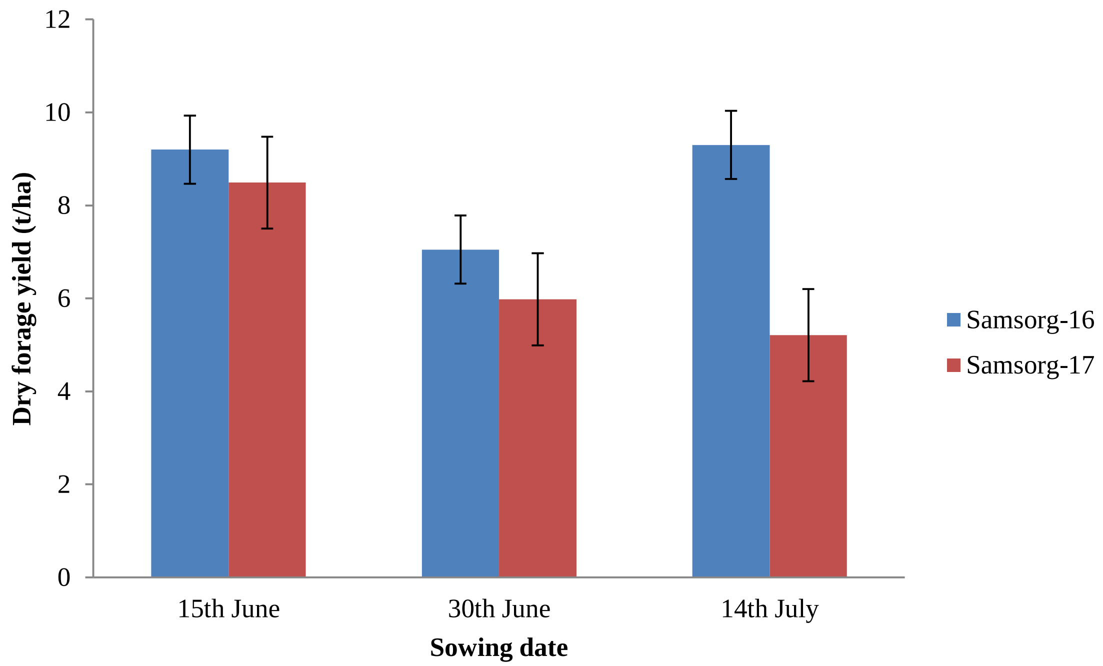

Figure 6: Interaction between variety and sowing date on mean dry forage yield (t/ha) of grain sorghum

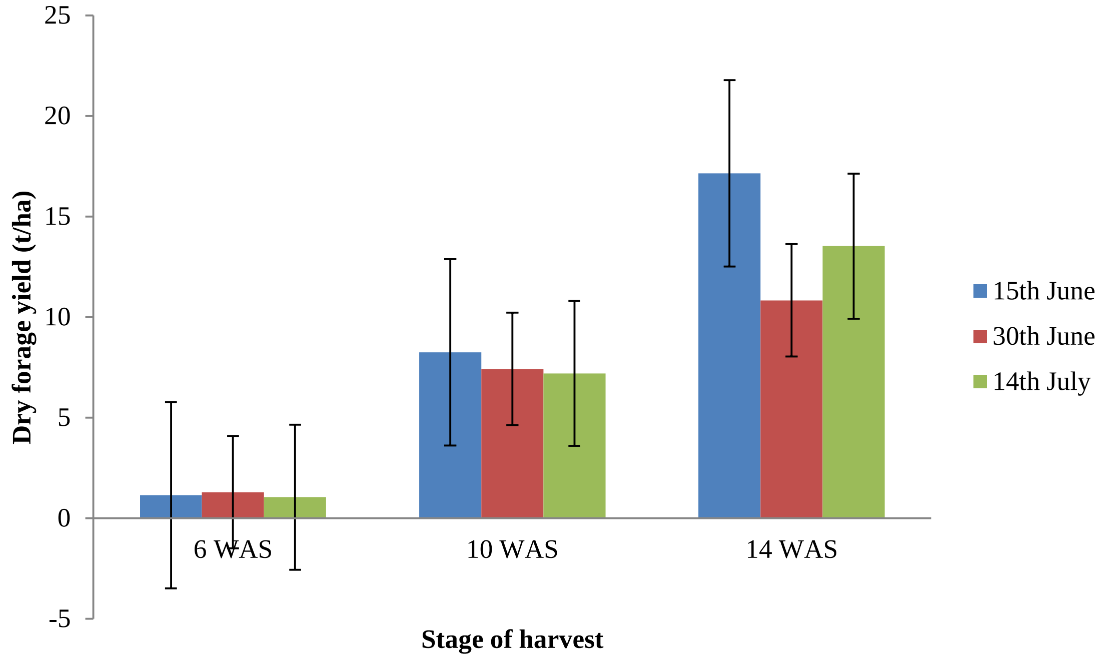

Figure 7: Interaction between sowing date and stage of harvest on mean dry forage yield (t/ha) of grain sorghum

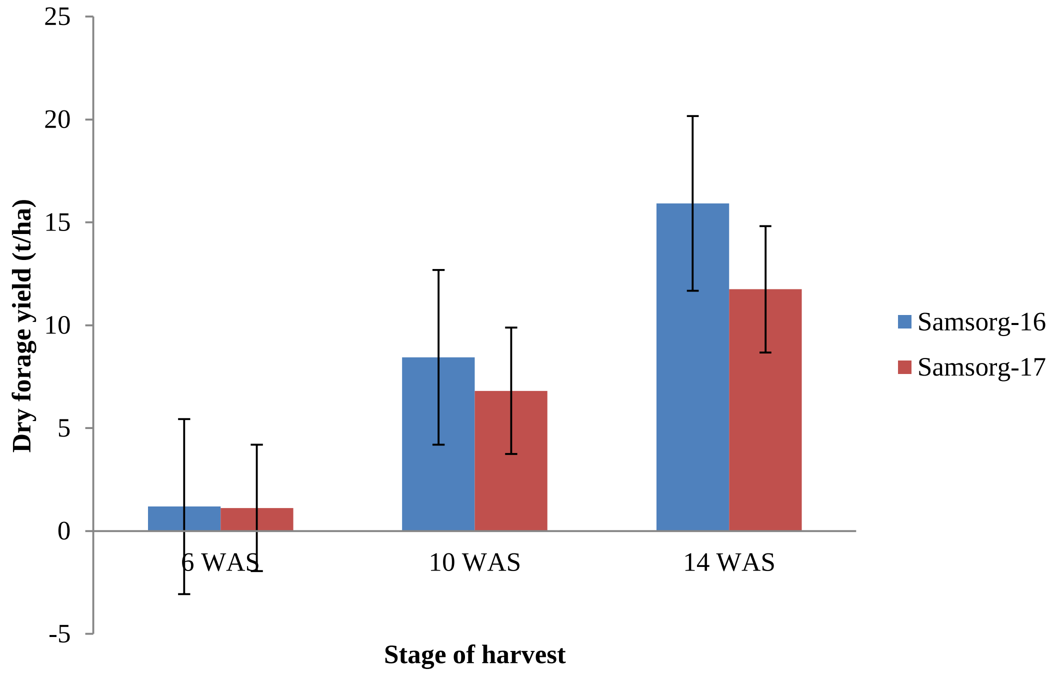

Figure 8: Interaction between variety and stage of harvest on mean dry forage yield (t/ha) of grain sorghum

4.5 Chemical Composition of Ensiled Grain Sorghum as Influenced by Variety and Sowing Date in 2018 Growing Season

There was no significant (P>0.05) effect of variety on temperature and pH of ensiled grain sorghum (Table 4.5). The temperature for both varieties was 22.93^{o}C while pH observed ranged between 3.82 and 3.83 for SAMSORG-16 and SAMSORG-17 varieties, respectively. There was significant (P<0.05) effect of variety on dry matter, crude protein, neutral detergent fibre, acid detergent fibre, calcium and phosphorus composition (Table 4.6) of ensiled grain sorghum. Dry matter, crude protein and calcium were higher in SAMSORG-17 and lower in SAMSORG-16 sorghum silages. Neutral detergent fibre, acid detergent fibre and phosphorus were significantly (P<0.05) higher in SAMSORG-16 silage and lower in SAMSORG-17 silage.

Significant effect (P<0.05) of sowing date was observed for temperature, pH, dry matter, crude protein, neutral detergent fibre, acid detergent fibre, calcium and phosphorus (Table 4.5) of ensiled grain sorghum. Temperature was higher for sorghum silage sown on 15th June and lower for sorghum silage sown on 14th July while pH was higher for sorghum silage sown on 30th Juneand lower for sorghum sown on 14th July. Dry matter was higher for sorghum silage sown on 15th June which was at par with sorghum silage sown on 14th July while lower dry matter was obtained for sorghum silage sown on 30th June. Crude protein, neutral detergent fibre and acid detergent fibre had higher values for sorghum silage sown on 15th June, followed by 30th June and lower for sorghum silage sown on 14th July. Calcium and phosphorus were higher for sorghum silage sown on 14th July, followed by 15th June and lower for sorghum silage sown on 30th June. There was significant (P<0.05) interaction effect between variety and sowing date on parameters measured except pH.

Table 4.5: Chemical composition (%) of ensiled grain sorghum as influenced by variety and sowing date in 2018 growing season

Treatment	T^{o}C	pH	DM	CP	NDF	ADF	Ca	P
Variety								
SAMSORG-16	22.93	3.83	71.70^{b}	6.78^{b}	62.79^{a}	47.34^{a}	0.42^{b}	0.06^{a}
SAMSORG-17	22.93	3.82	75.36^{a}	10.42^{a}	54.01^{b}	40.32^{b}	0.56^{a}	0.04^{b}
SEM	0.01^{NS}	0.06^{NS}	0.79*	0.47*	0.50*	0.50*	0.01*	0.01*
Sowing date								
15th June	24.00^{a}	4.01^{b}	74.70^{a}	12.94^{a}	66.13^{a}	51.07^{a}	0.50^{b}	0.05^{b}
30th June	23.00^{b}	4.20^{a}	73.40^{b}	6.62^{b}	55.62^{b}	47.09^{b}	0.44^{c}	0.04^{c}
14th July	21.80^{c}	3.27^{c}	74.49^{a}	6.25^{b}	53.45^{c}	33.34^{c}	0.53^{a}	0.06^{a}
SEM	0.01*	0.04*	0.53*	0.31*	0.33*	0.33*	0.01*	0.01*
Interaction								
V x S	<0.001	0.230	0.009	<0.001	<0.001	0.015	<0.001	<0.001

^{abc}Means with different superscripts within column differed significantly, SEM = standard error of mean, V – Variety, S = Sowing, DM = Dry matter, CP = Crude protein, NDF = Neutral detergent fibre, ADF = Acid detergent fibre, Ca = Calcium, P = Phosphorus

4.5.1 Interaction between variety and sowing date on dry matter of ensiled grain sorghum

The interaction between variety and sowing date on dry matter of ensiled grain sorghum (Figure 9) revealed that higher dry matter was obtained for silage made from SAMSORG-17 sown on 14th July which was similar with silages made from SAMSORG-17 sown on 15th and 30th June and SAMSORG-16 sown on 15th June. These were followed by silage made from SAMSORG-16 sown on 30th June which was at par with silage made from SAMSORG-17 sown on 30th June and SAMSORG-16 sown on 15th June while lower dry matter was observed for silage prepared from SAMSORG-16 sown on 14th July.

4.5.2 Interaction between variety and sowing date on crude protein of ensiled grain sorghum

Significantly ($P<0.05$) higher crude protein was obtained for silage made from SAMSORG-17 sown on 15th June, followed by silage made from SAMSORG-16 sown on 15th June which was at par with silage made from SAMSORG-17 sown on 30th June (Figure 10). These were followed by silage made from SAMSORG-17 sown on 14th July which was similar with silage made from SAMSORG-16 sown on 14th July while lower crude protein was recorded for silage made from SAMSORG-16 sown on 30th June.

4.6 Dry Matter and Crude Protein Contents of Grain Sorghum Forage as Influenced by Variety, Sowing Date and Stage of Harvest in 2018 and 2019 Growing Seasons

There was non-significant ($P>0.05$) effect of variety on dry matter and crude protein contents in 2018 and 2019 growing seasons and the mean (Table 4.6). Dry matter and crude protein contents ranged from 92.73 – 94.81% and 10.88 – 11.85%, respectively. Similar trend was observed for sowing date with non-significant ($P>0.05$) effect of sowing date on dry matter and crude protein contents. The dry matter and crude protein contents recorded for sowing dates ranged from 92.94 – 95.12% and 10.66 –12.03%, respectively.

