EFFECT OF DIFFERENT PROTEIN SUPPLEMENTS ON THE PERFORMANCE OF YANKASA SHEEP FED CONGO GRASS (*Brachiaria ruziziensis*$_{R.C.M}$)

By

SANI, Ibrahim

B. AGRIC. (A.B.U) 2009

A THESIS SUBMITTED TO THE SCHOOL OF POST GRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER DEGREE IN ANIMAL SCIENCE.

DEPARTMENT OF ANIMAL SCIENCE, FACULTY OF AGRICULTURE, AHMADU BELLO UNIVERSITY, ZARIA, NIGERIA

OCTOBER, 2014

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OCTOBER, 2014

DECLARATION

I Ibrahim Sani, hereby declare that this thesis titled "**Effect of different protein supplements on the performance of Yankasa sheep fed Congo grass (*Brachiaria ruziziensis* R.C.M)**" has been written by me and that it is the record of my own research work. It has not been part of any presentation for Master of Science Degree in Animal Science. The source of information derived from literature has been duly and specifically acknowledged in the text and a list of references provided. No part of this work has been presented for another Degree or Diploma at any institution.

_____ _____

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Department of Animal Science, Faculty of Agriculture,
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CERTIFICATION

This is to certify that this Thesis titled "**Effect of different protein supplements on the performance of Yankasa sheep fed Congo grass (*Brachiaria ruziziensis* r.c.m)**" written by Ibrahim Sani meets the regulations governing the award of Master of Science Degree in Animal Science, Faculty of Agriculture, Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

I dedicate this thesis to Almighty Allah (S.W.T.) for giving me the wisdom to carry out this work successfully and my lovely family (Mr and Mrs Sani, Hajara, Lawal, Tasiu and Sadiya) for their support and contribution towards the completion of my academic pursuit. May God bless you all. Thank you.

ACKNOWLEDGEMENT

My appreciation goes to the Almighty Allah who gave me the opportunity to come to Ahmadu Bello University for my Master Degree Programme, sustained and guided me throughout my academic endeavors. To God be the glory, honour and praise forever.

I wish to express my deepest gratitude to those who contributed to the success of this work, by their patience, enthusiastic, encouragement, guidance and supervision throughout the completion of my study. I gratefully acknowledge the help and support of Professors J. T. Amodu and C. B. I. Alawa, my supervisors who inspite of their very busy schedule still created time and the necessary guidance needed for the completion of this work. Indeed, your contributions and supervision brought me to this point, may Allah bless you abundantly. I must express my profound gratitude to the Head of Department of Animal Science Dr. S. Duru for his great contribution to my work.

I am greatly indebted to the Director of SAJ Foods Limited and SAJ Integrated Farm, Alhaji Sanusi Abdullahi who provided me with the experimental animals in his farm for the research Work.

My profound gratitude goes to my dear parents, Mr Sani Isiaka and Mrs Hadiza, my siblings, Hajara, Halima, Tasiu and Lawal Sani. Thanks for your love, concern and support both spiritually and financially.

ABSTRACT

There were two trials carried out in this research, the first trial was conducted to investigate the growth pattern, dry matter yield and biomass production of Congo grass (*Brachiaria ruziziensis* R.C.M). The trial lasted for 24 weeks, during which plant height, number of leaves/plant, number of tillers/plant, leaf-stem ratio, percentage soil cover, percentage greenness, dry matter yield and biomass production were measured. The plant height of *B. ruziziensis* increased from 20cm at week 4 to 135cm at week 24. Seven (7) tillers per plant was obtained at week 4, which increased to twelve (12) at week 24. The percentage greenness also increased from 40% at week 4 to 95% at week 24. The results showed that there were significant ($P<0.05$) differences in plant height, number of leaves per plant and number of tillers/plant between weeks 4, 6, 8, 12, 18 and 24. The leaf-stem ratio which was highest at week 6 (1.5:1) and lowest at week 18 and 24 (1.2:1) did not differ significantly ($P>0.05$) between the various weeks. The results obtained also indicated that the dry matter and fresh fodder yield production increased ($P<0.05$) from 5.7t ha^{-1} to 11.6t ha^{-1} and 8 to 32t ha^{-1}, respectively from week 6 to week 24. The second study was done to compare the performance of Yankasa sheep fed *Brachiaria ruziziensis* basal diet with different protein supplements of Cotton Seed Cake (CSC), Palm Kernel Cake (PKC), Brewer's Dried Grain (BDG) and sole *B. ruziziensis* grass (control). Sixteen (16) Yankasa sheep weighing between 18.5 and 21.5kg and aged 9-12 months were used in the experiment. The total dry matter and crude protein intake were highest ($P<0.05$) in animals on CSC supplement and lowest for those on BDG supplement. Digestibility of dry matter (DM) ranged from 61.3% in BDG to 66.8 % in CSC ($P<0.05$). Digestibility of crude protein was also highest in CSC (71.9%) and lowest in BDG (67.06%). The total live weight gain (TLWG) increased ($P<0.05$) from 0.91kg in animals