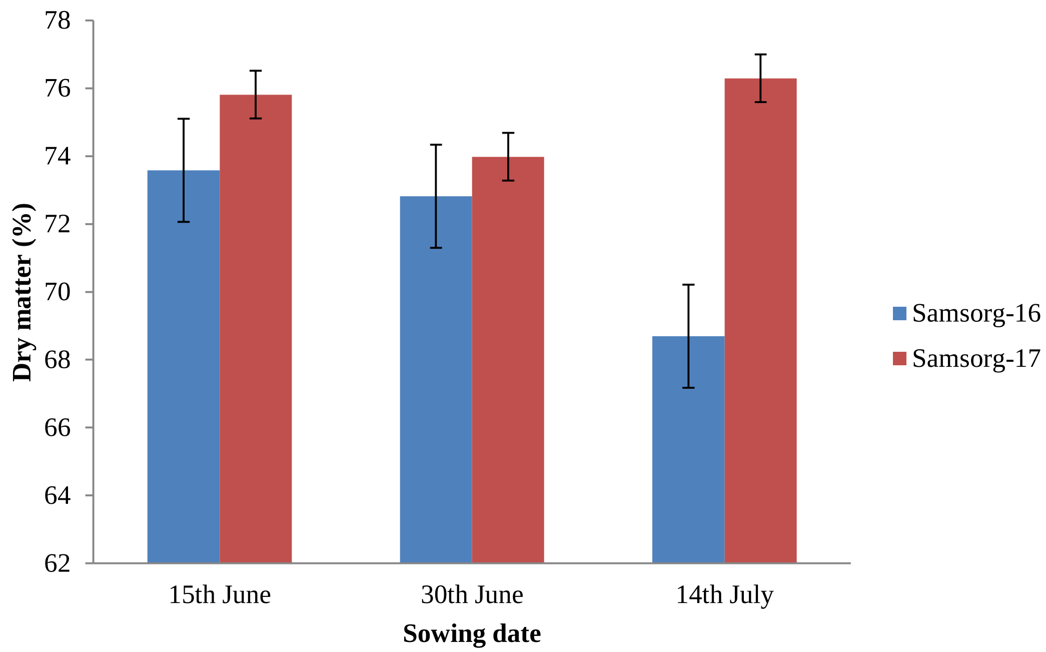

Figure 9: Interaction between variety and sowing date on dry matter (%) of ensiled grain sorghum

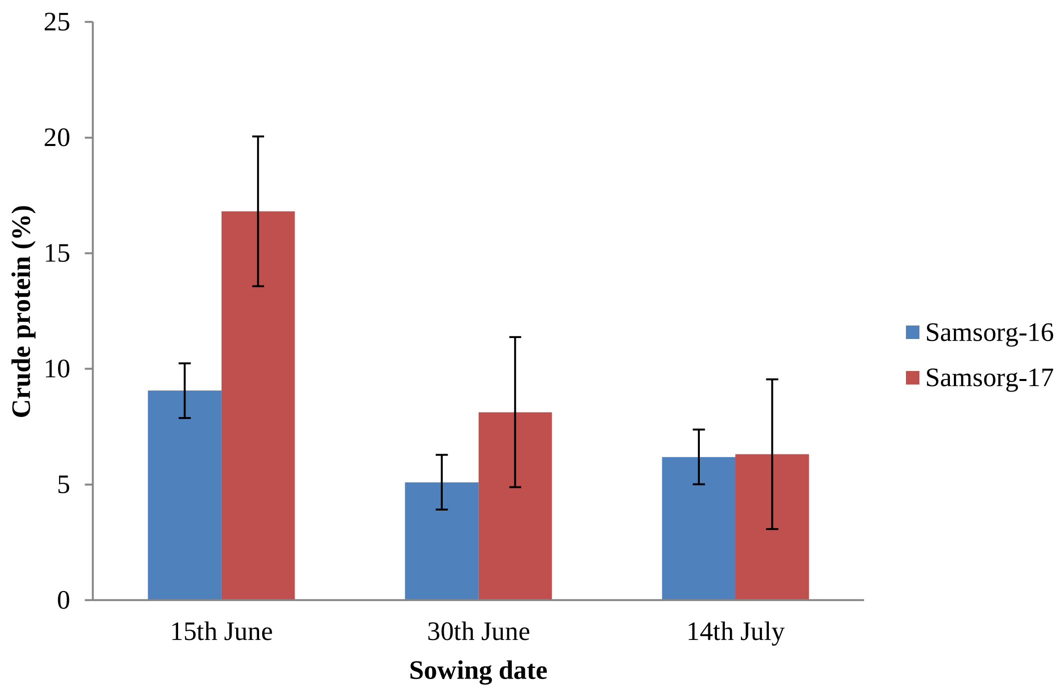

Figure 10: Interaction between variety and sowing date on crude protein (%) of ensiled grain sorghum

Stage of harvest had no significant (P>0.05) effect on dry matter and crude protein contents of the forage in both 2018 and 2019 growing seasons and the overall mean, respectively. However, there was significant (P<0.05) effect of stage of harvest on crude protein content in 2018 growing season and the overall mean in which higher crude protein contents were obtained for grain sorghum forage harvested at 6 WAS which was at par with grain sorghum forage harvested at 10 WAS while lower crude protein content was recorded for grain sorghum forage harvested at 14 WAS.

There was non-significant (P>0.05) interactions effect on dry matter and crude protein contents of grain sorghum forage in both 2018 and 2019 growing seasons and the mean.

4.7 Neutral Detergent Fibre and Acid Detergent Fibre Contents of Grain Sorghum Forage as Influenced by Variety, Sowing Date and Stage of Harvest in 2018 and 2019 Growing Seasons

Results of neutral detergent fibre (NDF) and acid detergent fibre (ADF) contents of grain sorghum forage as influenced by variety, sowing date and stage of harvest in 2018 and 2019 growing seasons are presented in Table 4.7. Variety had no significant (P>0.05) effect on NDF in 2019 growing season and ADF in 2018 and 2019 growing seasons and the overall mean, respectively. Whereas there was significant (P<0.05) effect of variety on NDF in 2018 growing season and the overall mean in which higher (P<0.05) NDF was recorded for SAMSORG-16 variety than SAMSORG-17 grain sorghum variety. The values of ADF obtained in this study for SAMSORG-16 and SAMSORG-17 grain sorghum varieties ranged from 31.43 – 39.47%.

There was significant (P<0.05) effect of sowing date on NDF and ADF in 2018 growing season and the overall mean in which higher (P<0.05) NDF was observed for grain sorghum sown on 30th June which was similar with that of grain sorghum sown on 15th June while lower NDF was

Table 4.6: Dry matter and crude protein contents of grain sorghum forage as influenced by variety, sowing date and stage of harvest in 2018 and 2019 growing seasons

Treatments	*Proximate composition (%)*					
	Dry Matter			Crude Protein		
	2018	2019	Mean	2018	2019	Mean
Variety						
SAMSORG-16	94.24	93.80	94.02	10.88	11.85	11.36
SAMSORG-17	94.81	92.73	93.77	11.71	11.75	11.73
SEM	2.13^{NS}	0.99^{NS}	1.36^{NS}	1.95^{NS}	1.00^{NS}	1.17^{NS}
Sowing date						
15^{th} June	95.12	92.94	94.03	12.03	11.96	11.99
30^{th} June	94.41	93.44	93.75	11.18	11.66	11.42
14^{th} July	94.06	93.42	93.91	10.66	11.78	11.22
SEM	1.42^{NS}	0.66^{NS}	0.90^{NS}	1.30^{NS}	0.67^{NS}	0.78^{NS}
Stage of harvest (WAS)						
6	93.44	92.84	93.25	12.51^{a}	12.07	12.23^{a}
10	94.68	93.06	93.76	12.23^{a}	11.95	12.15^{a}
14	95.46	93.90	94.68	9.14^{b}	11.38	10.26^{b}
SEM	1.42^{NS}	0.66^{NS}	0.90^{NS}	1.30*	0.67^{NS}	0.78*
Interactions						
V x S	0.431	0.573	0.795	0.739	0.871	0.857
S x W	0.743	0.067	0.836	0.789	0.948	0.746
V x W	0.907	0.100	0.816	0.434	0.092	0.786
V x S x W	0.539	0.986	0.890	0.951	0.726	0.905

^{abc}Means with different superscripts within columns differed significantly (P<0.05), SEM = Standard error of mean, WAS = Weeks after sowing, V = Variety, S = Sowing date, W = Stage of harvest

obtained for grain sorghum sown on 14th July. Higher (P<0.05) ADF was recorded for grain sorghum sown on 30th June while lower ADF was obtained for grain sorghum sown on 14th July which were at par with grain sorghum sown on 15th June in 2018 growing season and the overall mean.

In 2019 growing season and the overall mean, it was observed that sowing date had no significant (P>0.05) effect on NDF and ADF contents. Stage of harvest had significant (P<0.05) effect on NDF and ADF in both 2018 and 2019 growing seasons and the overall mean. Higher (P<0.05) NDF and ADF were recorded for grain sorghum forage harvested at 14 WAS, followed by grain sorghum forage harvested at 10 WAS while lower NDF and ADF were obtained for grain sorghum forage harvested at 6 WAS which were at par with grain sorghum forage harvested at 10 WAS in 2018 and 2019 growing seasons and 2018 growing season, respectively. There was significant (P<0.05) interaction effect on NDF in 2018 growing season and the overall mean and ADF in 2018 and 2019 growing seasons and their overall mean, respectively.

4.7.1 Interaction between variety and sowing date on mean neutral detergent fibre (%) of grain sorghum forage

The interaction between variety and sowing date on mean neutral detergent fibre (NDF) of grain sorghum forage is shown in Figure 11. Higher (P<0.05) NDF was recorded for SAMSORG-16 sown on 15th June which was at par with SAMSORG-16 sown on 30th June and SAMSORG-17 sown on 14th July. Lower (P<0.05) NDF was obtained for SAMSORG-17 sown on 15th June which was similar with SAMSORG-16 sown on 14th July and SAMSORG-17 sown on 30th June.

Table 4.7: Neutral detergent fibre and acid detergent fibre contents of grain sorghum forage as influenced by variety, sowing date and stage of harvest in 2018 and 2019 growing seasons

Treatments	*Chemical composition (%)*					
	Neutral Detergent Fibre (NDF)			Acid Detergent Fibre (ADF)		
	2018	2019	Mean	2018	2019	Mean
Variety						
SAMSORG-16	62.31[a]	64.32	63.31[a]	39.47	32.02	35.75
SAMSORG-17	58.35[b]	64.04	61.20[b]	39.10	31.43	35.26
SEM	1.00*	1.00[NS]	1.00*	1.00[NS]	0.99[NS]	0.99[NS]
Sowing date						
15th June	60.68[a]	64.07	62.38	38.26[b]	32.10	35.18[ab]
30th June	61.40[a]	64.09	62.74	40.81[a]	31.90	36.35[a]
14th July	58.92[b]	64.38	61.65	38.78[b]	31.18	34.98[b]
SEM	0.67*	0.67[NS]	0.67[NS]	0.67*	0.66[NS]	0.66*
Stage of harvest (WAS)						
6	58.74[b]	60.06[b]	59.40[c]	34.74[b]	21.91[c]	30.07[c]
10	59.95[b]	60.67[b]	61.49[b]	38.23[b]	32.19[b]	33.46[b]
14	62.30[a]	71.82[a]	65.89[a]	44.90[a]	41.08[a]	42.99[a]
SEM	0.67*	0.67*	0.67*	0.67*	0.66*	0.66*
Interactions						
V x S	<0.001	0.916	<0.001	0.005	0.023	0.193
S x W	<0.001	0.593	0.015	<0.001	0.025	0.051
V x W	<0.001	0.125	<0.001	<0.001	<0.001	0.643
V x S x W	<0.001	0.722	<0.001	<0.001	0.001	0.003

[abc]Means with different superscripts within columns differed significantly ($P<0.05$), SEM = Standard error of mean, WAS = Weeks after sowing, V = Variety, S = Sowing date, W = Stage of harvest

4.7.2 Interaction between sowing date and stage of harvest on mean neutral detergent fibre (%) of grain sorghum forage

The interaction between sowing date and stage of harvest on mean neutral detergent fibre (NDF) of grain sorghum forage is presented in Figure 12. Significantly ($P<0.05$) higher NDF was obtained for grain sorghum sown on 15th June harvested at 14 WAS which was at par with sorghum sown on 30th June and 14th July harvested at 14 WAS, respectively. This was followed by grain sorghum sown on 15th June harvested at 10 WAS which was similar with grain sorghum sown on 30th June harvested at 6 WAS and sorghum sown on 14th July and 30th June harvested at 10 WAS, respectively. Lower ($P<0.05$) NDF was recorded for grain sorghum sown on 14th July harvested at 6 WAS which was at par with grain sorghum sown on 15th June harvested at 6 WAS and 30th June harvested at 10 WAS, respectively.

4.7.3 Interaction between variety and stage of harvest on mean neutral detergent fibre (%) of grain sorghum forage

The interaction between variety and stage of harvest on mean neutral detergent fibre (NDF) of grain sorghum forage is shown in Figure 13. Higher ($P<0.05$) NDF was recorded for SAMSORG-16 grain sorghum harvested at 14 WAS, followed by SAMSORG-17 grain sorghum harvested at 14 WAS which was at par with SAMSORG-17 harvested at 10 WAS. This was closely followed by SAMSORG-16 grain sorghum harvested at 6 WAS which was similar with SAMSORG-16 and SAMSORG-17 grain sorghum harvested at 10 WAS, respectively. Lower ($P<0.05$) NDF was obtained for SAMSORG-17 grain sorghum harvested at 6 WAS.

4.7.4 Interaction between variety, sowing date and stage of harvest on mean neutral detergent fibre (%) of grain sorghum forage

The interaction between variety, sowing date and stage of harvest on mean neutral detergent fibre (NDF) of grain sorghum forage is given in Figure 14. Significantly ($P<0.05$) higher NDF was recorded for SAMSORG-16 grain sorghum sown on 15th June, harvested at 14 WAS which was similar with SAMSORG-17 grain sorghum sown on 14th July, harvested at 14 WAS. This was followed by SAMSORG-16 grain sorghum sown on 30th June, harvested at 14 WAS which was also at par with SAMSORG-17 grain sorghum sown on 14th July, harvested at 14 WAS. This was followed by SAMSORG-16 grain sorghum sown on 30th June, harvested at 6 WAS which was similar with SAMSORG-16 grain sorghum sown on 15th June, harvested at 10 WAS and SAMSORG-17 grain sorghum sown on 15th June, 30th June and 14th July harvested at 10 WAS, respectively. Lower ($P<0.05$) NDF was obtained for SAMSORG-17 grain sorghum sown on 14th July, harvested at 6 WAS which was at par with SAMSORG-17 grain sorghum sown on 15th June, harvested at 14 WAS.