fed *B. ruziziensis* grass solely (control) to 2.5kg in those fed Cotton Seed Cake, while feed conversion ratio reduced from 52.50 in *B. ruziziensis* to 29.15 in CSC treatment. It is concluded from this experiment that Yankasa sheep utilized CSC better than PKC, BDG and *Brachiaria ruziziensis* (control). It is therefore recommended that Congo Signal grass (*Brachiaria ruziziensis* $_{R.C.M}$) be harvested from week 24 for higher dry matter yield and biomass production. Also, *Brachiaria ruziziensis* should be supplemented with Cotton Seed Cake at a rate of 250g/d for better live weight and economic gain in Yankasa sheep production.

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CHAPTER ONE

1.0 INTRODUCTION

Ruminant animals play an important role in the farming systems of most countries of the world, this includes: the production of milk, meat, draught power, manure as well as hides and skins. Natural grazing land constitute the major feed resources, providing more than 90% of animal feed requirement, either in the form of grazing resources or conserved forages (Tolera and Abebe, 2007).

Brachiaria is a species of grass originating from the savannas of the Eastern part of Africa. The grass species is widely used as livestock feed. *Brachiaria* species are either annual or perennial grasses, with most of the species lacking rhizomes. The inflorescence has panicle branches composed of racemes and the entire plant usually do not grow higher than 1m. *Brachiaria* belongs to the C4 plants which tolerate drier conditions and more light exposure than many other plants (Watson and Dallwitz, 2008).

Brachiaria is the most important forage grass for pastures in the tropics (Singh, 2009). *Brachiaria* cultivars have impacted the economy of various countries in the tropics because of their ability to grow so well in low fertility acid soils and still able to produce highly nutritious forage for many ruminants. In the past 25-30 years *Brachiaria* cultivation and export has become a major component of sown pastures (Singh, 2009). In South America, Brazil represents the leading user of *Brachiaria* forage.

Brachiaria grass has a rapid growth especially in the wet season. Its compatibility with *Stylosanthes humilis* and *S. hamata* is highly noted and also its ease of establishment (Miles *et al.*, 1996).

Brachiaria ruziziensis combines well with other grasses and legumes. It combines well with legumes such as *Centrosema pubescence* or *Pueraria phaseoloidies*. In Zaire, it has been found to combine very well with *Setaria sphacelata* and *Stylosanthes guianensis*. In Northern Australia, *S. humilis* and *S. hamata* can be introduced by cultivating the grass and oversowing the legumes (Mellor *et a*l., 1973).

One of the major constraints of small ruminant production in Nigeria is nutrition, in which feeding constitutes about 85% of total cost of production (Alawa and Umunna, 1993). Therefore, feeding strategies are needed in order to increase animal performance using tropical grasses (Eugene *et al.*, 2010). Similarly, ruminants in the tropical and sub-tropical countries are likely to depend almost entirely on pasture and agricultural by-products of relatively poor nutritional status. Improvement in ruminant production will therefore require increased effort in investigating the different possible ways and means of upgrading poor roughages through increasing their digestibility and voluntary intake (Fadel, 2004).

Cotton is an important cash crop grown mainly in the northern part of Nigeria. The processing of cotton results in a number of by-products that are valuable feed ingredients for livestock, such as whole cottonseed, delinted cottonseed and cottonseed meal or cake. Cottonseed meal has long been a popular and economic protein concentrate for animal feeding. The realities of least cost ration formulation and simple economic incentive have been the prime reason that this co-product of the cottonseed oil extraction industry has found its way into feeds for many classes of animals. Cotton Seed Cake has some anti-nutritional and natural limiting factors that must be considered for safe use. Chief among these factors are protein level and quality, fibre level, trypsin inhibitor and the gossypol content (NCPA, 1990). These anti-nutritional factors readily undergo physical and chemical change when heated and have been found to be destroyed during

processing. The complex processes of rumination and the microbial population of the rumen will efficiently handle any residue from such anti-nutritional factors. This could explain why the feed ingredient did not have negative influence on the performance of animals on Cotton Seed Cake (Oladotun *et al*., 2003).

Palm Kernel Cake (PKC) or Palm Kernel Meal (PKM) on the other hand is the main by-product of the palm oil industry and Nigeria is a major producer of palm oil. Large quantities of the meal are therefore produced and about 75% of our PKM was until recently, being exported abroad. However, since the efforts of the Federal Government to make Nigeria self sufficient agriculturally and on account of the embargo on feed stuffs exportation, PKM is increasingly available from the large commercial oil millers and the small and local crushers (Umunna *et al*., 1980).