4.7.5 Interaction between variety, sowing date and stage of harvest on mean acid detergent fibre (%) of grain sorghum forage

The interaction between variety, sowing date and stage of harvest on mean acid detergent fibre (ADF) of grain sorghum forage is shown in Figure 15. Higher ($P<0.05$) ADF was recorded for SAMSORG-17 grain sorghum sown on 14th July, harvested at 14 WAS which was similar with SAMSORG-16 grain sorghum sown on 30th June, harvested at 14 WAS and SAMSORG-16 and SAMSORG-17 grain sorghums, harvested at 14 WAS, respectively. This was followed SAMSORG-16 grain sorghum sown on 14th July, harvested at 14 WAS which was at par with SAMSORG-17 grain sorghum sown on 30th June, harvested 14 WAS and SAMSORG-16 and SAMSORG-17 grain sorghums, harvested at 14 WAS, respectively. While lower ($P<0.05$) ADF was obtained for SAMSORG-17 grain sorghum sown on 14th July, harvested at 6 WAS which was similar with SAMSORG-16 and SAMSORG-17 grain sorghums sown on 15th June, harvested at 6 WAS, respectively.

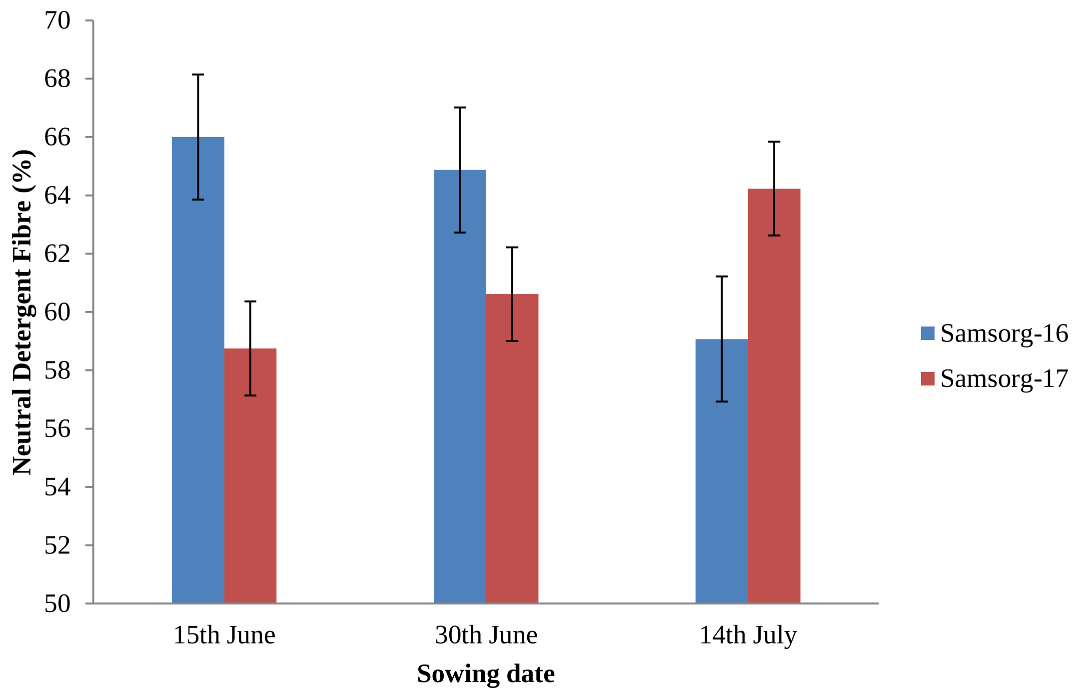

Figure 11: Interaction between variety and sowing date on mean neutral detergent fibre (%) of grain sorghum forage

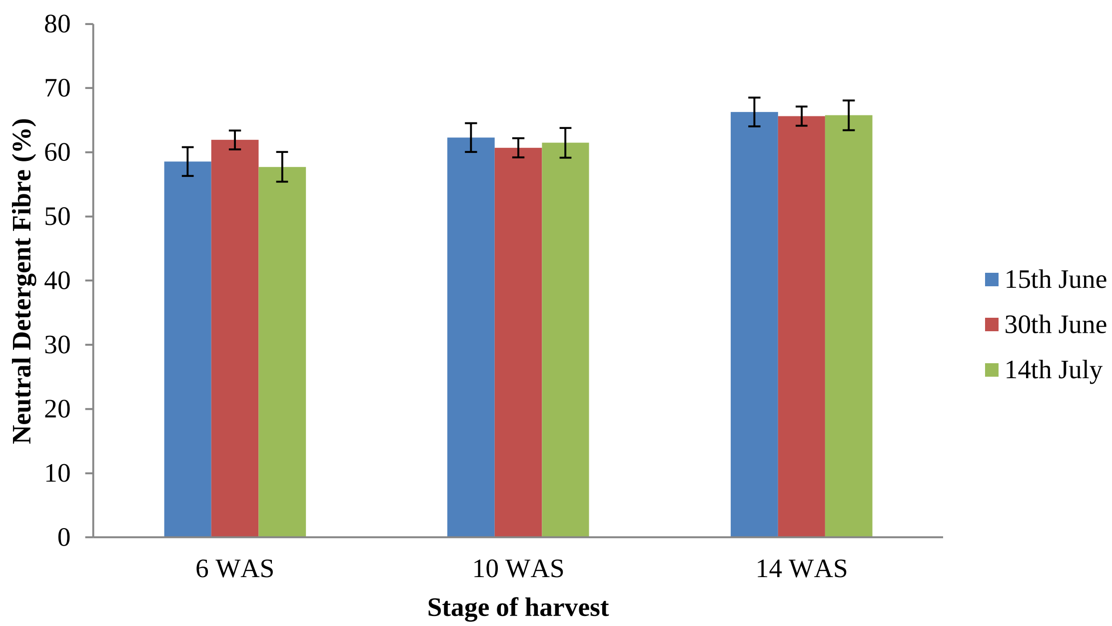

Figure 12: Interaction between sowing date and stage of harvest on mean neutral detergent fibre (%) of grain sorghum forage

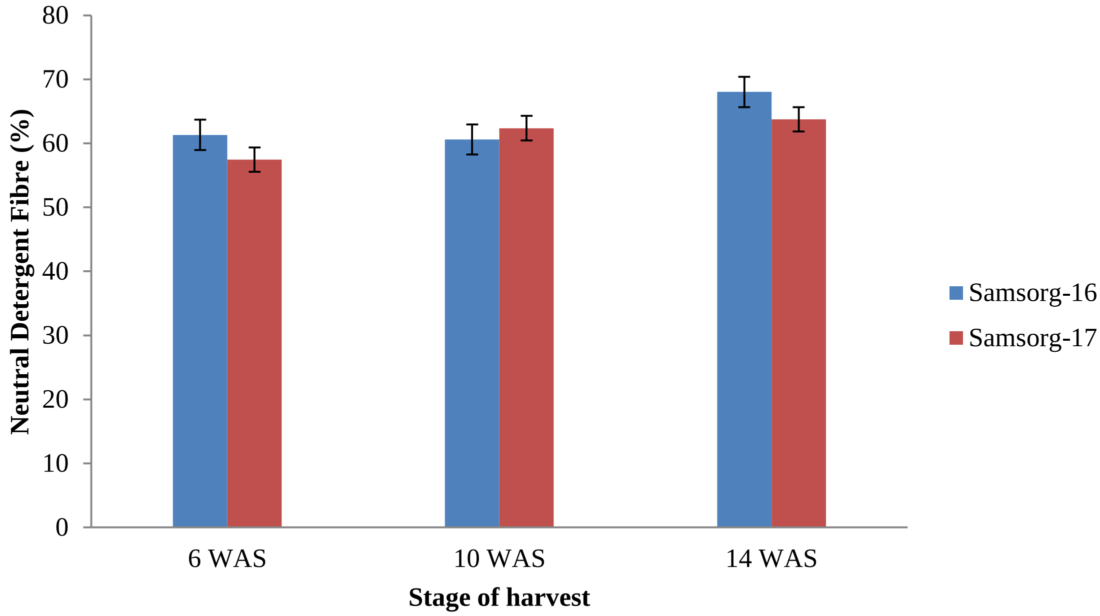

Figure 13: Interaction between variety and stage of harvest on mean neutral detergent fibre (%) of grain sorghum forage

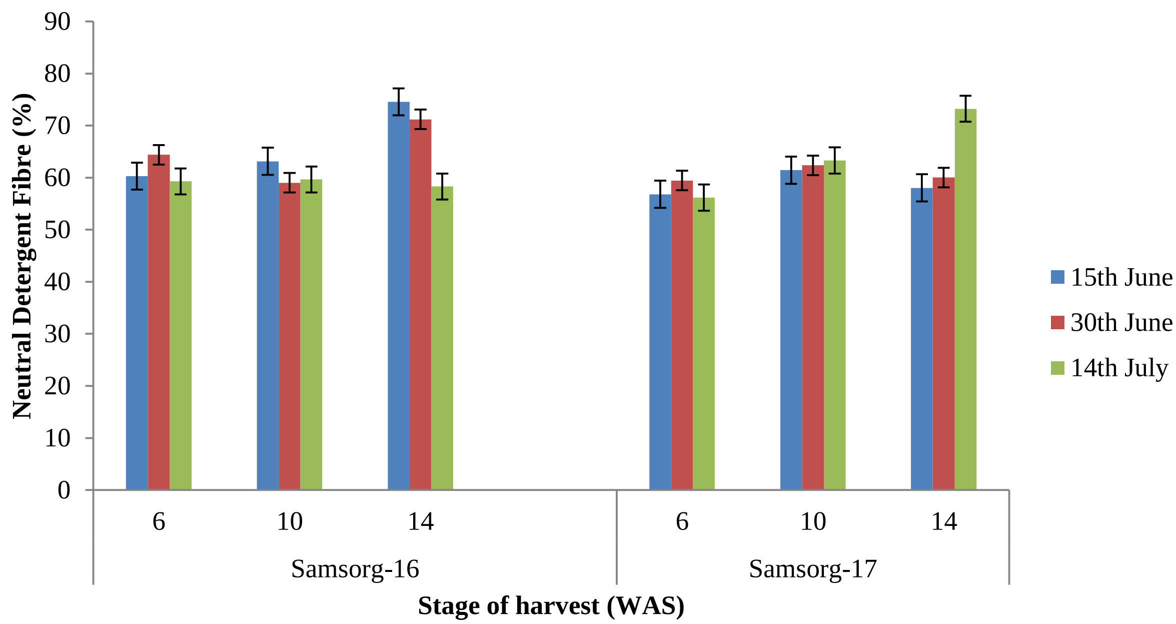

Figure 14: Interaction between variety, sowing date and stage of harvest on mean neutral detergent fibre (%) of grain sorghum forage

4.8 Calcium and Phosphorus Concentration of Grain Sorghum Forage as Influenced by Variety, Sowing Date and Stage of Harvest in 2018 and 2019 Growing Seasons

The calcium (Ca) and phosphorus (P) concentration of grain sorghum forage as influenced by variety, sowing date and stage of harvest in 2018 and 2019 growing seasons (Table 4.8) revealed that there was significant (P<0.05) effect of variety on the Ca and P contents of grain sorghum forage in 2019 growing season and the overall mean and 2018 growing season, respectively. Higher (P<0.05) Ca and P contents were obtained for SAMSORG-17 variety of grain sorghum forage while lower values were recorded for SAMSORG-16 variety. Non-significant (P>0.05) effect of variety on Ca and P contents was observed in both 2018 and 2019 growing seasons and the overall mean.

Sowing date had significant (P<0.05) effect on Ca and P contents in 2019 growing season and the overall mean and 2018 and 2019 growing seasons and the overall mean, respectively. Higher (P<0.05) Ca concentration was obtained for grain sorghum forage sown on 14th July while lower Ca was recorded for grain sorghum sown on 30th June in 2019 growing season and the mean. Phosphorus (P) concentration was higher (P<0.05) for grain sorghum forage sown on 14th July while lower values were observed for grain sorghum forage sown on 15th June which was similar with grains sorghum forage sown on 30th June in 2018 growing season and the overall mean. Where as in 2019 growing season, higher (P<0.05) P concentration was recorded for grain sorghum forage sown on 15th June which was at par with grain sorghum forage sown on 30th June while lower P was obtained for grain sorghum forage harvested on 14th July.

There was significant (P<0.05) effect of stage of harvest on Ca and P concentration in 2018 and 2019 growing seasons and the overall mean. Higher (P<0.05) Ca concentration was obtained for grain sorghum forage harvested at 10 WAS, followed by grain sorghum forage harvested at 14

WAS while lower Ca concentration was recorded for grain sorghum forage harvested at 6 WAS. Phosphorus (P) was significantly (P<0.05) higher for grain sorghum forage harvested at 6 WAS while lower P was obtained for grain sorghum forage harvested at 14 WAS which was at par with grain sorghum forage harvested at 10 WAS in 2018 growing season and the overall mean.

All interactions were significant (P<0.05) except interaction for P concentration between variety by sowing date and stage of harvest for P in 2019 growing season.

4.8.1 Interaction between variety and sowing date on mean calcium concentration (%) of grain sorghum forage

The interaction between variety and sowing date on mean calcium (Ca) concentration of grain sorghum forage is given in Figure 16. Significantly (P<0.05) higher Ca content was obtained for SAMSORG-17 grain sorghum sown on 14th July, followed by SAMSORG-17 grain sorghum sown on 15th June while lower Ca content was recorded for SAMSORG-16 grain sorghum sown 14th July which was at par with SAMSORG-17 grain sorghum sown on 30th June.

4.8.2 Interaction between sowing date and stage of harvest on mean calcium concentration (%) of grain sorghum forage

The interaction between sowing date and stage of harvest on mean calcium (Ca) concentration of grain sorghum forage is shown in Figure 17. Higher (P<0.05) Ca content was obtained for grain sorghum sown on 14th July harvested at 10 WAS, which was followed by grain sorghum sown on 15th June harvested at 10 WAS which was similar with grain sorghum sown on 30th June harvested at 10 WAS. These were followed by grain sorghum sown on 15th June harvested at 14 WAS which was at par with grain sorghum sown on 14th July harvested at 14 WAS. Lower (P<0.05) Ca content was recorded for grain sorghum sown on 30th June harvested at 6 WAS which was similar with grain sorghum sown on 15th June harvested at 6 WAS.

Table 4.8: Calcium and phosphorus concentration of grain sorghum forage as influenced by variety, sowing date and stage of harvest in 2018 and 2019 growing seasons

Treatments	*Chemical composition (%)*					
	Calcium (Ca)			Phosphorus (P)		
	2018	2019	Mean	2018	2019	Mean
Variety						
SAMSORG-16	0.07	0.51^{b}	0.29^{b}	0.25^{b}	0.25	0.25
SAMSORG-17	0.06	0.59^{a}	0.33^{a}	0.29^{a}	0.25	0.27
SEM	0.01^{NS}	0.01*	0.01*	0.01*	0.01^{NS}	0.01^{NS}
Sowing date						
15th June	0.08	0.55^{b}	0.31^{ab}	0.24^{b}	0.27^{a}	0.25^{b}
30th June	0.06	0.52^{c}	0.29^{b}	0.25^{b}	0.26^{a}	0.25^{b}
14th July	0.07	0.59^{a}	0.33^{a}	0.34^{a}	0.23^{b}	0.28^{a}
SEM	0.01^{NS}	0.01*	0.01*	0.01*	0.01*	0.01*
Stage of harvest (WAS)						
6	0.05^{b}	0.43^{c}	0.26^{c}	0.36^{a}	0.30^{a}	0.33^{a}
10	0.08^{ab}	0.66^{a}	0.36^{a}	0.24^{b}	0.25^{b}	0.24^{b}
14	0.07^{a}	0.57^{b}	0.31^{b}	0.23^{b}	0.21^{c}	0.22^{b}
SEM	0.01*	0.01*	0.01*	0.01*	0.01*	0.01*
Interactions						
V x S	<0.001	<0.001	<0.001	0.016	<0.001	0.001
S x W	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
V x W	0.004	<0.001	<0.001	<0.001	<0.001	<0.001
V x S x W	0.001	<0.001	<0.001	<0.001	0.093	<0.001

[abc]Means with different superscripts within columns differed significantly (P<0.05), SEM = Standard error of mean, WAS = Weeks after sowing, V = Variety, S = Sowing date, W = Stage of harvest

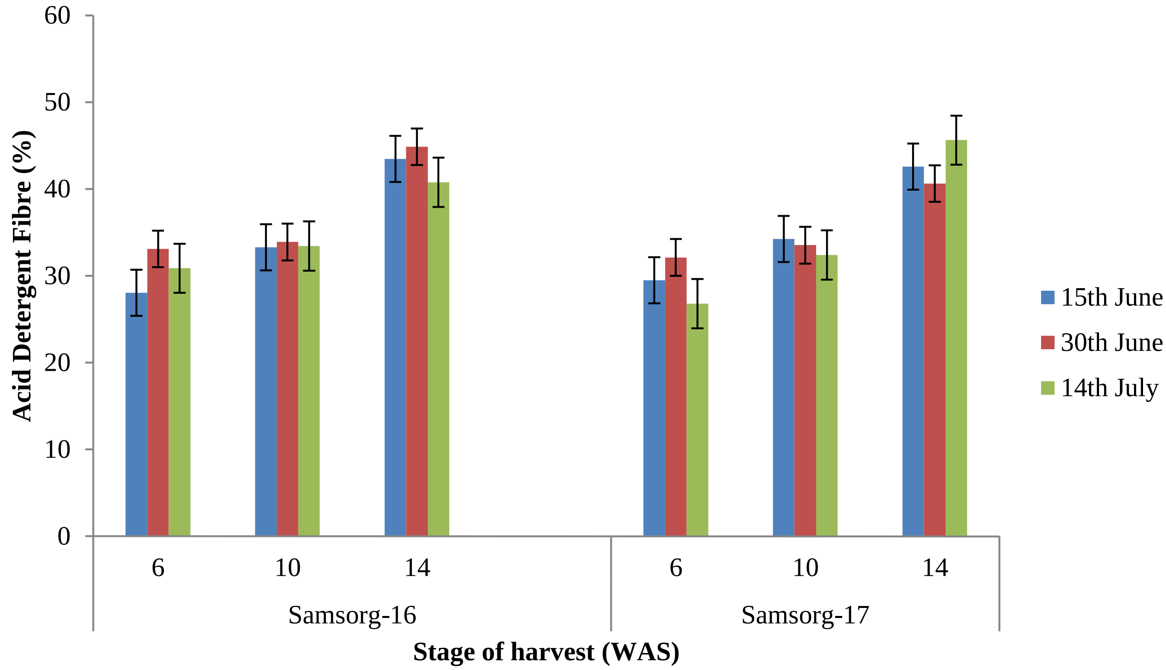

Figure 15: Interaction between variety, sowing date and stage of harvest on mean acid detergent fibre (%) of grain sorghum forage

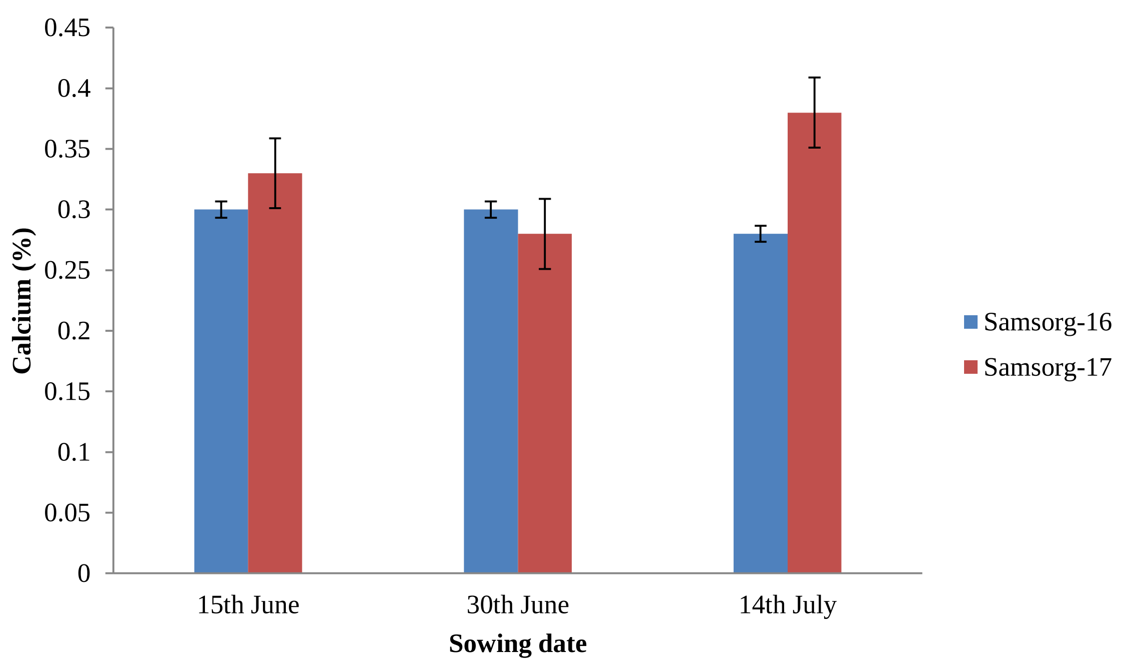

Figure 16: Interaction between variety and sowing date on mean calcium concentration (%) of grain sorghum forage

4.8.3 Interaction between variety and stage of harvest on mean calcium concentration (%) of grain sorghum forage

The interaction between variety and stage of harvest on mean calcium (Ca) concentration of grain sorghum revealed that significantly (P<0.05) higher Ca content was obtained for SAMSORG-17 grain sorghum harvested at 10 WAS, followed by SAMSORG-17 grain sorghum harvested at 14 WAS (Figure 18). This was followed by SAMSORG-16 grain sorghum harvested at 10 WAS. While lower (P<0.05) Ca content was recorded for SAMSORG-17 grain sorghum harvested at 6 WAS.

4.8.4 Interaction between variety, sowing date and stage of harvest on mean calcium concentration (%) of grain sorghum forage

The interaction between variety, sowing date and stage of harvest on mean calcium (Ca) concentration of grain sorghum forage is given in Figure 19. Higher (P<0.05) Ca content was recorded for SAMSORG-17 grain sorghum sown on 14th July harvested at 10 WAS, followed by SAMSORG-17 grain sorghum sown on 14th July harvested at 14 WAS. This was followed by SAMSORG-17 grain sorghum sown on 15th June harvested at 14 WAS. Lower (P<0.05) Ca content was obtained for SAMSORG-16 grains sorghum sown on 14th July harvested at 14 WAS which was at par with SAMSORG-17 grain sorghum sown on 15th and 30th June harvested at 6 WAS, respectively.

4.8.5 Interaction between variety and sowing date on mean phosphorus concentration (%) of grain sorghum forage

The interaction between variety and sowing date on mean phosphorus (P) concentration of grain sorghum forage is presented in Figure 20. Higher (P<0.05) P content was obtained for SAMSORG-17 grain sorghum sown on 14th July which was similar with SAMSORG-16 grain sorghum sown on 14th July. This was followed by SAMSORG-17 grain sorghum sown on 30th

June which was at par with SAMSORG-16 grain sorghum sown on 14th July. Lower (P<0.05) P content was recorded for SAMSORG-16 grain sorghum sown on 30th June which was similar with SAMSORG-16 grain sorghum sown on 15th June.

4.8.6 Interaction between sowing date and stage of harvest on mean phosphorus concentration (%) of grain sorghum forage

The interaction between sowing date and stage of harvest on mean phosphorus (P) concentration of grain sorghum forage is shown in Figure 21. Higher (P<0.05) P content was obtained for grain sorghum sown on 14th July harvested at 6 WAS, which was followed by grain sorghum sown on 15th June harvested at 6 WAS. These were then followed by grain sorghum sown on 30th June harvested at 6 WAS which was followed by grain sorghum sown on 30th June harvested at 10 WAS. Lower (P<0.05) P content was recorded for grain sorghums sown on 15th June harvested at 10 WAS and 30th June and 14thJuly harvested at 14 WAS, respectively which were similar with grain sorghum sown on 15th June harvested at 14 WAS.

4.8.7 Interaction between variety and stage of harvest on mean phosphorus concentration (%) of grain sorghum forage

The interaction between variety and stage of harvest on mean phosphorus (P) concentration of grain sorghum forage (Figure 22**)** indicated that significantly (P<0.05) higher P content was recorded for SAMSORG-17 grain sorghum harvested at 6 WAS. This was followed by SAMSORG-16 grain sorghum harvested at 6 WAS which was followed by SAMSORG-17 grain sorghum harvested at 10 WAS which was similar with SAMSORG-16 grain sorghum harvested at 14 WAS. Lower (P<0.05) P content was obtained for SAMSORG-17 grain sorghum harvested at 14 WAS.

4.8.8 Interaction between variety, sowing date and stage of harvest on mean phosphorus concentration (%) of grain sorghum forage

The interaction between variety, sowing date and stage of harvest on mean phosphorus (P) concentration of grain sorghum forage is shown in Figure 23. Significantly (P<0.05) higher P content was obtained for SAMSORG-17 grain sorghum forage sown on 14th July harvested at 6 WAS, which was followed by SAMSORG-16 grain sorghum sown on 14th July and SAMSORG-17 grain sorghum sown on 15th June harvested at 6 WAS, respectively which were at par with SAMSORG-17 grain sorghum sown on 30th June harvested at 6 WAS. Lower (P<0.05) P content was recorded for SAMSORG-17 grain sorghum sown on 14th July harvested at 14 WAS.

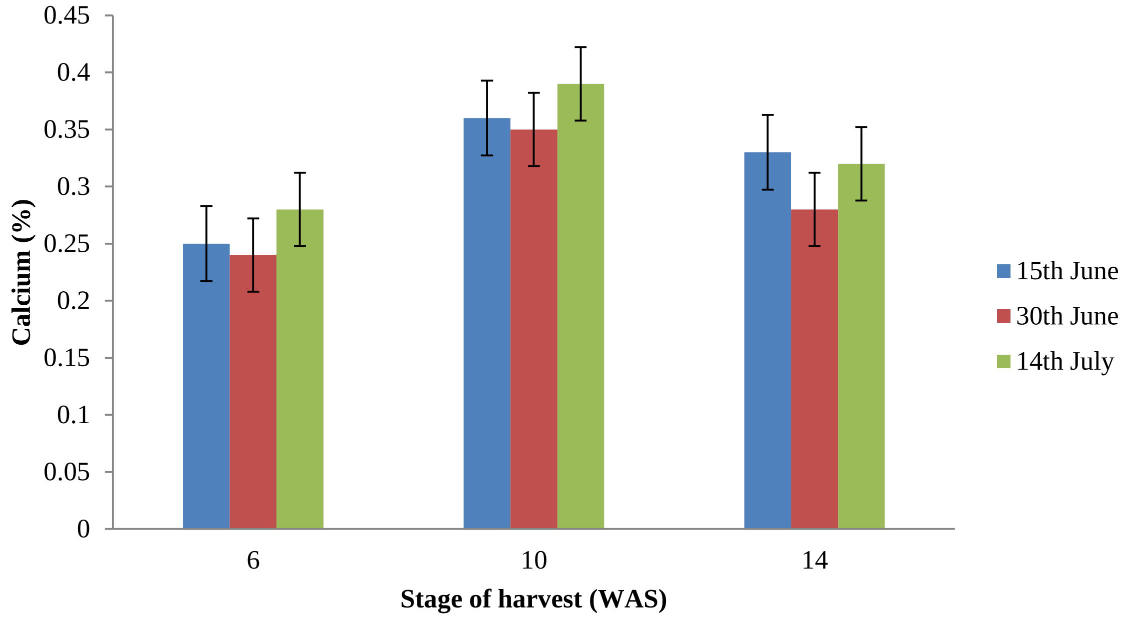

Figure 17: Interaction between sowing date and stage of harvest on mean calcium concentration (%) of grain sorghum forage

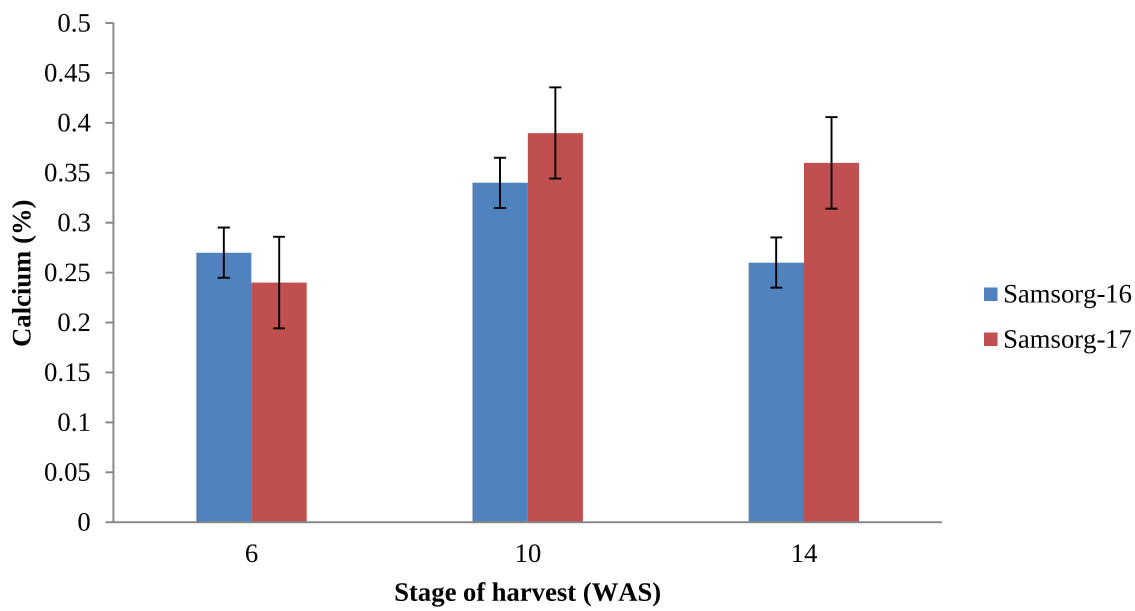

Figure 18: Interaction between variety and stage of harvest on mean calcium concentration (%) of grain sorghum forage

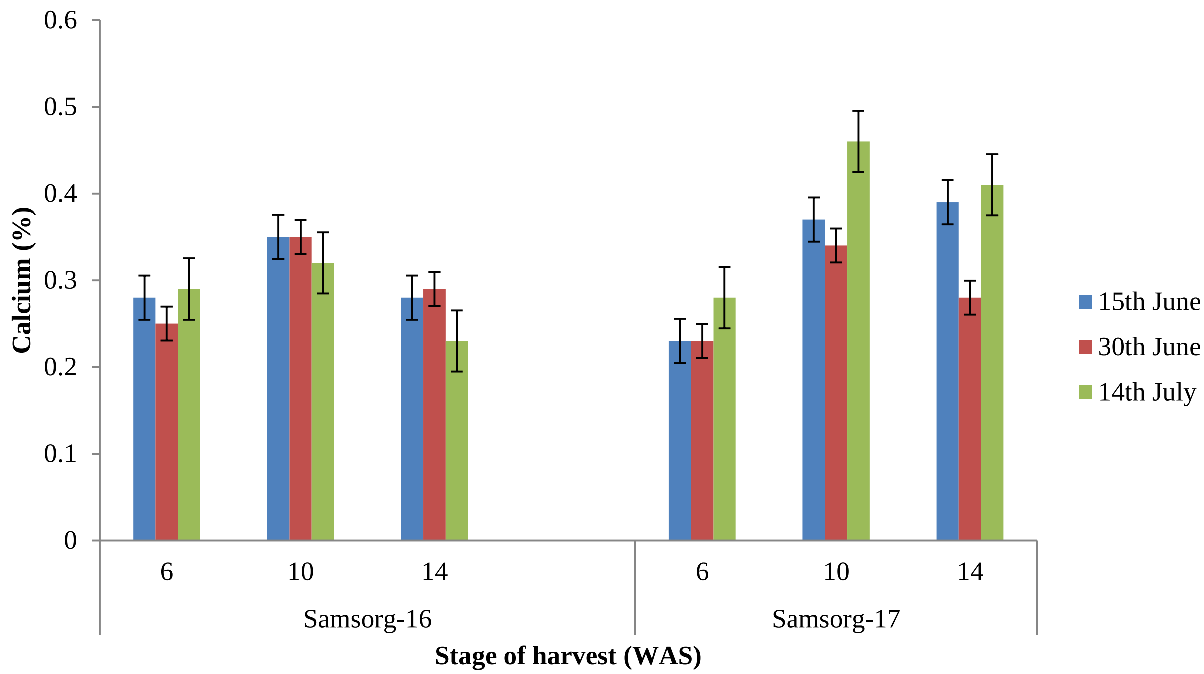

Figure 19: Interaction between variety, sowing date and stage of harvest on mean calcium concentration (%) of grain sorghum forage

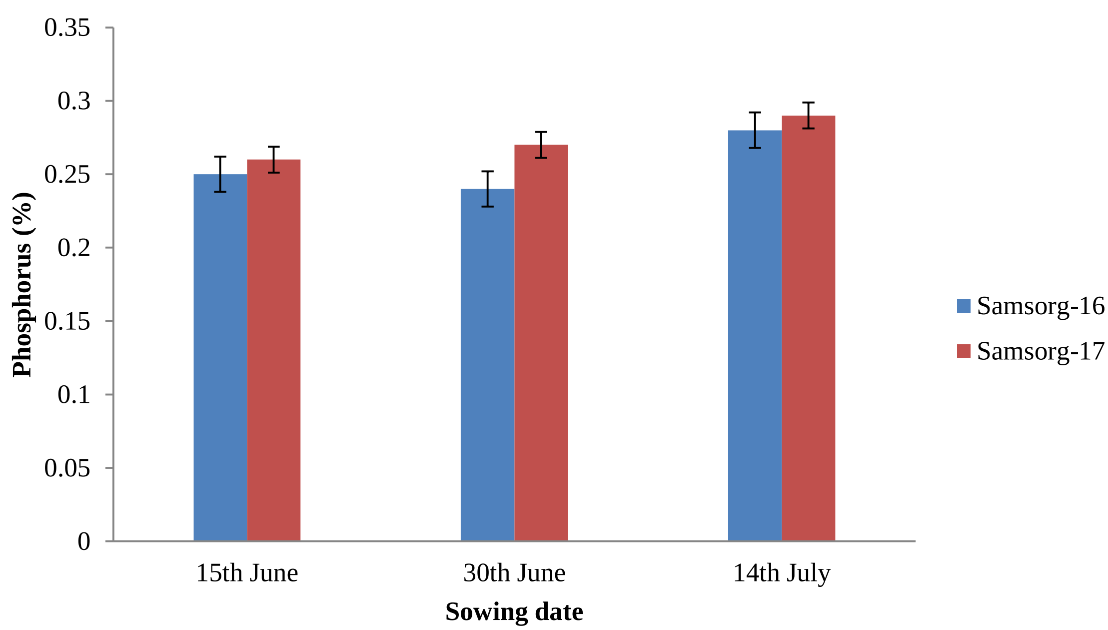

Figure 20: Interaction between variety and sowing date on mean phosphorus concentration (%) of grain sorghum forage

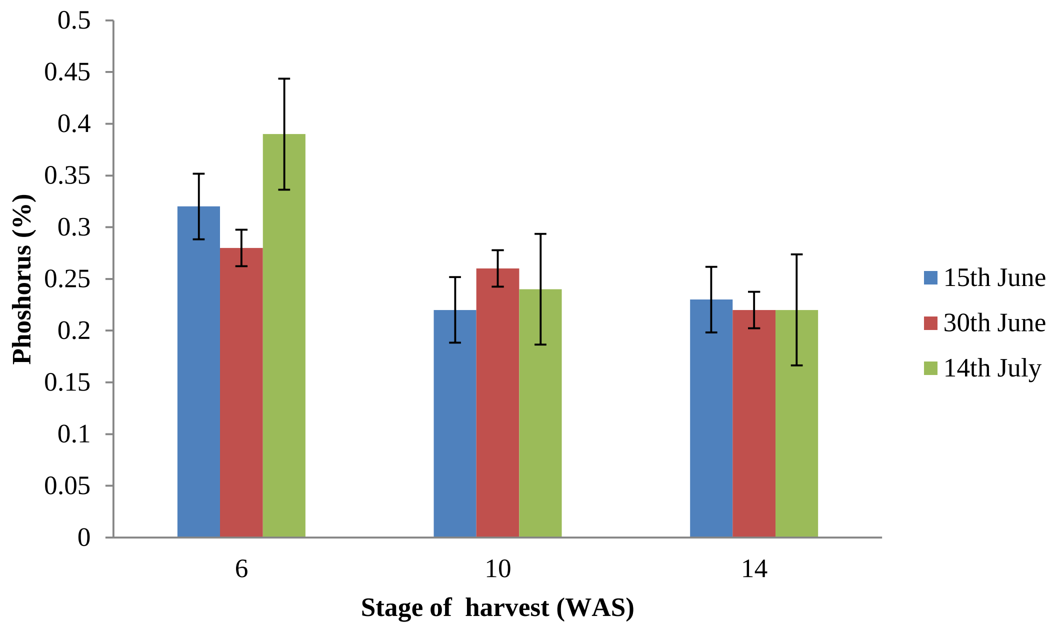

Figure 21: Interaction between sowing date and stage of harvest on mean phosphorus concentration (%) of grain sorghum forage

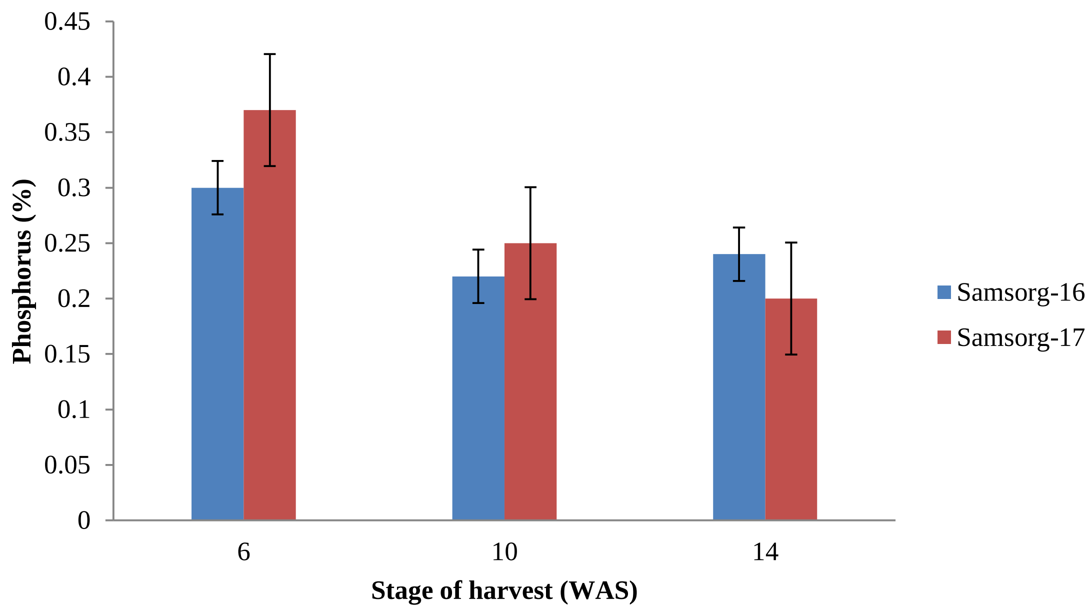

Figure 22: Interaction between variety and stage of harvest on mean phosphorus concentration (%) of grain sorghum forage

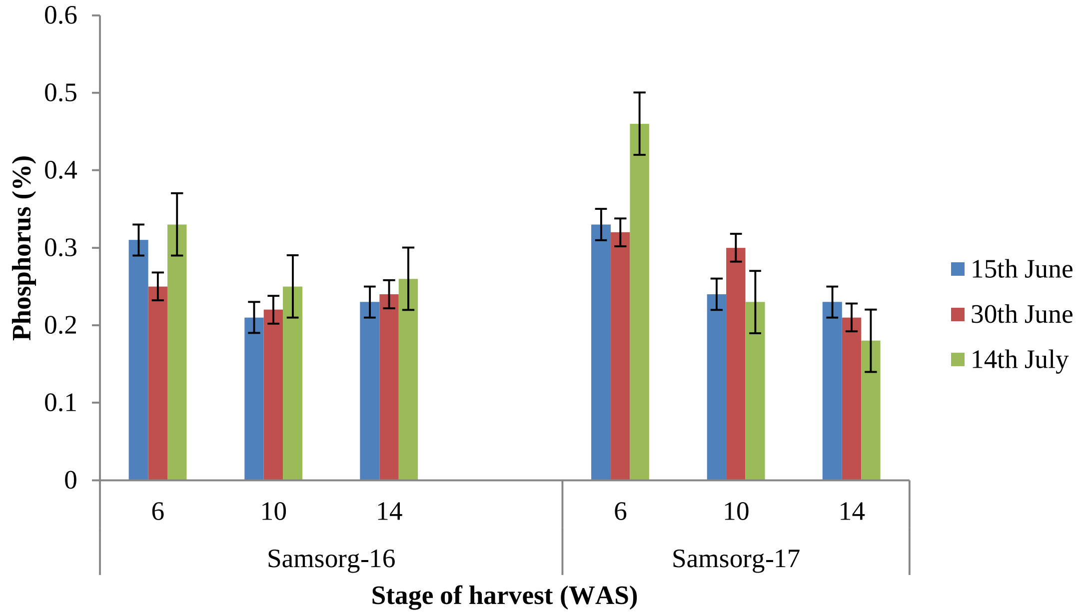

Figure 23: Interaction between variety, sowing date and stage of harvest on mean phosphorus concentration (%) of grain sorghum forage

Experiment II: Effect of Feeding Regime on Performance of Growing Yankasa Rams Fed Basal Diet of Sorghum Hay or Silage Supplemented with Concentrate

4.9 Chemical Composition of Experimental Diets Fed to Growing Yankasa Rams

The chemical composition of diets fed to growing Yankasa rams is presented in Table 4.9. The dry matter content of the diets ranged from 75.36% for grain sorghum silage to 97.31% for concentrate daily. The crude protein content of the diets ranged from 10.42% for grain sorghum silage to 14.77% for concentrate and neutral detergent fibre (NDF) and acid detergent fibre (ADF) ranged from 14.66 to 70.03% and 2.64% to 40.32%, respectively.

4.10 Effect of Feeding Regime on Growth of Yankasa Rams Fed a Basal Diet of Grain Sorghum Hay or Silage Supplemented with Concentrate

The effect of feeding regime on growth of Yankasa rams fed a basal diet of grain sorghum hay or silage supplemented with concentrate is presented in Table 4.10. There was significant ($P<0.05$) effect of feeding regime of concentrate supplementation on hay intake, concentrate intake, total feed intake, daily intake, weight gain, daily weight gain and feed conversion ratio, respectively. Higher ($P<0.05$) silage intake was obtained for rams fed silage + concentrate supplemented after 2-days which was similar with rams fed silage + concentrate supplemented daily and silage + concentrate supplemented after every other day. A different trend was observed for concentrate intake, total feed intake and daily feed intake in which significantly ($P<0.05$) higher concentrate intake, total feed intake and daily feed intake were recorded for rams fed silage + concentrate supplement daily, followed by rams fed hay + concentrate supplement daily, followed by that of rams fed silage + concentrate supplement after every other day while lower concentrate intake, total feed intake and daily feed intake were obtained for rams fed silage + concentrate supplement after 2-days.

Table 4.9: Chemical composition of experimental diets fed to growing Yankasa rams

Parameters (%)	Concentrate	Hay	Silage
Dry matter	97.31	94.41	75.36
Crude protein	14.77	11.35	10.42
NDF	14.66	70.03	54.01
ADF	2.64	39.90	40.32

NDF = Neutral detergent fibre, ADF = Acid detergent fibre

There was non significant (P>0.05) effect of feeding regime on initial weight and final weight. However, weight gain and daily weight gain were significantly (P<0.05) higher for rams fed grain sorghum silage + concentrate supplement daily, followed by rams fed silage + concentrate supplement after every other day which was similar to that of rams fed silage + concentrate supplement after 2-days, while lower weight gain and daily weight gain were recorded for rams fed grain sorghum hay + concentrate supplement daily. The best feed conversion ratio (FCR) was obtained for rams fed sorghum silage + concentrate supplement after 2-days which was at par with rams fed silage + concentrate supplement after every other day, followed by that of rams fed silage + concentrate supplement daily while poor FCR was observed for rams fed sorghum hay + concentrate supplement daily.

4.11 Apparent Nutrient Digestibility by Growing Yankasa Rams Fed a Basal Diet of Grain Sorghum Hay or Silage Supplemented with Concentrate as Influenced by Feeding Regime

There was significant (P<0.05) effect of feeding regime on the apparent nutrient digestibility by growing Yankasa rams fed a basal diet of grain sorghum hay and silage (Table 4.11). Higher (P<0.05) dry matter and crude protein digestibility coefficients were observed for rams fed silage + concentrate after every other day, followed by rams fed silage + concentrate daily which was similar with rams fed silage + concentrate after 2-days while lower digestibility value was recorded in rams fed hay + concentrate daily. Neutral detergent fibre (NDF) was higher (P<0.05) in rams fed silage + concentrate after every other day which was similar to rams fed silage + concentrate daily and hay + concentrate daily. Higher (P<0.05) ADF was obtained in rams fed silage + concentrate daily which was at par with rams fed silage + concentrate after every other day, followed by rams fed hay + concentrate daily while lower ADF digestibility value was observed in rams fed silage + concentrate after 2-days.

Table 4.10: Effect of feeding regime on growth of Yankasa rams fed a basal diet of grain sorghum hay or silage supplemented with concentrate

Parameters	*Feeding Regime*				SEM
	Hay + Conc daily	Silage + Conc daily	Silage + Conc Skip-a-day	Silage + Conc Skip-2-days	
Hay/Silage Intake (kg)	25.28^{b}	29.06^{a}	28.71^{a}	29.23^{a}	0.67*
Concentrate Intake (kg)	17.87^{b}	19.41^{a}	10.67^{c}	6.19^{d}	0.39*
Total Feed Intake (kg)	43.15^{b}	48.47^{a}	39.38^{c}	35.41^{d}	1.04*
Daily Feed Intake(kg)	0.65^{b}	0.73^{a}	0.60^{c}	0.54^{d}	0.02*
Initial Weight (kg)	18.75	18.75	18.75	18.88	0.43^{NS}
Final Weight (kg)	21.60	22.10	21.88	21.95	0.40^{NS}
Weight Gain (kg)	2.85^{c}	3.35^{a}	3.13^{b}	3.08^{b}	0.08*
Daily Weight Gain (g/day)	43.18^{c}	50.76^{a}	47.35^{b}	46.59^{b}	1.27*
FCR	15.40^{b}	14.54^{b}	12.76^{a}	11.65^{a}	0.57*

^{abcd}Means with different superscript within rows differed significantly (P<0.05), SEM = Standard error of mean, NS = Non- significant, FCR = Feed conversion ratio

Table 4.11: Apparent nutrient digestibility by growing Yankasa rams fed a basal diet of grain sorghum hay or silage supplemented with concentrate as influenced by feeding regime

Parameters (%)	*Feeding Regime*				SEM
	Hay + Conc daily	Silage + Conc daily	Silage + Conc Skip-a-day	Silage + Conc Skip-2-days	
Dry matter	72.39[c]	74.75[b]	79.22[a]	74.21[b]	0.87*
Crude protein	79.38[c]	81.86[b]	85.59[a]	81.75[b]	0.63*
NDF	72.83[a]	75.28[a]	75.30[a]	67.86[b]	1.24*
ADF	73.54[b]	79.19[a]	78.02[a]	69.47[c]	0.78*

[abc]Means with different superscript within rows differed significantly (P<0.05), SEM = Standard error of mean, NS = Non- significant

4.12 Effect of Feeding Regime on Nitrogen Retention in Growing Yankasa Rams Fed a Basal Diet of Grain Sorghum Hay or Silage Supplemented with Concentrate

The effect of feeding regime on nitrogen retention in growing Yankasa rams fed a basal diet of grain sorghum hay or silage supplemented with concentrate is shown in Table 4.12. There was significant (P<0.05) effect of the treatment on nitrogen retention indices of growing Yankasa rams in which higher nitrogen intake was obtained in rams fed silage + concentrate daily, followed by rams fed silage + concentrate after every other day while lower nitrogen intake was recorded in rams fed hay + concentrate daily. Higher (P<0.05) faecal nitrogen loss was observed in rams fed silage + concentrate daily, followed by rams fed silage + concentrate after 2-days which was at par with rams fed silage + concentrate after every other day while lower faecal nitrogen loss was recorded in rams fed hay + concentrate daily. Urinary nitrogen loss was however higher (P<0.05) in rams fed hay + concentrate daily which was similar to rams fed silage + concentrate daily and silage + concentrate after 2-days while lower urinary nitrogen loss was obtained in rams fed silage + concentrate after every other day which was at par with rams fed silage + concentrate after 2-days. Higher (P<0.05) total nitrogen loss was recorded in rams fed silage + concentrate daily while lower total nitrogen loss was obtained in rams fed silage + concentrate after every other day which was similar to rams fed hay + concentrate daily and silage + concentrate after 2-days. It was obtained that higher (P<0.05) nitrogen absorbed and nitrogen retained were obtained in rams fed silage + concentrate daily which was at par with rams fed silage + concentrate after every other day, followed by rams fed silage + concentrate after 2-days while lower nitrogen absorbed and nitrogen retained were observed in rams fed hay + concentrate daily. Higher (P<0.05) nitrogen absorbed as percent intake and nitrogen retained as percent intake were recorded in rams fed silage + concentrate after every other day, followed by rams fed silage + concentrate daily which were similar with rams fed silage + concentrate after

2-days while lower nitrogen absorbed as percent intake and nitrogen retained as percent intake were obtained in rams fed hay + concentrate daily.

4.13 Effect of Feeding Regime and Sampling Time on Rumen Metabolites of Growing Yankasa Rams Fed a Basal Diet of Grain Sorghum Hay or Silage Supplemented with Concentrate

Results of effects of feeding regime and sampling time on rumen metabolites of growing Yankasa rams fed a basal diet of grain sorghum hay or silage supplemented with concentrate are presented in Table 4.13.There was significant ($P<0.05$) effect of feeding regime on ruminal pH, temperature, total volatile fatty acids (TVFAs) and ammonia-nitrogen (NH_3-N). Higher ($P<0.05$) pH was recorded in rams fed silage + concentrate supplement after 2-days, followed by rams fed silage + concentrate supplement daily, while lower pH was recorded in rams fed hay + concentrate supplement daily which was similar to that of rams fed silage + concentrate supplement after every other day. Significantly ($P<0.05$) higher temperature was recorded in rams fed silage + concentrate supplement after 2-days which was at par with rams fed silage + concentrate supplement after every other day while lower temperature was recorded in rams fed hay + concentrate supplement daily which was similar to rams fed silage + concentrate supplement daily. Higher ($P<0.05$) TVFAs was recorded in rams fed silage + concentrate supplement after every other day which was at par with rams fed hay + concentrate supplement daily and rams fed silage + concentrate supplement after-2-days. Lower TVFAs was obtained in rams fed silage + concentrate supplement daily. Significantly ($P<0.05$) higher NH_3-N was observed in rams fed silage + concentrate supplement after 2-days which was similar with rams fed silage + concentrate supplement after every other day and rams fed hay + concentrate supplement daily; while lower rumen NH_3-N was obtained in rams fed silage + concentrate supplement daily.

Table 4.12: Effect of feeding regime on nitrogen retention in growing Yankasa rams fed a basal diet of grain sorghum hay or silage supplemented with concentrate

Parameters (g/day)	*Feeding Regime*				SEM
	Hay + Conc daily	Silage + Conc daily	Silage + Conc Skip-a-day	Silage + Conc Skip-2-days	
N Intake	13.38^{d}	21.62^{a}	20.65^{b}	18.17^{c}	0.41*
Faecal N Loss	2.71^{c}	3.76^{a}	2.96^{b}	3.20^{b}	0.12*
Urinary N Loss	0.95^{a}	0.92^{a}	0.56^{b}	0.72^{ab}	0.12*
Total N Loss	3.65^{b}	4.67^{a}	3.52^{b}	3.92^{b}	0.22*
N Absorbed	10.67^{c}	17.86^{a}	17.69^{a}	14.97^{b}	0.38*
N Retained	9.73^{c}	17.13^{a}	16.95^{a}	14.25^{b}	0.44*
N Absorbed as % intake	79.41^{c}	82.71^{b}	85.62^{a}	82.41^{b}	0.66*
N Retained as % intake	72.16^{c}	78.56^{b}	82.72^{a}	78.44^{b}	1.22*

^{abcd}Means with different superscript within rows differed significantly (P<0.05), SEM = Standard error of mean, N = Nitrogen

Similarly, there was significant ($P<0.05$) effect of sampling time on pH, temperature, total VFAs and NH_3-N (Table 4.13). The pH and NH_3-N decreased as sampling time was delayed from 0 to 8 hours in which higher ($P<0.05$) pH and NH_3-N were recorded at 0 hour before feeding which was at par with 4 hours post-feeding, while lower pH and NH_3-N were obtained at 8 hours post feeding. Higher ($P<0.05$) temperature was obtained at 4 hours post-feeding while lower temperature was recorded at 0 hour before feeding, which was similar to 8 hours post feeding. There was increase in TFVAs as sampling time was delayed from 0 to 8 hours. Higher ($P<0.05$) TVFAs was obtained at 8 hours post-feeding, while lower TVFAs was recorded at 0 hour before feeding which was at par with 4 hours post-feeding. There was non-significant ($P>0.05$) interaction effect on pH, temperature, TVFAs and NH_3-H.

4.14 Costs-Benefit Analysis of Growing Yankasa Rams Fed a Basal Diet of Grain Sorghum Hay and Silage Supplemented with Concentrate at Different Feeding Regimes

The costs-benefit analysis of growing Yankasa rams fed a basal diet of grain sorghum hay or silage supplemented with concentrate at different feeding regimes is presented in Table 4.14. Feeding regime varied on total concentrate intake, total hay/silage intake, total hay/silage cost, total concentrate cost, total feed cost, live weight gain and cost/ kg gain. Higher total concentrate cost (₦1813.20) was recorded for rams fed silage + concentrate daily, followed by rams fed hay + concentrate daily, which was then followed by rams fed silage + concentrate after every other day while lower total concentrate cost (₦577.90) was obtained for rams fed silage + concentrate after 2-days. Different trend was observed for total hay/silage cost; in which higher total hay/silage cost (₦2922.70) was obtained for rams fed silage + concentrate after 2-days, followed by rams fed silage + concentrate daily and followed by rams fed silage + concentrate after every other day while lower ($P<0.05$) total hay cost (₦1263.90) was recorded for rams fed hay +

concentrate daily. Higher total feed cost (₦4718.70) and cost per kg gain (₦1415.30) were obtained for rams fed silage + concentrate daily, followed by rams fed silage + concentrate after every other day, which was then followed by rams fed silage + concentrate after 2-days while lower total feed cost (₦2933.20) and cost per kg gain (₦1046.40) were recorded for rams fed hay + concentrate daily.

Table 4.13: Effect of feeding regime and sampling time on rumen metabolites of growing Yankasa rams fed a basal diet of grain sorghum hay or silage supplemented with concentrate

Treatment	pH	Temp (°C)	TVFA (mmol)	NH_3-N(mg/dl)
Feeding Regime				
Hay + Conc daily	5.48^{c}	31.44^{b}	26.67^{a}	9.84^{a}
Silage + Conc daily	5.89^{b}	31.91^{b}	23.33^{b}	8.81^{b}
Silage + Conc Skip-a-day	5.58^{c}	33.53^{a}	26.89^{a}	10.17^{a}
Silage + Conc Skip-2-days	6.20^{a}	34.59^{a}	25.78^{ab}	10.52^{a}
SEM	0.10*	0.71*	1.34*	0.47*
Sampling Time (Hours)				
0	5.93^{a}	31.22^{b}	22.83^{b}	10.74^{a}
4	5.86^{ab}	35.53^{a}	23.17^{b}	10.34^{a}
8	5.58^{b}	31.85^{b}	31.00^{a}	8.43^{b}
SEM	0.13*	0.94*	1.78*	0.63*
Interaction				
F x S	0.936	0.219	0.908	0.517

[ab]Means with different superscript within column differed significantly ($P<0.05$), SEM = Standard error of mean, F = Feeding regime, S = Sampling time, TVFA = Total volatile fatty acid, NH_3 = Ammonia

Table 4.14: Costs-benefit analysis of growing Yankasa rams fed a basal diet of grain sorghum hay or silage supplemented with concentrate at different feeding regimes

Parameters	Hay + Conc daily	Silage + Conc daily	Silage + Conc Skip-a-day	Silage + Conc Skip-2-days
Cost of Conc. (₦/kg)	93.40	93.40	93.40	93.40
Total Conc. Intake (kg)	17.87	19.41	10.67	6.19
Cost of Hay/Silage (₦/kg)	50.00	100.00	100.00	100.00
Total Hay/Silage Intake (kg)	25.28	29.06	28.71	29.23
Total Hay/Silage Cost/ram (₦)	1263.90	2905.50	2870.80	2922.70
Total Conc. Cost/ram (₦)	1669.30	1813.20	996.80	577.90
Total Feed Cost/ram (₦)	2933.20	4718.70	3867.60	3500.60
Live Weight Gain (kg)	2.85	3.35	3.13	3.08
Cost/ kg gain (₦)	1046.40	1415.30	1253.00	1151.50

Cost of concentrate = a; Total concentrate intake = b; Cost of Hay = c; Total Hay intake = d; Total feed cost/ram = [(a * b) + (c * d)]; Cost/ kg gain = Total Feed Cost / Weight gain

CHAPTER FIVE

5.0 DISCUSSION

5.1 Varietal Response

5.1.1 Growth components and forage yield of sorghum

The taller plant height obtained for SAMSORG-16 grain sorghum variety was responsible for the higher dry forage yield which could be attributed to the tall nature of the variety and the varietal difference when compared with SAMSORG-17. Whereas the non-significant effect of variety on LAI could be as a result of the variation in the leaf length, leaf width and the number of leaves. The long leaf length observed in SAMSORG-16 was complemented with the leaf width of SAMSORG-17 variety thereby equalizing the LAI. The values of plant height, number of leaves, LAI and dry forage yield were higher than the values reported by Munza (2017) and Adewumi (2019) but within the range of 4.40 to 19.13 t/ha for different sorghum cultivars reported by Singh *et al.* (2014). Dry forage yields of SAMSORG-16 and SAMSORG-17 sorghum obtained implies that both varieties can be used as forage by both crop and livestock owners.

5.1.2 Chemical composition of sorghum forage

Dry matter, crude protein, ADF and P contents for both SAMSORG-16 and SAMSORG-17 forages were similar. Higher NDF recorded for SAMSORG-16 might be as a result of increase formation and thickening of the cell wall which is more prominent in SAMSORG-16. This contradicts the findings of Zakka (2019) who reported significant variation in dry matter and crude protein contents of bush head sorghum and sweet sorghum. SAMSORG-17 variety can be said to be more digestible since it has a lower NDF content as compared to the SAMSORG-16 sorghum variety. This agrees with the report of Tainton (1999) who stated that forages with low NDF content are usually high quality forages and have high level of intake and digestion. The values of NDF and ADF obtained in this present study were higher than the values reported by Adewumi (2019) and Zakka (2019) for indigenous sweet sorghum, SAMSORG-17, bush head sorghum and sweet sorghum, respectively. Higher Ca concentration recorded for SAMSORG-17 forage could due to the yellow colour of the grain. The value of Ca obtained in this study is lower than the value reported by Munza (2017) and Zakka (2019) for Samsorg-16, bush head sorghum and sweet sorghum.

5.1.3 Ensiled sorghum forage

The high dry matter, crude protein and Ca recorded for SAMSORG-17 may be attributed to the varietal difference in which the yellow colour of the grain of SAMSORG-17 sorghum could be responsible for the high crude protein. Whereas the high NDF, ADF and P contents obtained for SAMSORG-16 could be due to thickening of the cell well. The DM and ADF recorded in this study were higher than the values reported by Kumari *et al*. (2013) for chopped sweet sorghum silage.

5.2 Sowing Date Response

5.2.1 Growth components and forage yield of sorghum

More number of leaves and wider LAI resulted in the higher dry forage yield recorded for sorghum sown on 15th June. Leaf area index (LAI) is a measure of the size of photosynthetic or assimilatory system of the plant. It is considered to be mainly concerned with accumulation and partitioning of photosynthetic part of the plant. It has an economic role in the final biomass of the crop. It may also be ascribed to better leaf growth possibly due to soil moisture and environmental resources; hence more leaves per plant, wider LAI and then higher yield. This could be related to differences in rainfall received, sunshine variation, management practice e,g weeding and plant genetic capacity. This agrees with Diawara (2012) who reported reduction in yield and yield components with delayed sowing. Sowing date affects not only the time from sowing to flowering but time from flowering to physiological maturity of grain sorghum (**Yu and Tuinstra, 2001**). The total time from sowing to physiological maturity decreased as sowing time was delayed from early May to early June as reported by (**Pauli *et al*., 1964**).

5.2.2 Chemical composition of sorghum forage

Sowing date did not affect dry matter, crude protein and NDF contents of sorghum forage; whereas ADF, Ca and P contents were affected by sowing date. Higher ADF recorded for sorghum forage sown on 15^{th} and 30^{th} June may be as result of the even distribution of the environmental resources (rainfall) which leads formation and thickening of the cell wall. Higher Ca and P contents obtained for sorghum sown on 14^{th} July could be due to rapid absorption of the minerals from the soil resulting from frequent rainfall.

5.2.3 Ensiled sorghum forage

Higher DM, CP, and NDF obtained for sorghums sown on 15^{th} June could be ascribed to enough time for the sorghum to utilize the available resources that was distributed evenly. The DM and CP imply that the silage is of quality to meet the nutrient requirement of growing rams. The temperature obtained is below 37^{o}C, as high temperature could reduce fermentation quality, enhance protein degradation and reduce rapid pH decline necessary for efficient fermentation (Adesogan and Newmann, 2008). The pH obtained in this study is within 4.2 and below reported by Iqbal and Bethune (2015) that must be attained for good quality silage. Mineral elements play special roles in the proper functioning of the rumen microorganisms especially those which digest plant cellulose, utilization of energy, protein and metabolism among other functions

(McDowell, 1996). The P content was lower than (0.4-0.9g/day) required for growing goats (Fjell *et al.*, 1991).

5.3 Stage of Harvest Response

5.3.1 Growth components and forage yield of sorghum

The increase in plant height, number of leaves, LAI and dry forage yield as harvesting age was delayed from 6 to 14 WAS might be due to the increase in physiological activities of the plant. This might be attributed to enough time for utilization of the available resources required for dry matter production. Radiation interception and photosynthesis are of major importance in yield determination due to their role in dry matter production (Diawara, 2012). This agrees with the findings of Ishiaku (2016), Munza *et al*. (2018) and Zakka (2019) who reported increased plant height, number of leaves, LAI and dry forage yield as the stage of harvest advanced for *Sorghum almum*, SAMSORG-16 grain sorghum and bush head and sweet sorghum, respectively in Shika, Nigeria.

5.3.2 Chemical composition of sorghum forage

The decrease in crude protein content with delayed stage of harvest may be attributed to the stage of maturity at harvest. This concurs with the findings of Zakka (2019) and Adewumi (2019) who reported decline in crude protein as stage of harvest was delayed. Crude protein values obtained in this study were higher than the values reported by Munza (2017) and Zakka (2019) but within the range of values reported by Adewumi (2019). Increased NDF and ADF as stage of harvest advanced from 6 to 14 WAS could be as a result of increased formation and thickening of the structural fibre, cell wall and lignification (Hassan *et al.*, 2018 and Adewumi, 2019). These results corroborated with the findings of earlier researchers who reported that structural fibre contents considerably increased with advancing maturity (Carmi *et al.*, 2005; Miron *et al.*, 2006). The acid detergent fibre (ADF) reported in the study agrees with Blezinger (1999) who reported the acid detergent fibre (ADF) of 31 % to 40 % as good to very good quality. Increased Ca content with delayed stage of harvest could be due to the mobilization of nutrient in preparation for grain filling while decreased P content may be attributed to utilization of P during photosynthesis. The value of Ca obtained in this study is lower than the value reported by Munza (2017) and Zakka (2019) for sorghum forages while the value of P was similar.

5.4 Interactive Effect

5.4.1 Growth components and forage yield of sorghum

Higher dry forage yield recorded for SAMSORG-16 sorghum sown on 15th June could be attributed to the positive correlation existing between varieties and Sowing dates. It was revealed by Diawara (2012) that it is not just getting the right variety but the appropriate date of sowing the variety. This agrees with Caravetta *et al*. (1990) who reported that growth components in sorghum were affected by genotype and environmental conditions. It also concurs with Diawara (2012) who reported significant variety and planting date interaction effect in yield and its components, dry forage yield inclusive.

Significant dry forage yield for sorghum sown on 15th June, harvested at 14 WAS may be related to proper utilization of the available environmental resources. The plant height, number of leaves and LAI are functions of variety and growth stage; which also depends on the growing conditions, sowing date inclusive (Diawara, 2012). This is also attributed to the fact that when age at harvest is delayed, dry forage yield increases.

The high dry forage yield obtained for SAMSORG-16 variety, harvested at 14 WAS revealed that it is not just getting the best variety but the right age to harvest. This agrees with Caravetta *et al*. (1990) who reported that growth and yield components in sorghum were affected by genotype and stage of harvest. The result is in line with the report of Zakka (2019) and Adewumi (2019) who observed significant interaction effect between variety and stage of cutting on forage yield.

5.4.2 Ensiled sorghum forage

The high crude protein content recorded for SAMSORG-17 variety, sown on 15th June may be attributed to the varietal difference and the prevailing environmental resources (Diawara, 2012).

5.4.3 Chemical composition of sorghum forage

Significant ($P<0.05$) interaction on NDF, ADF, Ca and P (Figure 34 – 73) observed in this present study may be attributed to the varietal difference, prevailing environmental resources and stage of maturity (Diawara, 2012).

5.5 Chemical Composition of the Experimental Diets Fed to Growing Yankasa Rams

Chemical composition of the experimental diets fed to growing Yankasa rams (Table 4.9) revealed that the dry matter (DM) contents of the concentrate and hay were above 91.00 %. This might be due to dryness of the concentrate and fibrous nature of the hay. The value of DM observed in this study for the silage was higher than the values reported by Adewumi (2019) for indigenous sweet sorghum and SAMSORG-17 silages. The crude protein contents reported in this study were above the requirement for sheep and goats for growth (Wada *et al*., 2016). The neutral detergent fibre (NDF) was below the value suggested by Muia (2000) as critical limit for efficient utilization of roughages. The acid detergent fibre (ADF) reported was below 30.00%

thus indicating that the diets were of very good quality in line with the reported of Blezinger (1999).

5.6 Effect of Feeding Regime on Growth of Yankasa Rams Fed a Basal Diet of Grain Sorghum Hay or Silage Supplemented with Concentrate

Effect of feeding regime on growth of Yankasa rams fed a basal diet of grain sorghum hay or silage supplemented with concentrate is presented in Table 4.10. Diets containing silage were consumed better than the diet containing hay. Consumption of concentrate by rams fed silage + concentrate daily was higher than rams fed hay + concentrate daily, silage + concentrate supplement after every other day and silage + concentrate supplement after 2-days, respectively. Total feed intake by rams fed silage + concentrate daily was higher than rams fed hay + concentrate daily, silage + concentrate supplement after every other day and silage + concentrate supplement after 2-days, respectively. However, the findings disagree with the result obtained by Fadel-Elseed (2004) which stated that intake of dry matter was not influenced by feeding frequency of supplement. The increase in intake by rams fed concentrate supplement daily could be as result of the daily supplementation of the concentrate. Weight gain and average daily gain for rams fed silage + concentrate daily were higher than rams fed silage + concentrate supplement after every other day, silage + concentrate supplement after 2-days and hay + concentrate daily, respectively. It also disagrees with Yashim (2014) who obtained a higher weight gain and the average daily gain for skip-a-day frequency when *Ficus sycomorus* leaf meal was fed to Yankasa sheep in concentrate. Higher weight gained by rams fed silage + concentrate daily may be attributed to the amount of feed consumed by the rams and the better utilization of the feed by the rams. Better performance of the rams fed silage + concentrate supplementation after every other day and after 2-days when compared with rams fed hay + concentrate daily despite their high intake of feed revealed the better feed conversion ratio of the feeds with much retention time of the diet in the gastro intestinal tract (GIT).

5.7 Apparent Nutrient Digestibility by Growing Yankasa Rams Fed a Basal Diet of Grain Sorghum Hay or Silage Supplemented with Concentrate as Influenced by Feeding Regime

Feeding regime significantly (P<0.05) influenced the apparent nutrient digestibility by growing Yankasa rams (Table 4.11). Dry matter digestibility coefficient obtained in this study for rams fed silage + concentrate supplement after every other day **was higher than rams fed silage + concentrate supplement daily, silage + concentrate supplement after 2-days and hay + concentrate daily. Similar trend was observed for crude protein, in which the digestibility coefficient for rams fed silage + concentrate supplement after** every other day **was higher than rams fed silage + concentrate supplement daily, silage + concentrate supplement after 2-days and hay + concentrate daily,** respectively**. The restriction of concentrate supplement may be responsible for the efficient utilization hence better digestibility. Higher digestibility of the nutrients recorded for rams fed silage + concentrate supplement after** every other day **and silage + concentrate supplement daily may be responsible for the higher weight gained by the animals in these treatments. The digestibility coefficients recorded in this study for the rams were higher than the values reported by**

Adewumi (2019) for Red Sokoto goats fed concentrate + indigenous sweet sorghum silage and concentrate + SAMSORG-17 sorghum silage.

5.8 Effect of Feeding Regime on Nitrogen Retention in Growing Yankasa Rams Fed a Basal Diet of Grain Sorghum Hay or Silage Supplemented with Concentrate

Nitrogen retention is the major indicator used to assess the nutritional protein status of ruminant livestock (Abdu *et al.,* 2012; Hassan *et al.,* 2016). All animals were in positive nitrogen balance which indicated that growing Yankasa rams received adequate amounts of nitrogen from the diets fed (Table 4.12). Higher nitrogen absorbed and retained and as percentage of the intake in rams fed both silage + concentrate daily and silage + concentrate after every other day were in agreement with the report of Sarwar *et al*. (2003) and Bello (2017) which suggested that nitrogen retention depends on good digestibility of nutrients and/or utilization. Also, nitrogen excreted in the faeces and urine is related to the digestion and absorption of nitrogen. High excretion of urinary nitrogen is associated with high rumen nitrogen degradability (McDonald *et al.,* 2002).

5.9 Effect of Feeding Regime and Sampling Time on Rumen Metabolites of Growing Yankasa Rams Fed a Basal Diet of Grain Sorghum Hay or Silage Supplemented with Concentrate

Feeding regime had significant ($P<0.05$) effect on pH, temperature, total volatile fatty acid (TVFA) and ammonia nitrogen (NH_3-N) (Table 4.13). Rumen pH, temperature and NH_3-N increased when concentrate supplementation was reduced from silage + concentrate daily to silage + concentrate after 2-days. Ruminal pH is an important factor that measures the acidity and alkalinity of rumen content in ruminants and for optimum rumen microbial fermentation. Gozar *et al*. (2001) reported that when the ruminal pH is low, microbial diversity is reduced as protozoa numbers may sharply decline and the bacterial population altered and largely reduced. The pH values in this study falls within the recommended range of 5.50 – 7.50 (Russell, 1996).

Osinowo *et al.* (1994) suggested that for optimum rumen microbial fermentation the rumen pH should range between 6.00 and 7.00. The pattern of rumen NH_3-N production was dependent on the pattern of intakes of hay, concentrate and total dry matter intake. The increase in NH_3-N level with the reduction of concentrate contradicts the report by Adeleke (2015) which stated that increased intake of protein from concentrate component of the diet was associated with higher concentration of NH_3-N in the rumen. Ammonia is the nitrogen source of main microbes in the rumen (Bandle and Gupta, 1997) and NH_3-N concentration is an indicator of degradation and utilization of nitrogen source by rumen microbes (Wang *et al*., 2008).

The effect of sampling time on rumen metabolites was highly varied. Rumen pH and NH_3-N declined from 0 to 8 hours post-feeding while TFVAs increased from 0 to 8 hours post-feeding. The significant decline in rumen pH at 8 hours post-feeding could be as a result of high concentration of TFVAs, as it has been reported that high concentration of TVFA has a reducing effect over rumen pH (Abubakar *et al.*, 2010). The value of the TVFAs obtained from this study was within 19.57 - 36.57 mmol/L reported by Jokthan (2007) when pigeon pea forage was supplemented in sheep diet and the 28.80 – 56.80 mmol/L reported by Adamu (2015) when Yankasa rams were fed with groundnut haulm. Volatile fatty acids (VFAs) are the main energy sources for ruminants feeding solely on roughages. Thus their concentration in the diet gives an indication of their energy value. This implies that the rams received enough TVFAs capable of meeting their energy need. The increase in TFVAs noticed across the time of sampling means that the microbes in the rumen of the rams had enough time to act on the feed thereby producing TVFAs. The increase suggested that the treatment diets improved the anaerobic fermentation of the diet which stimulated the yield of more TVFAs (Bello, 2017). This improved yield of TVFAs may be due to the increase in digestibility of the diets. There was non-significant ($P>0.05$) interaction effect between feeding regime and sampling time on the rumen indices.

5.10 Costs-Benefit Analysis of Growing Yankasa Rams Fed a Basal Diet of Grain Sorghum Hay or Silage Supplemented with Concentrate at Different Feeding Regimes

The result indicated that treatment diet with hay + concentrate was more economically superior and cost effective than treatments containing silage + concentrate supplement due to feed cost reduction observed in the study. The variation may be attributed to the costs of the basal diets (hay and silage) and also the feeding regime. Those fed daily supplement consumed more concentrate hence the high cost of feed consumed.

CHAPTER SIX

6.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary

This study was conducted to evaluate the forage yield and quality of sorghum (*Sorghum bicolor* L. Moench) varieties at different sowing dates, harvest and utilization of the silage by growing Yankasa rams at Ahmadu Bello University, Zaria. The agronomic studies was laid in a split plot design with a factorial arrangement (2 x 3 x 3) consisting of two sorghum varieties (SAMSORG-16 and SAMSORG-17), three sowing dates (15th June, 30th June and 14th July) and three stages of harvest (6, 10 and 14 weeks after sowing (WAS), replicated three times, respectively in 2018 and 2019 growing seasons. The result showed that plant height (207.20 cm) was higher for SAMSORG-16 variety in 2019 growing season and the mean. Number of leaves (12.61) was higher for SAMSORG-17 variety in 2019 growing season. Higher plant height (211.12 cm) was observed for sorghum sown on 15th June in 2018 growing season while in 2019 growing season and the mean, higher plant height (163.43 and 181.26 cm) was revealed for sorghum sown on

30th June. Higher number of leaves (13.73, 12.38 and 13.06) was obtained for sorghum sown on 15th June in 2018 and 2019 growing seasons and the mean. Higher LAI (7.06, 5.18 and 6.12) was recorded for sorghum sown on 15th June in 2018 and 2019 growing seasons and the mean. Higher plant height (307.02, 213.29 and 260.16 cm), number of leaves (17.33, 15.41 and 16.37), LAI (8.97, 6.97 and 7.97). Fresh and dry forage yield (41.09 and 7.90 t/ha and 42.98 and 8.52t/ha) were higher for SAMSORG-16 variety in 2019 growing season and the mean. Higher fresh and dry forage yield (54.73 and 10.49 t/ha and 46.69 and 8.85 t/ha) was recorded for sorghum sown on 15th June in 2018 growing season and the mean while in 2019 growing season, higher fresh and dry forage yield (42.72 and 8.40 t/ha) was obtained for sorghum sown on 14th July. Higher fresh and dry forage yield (58.78 and 14.47 t/ha, 54.56 and 13.21 t/ha and 56.67 and 13.84 t/ha, respectively) were recorded for sorghums harvested at 14 WAS in 2018 and 2019 growing seasons and the mean, respectively. Higher NDF was obtained for SAMSORG-16 sorghum forage while Ca was recorded for SAMSORG-17 sorghum forage. Higher ADF was observed in sorghum forage sown on 30th June, while higher Ca and P contents were recorded for sorghum forage sown on 14th July. Higher crude protein and P were obtained for sorghum forage harvested at 6 WAS while higher NDF and ADF were recorded for sorghum forage harvested at 14 WAS although higher Ca was obtained for sorghum forage harvested at 10 WAS. Silage made from SAMSORG-17 sorghum give the highest DM, CP and Ca while higher NDF and ADF were obtained in SAMSORG-16 sorghum silage whereas sorghum sown on 15th June recorded the highest DM, CP, NDF and ADF.

Improved total feed intake and weight gain were obtained in Yankasa rams fed silage supplemented with concentrate daily. Feeding Yankasa rams silage and concentrate supplement after every other day or after 2-days gave similar weight gain. Feeding silage and concentrate supplement after every other day boosted the digestibility of dry matter, crude protein, neutral detergent fibre and acid detergent fibre and led to an increase in the percentage of nitrogen absorbed and retained in Yankasa rams. Feeding Yankasa rams silage and concentrate supplement after every other day or after 2-days resulted in higher rumen pH, temperature, total volatile fatty acids (TFVAs) and ammonia nitrogen (NH_3-N). Higher TFVAs was obtained at 8 hours post feeding while ammonia nitrogen (NH_3-N) was higher at 0 hours post-feeding. The least cost per kg gain (₦1046.40) was recorded in rams fed hay + concentrate daily. Also, when feeding sorghum silage, concentrate supplement should be administered after 2-days.

6.2 Conclusions

The following conclusions were drawn from the study:

1. Higher dry forage yield (8.52 t/ha) was recorded for SAMSORG-16 variety
2. Similar dry matter and crude protein were recorded for both SAMSORG-16 (94.02 and 11.36 %) and SAMSORG-17 (93.77 and 11.73%) forages.
3. Better quality silage in terms of dry matter (75.36%) and crude protein (10.42%) was made from SAMSORG-17 variety.
4. Sowing date of 15th June gave higher dry forage yield (8.85 t/ha), dry matter (94.03%) and crude protein (11.99%); and better quality silage with high dry matter (74.70%) and crude protein (12.94%).
5. Stage of harvest of 14 WAS gave higher dry forage yield (13.84 t/ha) and dry matter (94.68%) with lower crude protein (10.26%). Whereas higher crude protein (12.23%) was recorded at 6 WAS.
6. SAMSORG-16 sown on 15th June gave higher dry forage yield.
7. Sowing date of 15th June, harvested at 14 WAS gave higher dry forage yield.

8. SAMSORG-16 sorghum harvested at 14 WAS gave higher dry forage yield.

9. Higher weight gain was obtained for rams fed silage + concentrate supplement daily.

6.3 Recommendations

1. For optimum forage yield and quality, SAMSORG-16 variety should be sown on 15th June and harvested at 14 WAS.

2. Farmers should feed SAMSORG-17 silage and concentrate supplement for better weight gain.

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