Although PKC supplies both protein and energy, the by-product or commodity is taken as a source of protein. PKC was ranked a little higher than Copra cake but lower than fish meal and groundnut cake especially in its protein value (Devendra, 1977). PKC is a medium grade protein feed and with its high fibre content it is often considered as suitable for feeding of ruminants. Its protein is highly degradable in ruminant animals (Carvalho *et al*., 2005). The nutritive value of PKC varies considerably based on source and methodology of oil removal (Hindle *et al*., 1995). Earlier studies showed that cattle and buffaloes fed PKC as supplement or basal diets generally results in improved growth performance (Jelan *et al*., 1991). Collingwood (1958) reported increased butterfat production when PKM was fed to dairy cattle. Babatunde *et al*., (1975) on the other hand reported poorer feed efficiency, reduced growth rate and feed intake for pigs fed PKM as the major protein source and concluded that it should not be used as the sole protein concentrate in pig diets.

Brewers' Dried Grain is a major by-product of brewing which in Nigeria is used as manure or disposed as waste. The dry product, Brewer Dry Grain (BDG) has been tested in monogastric feeds. Babatunde *et al.,* (1975) showed that pigs could tolerate up to 15% of BDG in the diet. Preston *et al*. (1973) evaluated the energy value of BDG (78% TDN) for cattle and obtained a net energy value comparable to that of maize (80% TDN).

Since Cotton Seed Cake, Brewer's Dried Grain and Palm Kernel Cake are readily available and cheaper than other conventional protein sources such as Groundnut cake, Soya bean Cake or Meal, fish meal e.t.c, it was desirable to evaluate these products as major protein sources in the diets of ruminants (Umunna *et al*., 1980).

1.1 JUSTIFICATION

Factors that hinder livestock production in Nigeria are many and critical. Among these are the continuous rise in prices and scarcity of some of the conventional protein sources. There is also a great demand for such protein sources as feed for monogastric animals and there is therefore an urgent need to find alternative sources of protein that are cheap and also of low nutritive value for monogastric animals or man. Cotton Seed Cake, Brewer's Dried Grain (BDG) and Palm Kernel Meal (PKM) fall into this class. Cotton Seed Cake/meal is a good protein source (25-45% crude protein) and also a good source of energy (NRC, 1998).

There is a clear need for alternative means of supplementing the year round forage requirements of livestock that will ensure better performance and positive economic gain through high carrying capacity (Meek *et al*., 2004). Provision of supplementary feed to animals on natural pastures is one of the strategies farmers can use to alleviate the problem of poor forage quality. When provided with protein supplements, ruminants are able to increase intake of low quality

forages most especially from natural pastures and crop residues. Supplementation of poor quality forages was reported to increase dry matter intake and performance of animals. The availability of Cotton Seed Meal and groundnut meal in some tropical countries provide a valuable source of N supplementation to the poor quality forages obtained in these regions (Bailey and Sim, 1998).

Cotton seeds differ in level of gossypol present in their seeds. The presence of gossypol in cotton seeds have restricted the feeding of whole cottonseeds to non-ruminant animals. Therefore, the feeding of Cotton Seed Cake, a by-product of cottonseed is found to be limited in the feeds of monogastric animals (Abou-Donia, 1989).

The quality of cottonseed cake varies a lot depending on the methods of oil extraction and the concentration of gossypol in the meal (Goetch and Owens, 1985; Ikurior and Fetuga, 1984). The Undelinted Undecorticated Cotton Seed Cake (UUCSC) is cheaper than the major protein sources such as groundnut cake and soyabean meal which are commonly used in the formulation of rations for monogastric animals in Nigeria.

1.2 OBJECTIVES OF STUDY

The objectives of this study are:

1. To determine the growth pattern, fresh and dry matter yields and chemical composition of *Brachiaria ruziziensis*.
2. To determine the dry matter intake and growth performance and nutrient digestibility of Yankasa sheep fed different supplements of protein feed and basal ration of *B. ruziziensis.*
3. To evaluate the appropriate basal and supplement feed combinations for Yankasa sheep in order to improve small ruminant production in Nigeria.

4. To estimate the cost benefit of utilizing protein supplements and *B. ruziziensis* in the feeds of Yankasa sheep.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin, adaptation and Distribution

Brachiaria species are mainly found in Lake Edward and Lake Kivu districts of Congo, Rwanda, Burundi, and the Ruzizi plains in Zaire, now widely distributed in the tropics. It occurs in grasslands, disturbed areas and is naturalised throughout the humid tropics and also cultivated and grown in Queensland (Australia), Srilanka, Thailand and tropical America in places like Korovinia (Fiji), Quilichao (Colombia), French Guyana, Honduras and Costa rica (McGregor, 1988).

Several commercially grown *Brachiaria* species are well adapted to low-fertility, acid soils of the tropics. Research to identify plant attributes that contribute to efficient acquisition and use of nutrients for plant growth is recent. Several root and shoot attributes have been shown to contribute to the adaptation of *Brachiaria* species to acid soils, these include their ability to change the partitioning of fixed carbon to favour root growth, to acquire nitrogen (N) through associative fixation, to acquire Phosphorus (P) through extensive root systems and mycorrhizal association and to acquire Calcium (Ca) through highly branched root systems. Differences in adaptation to acid soils among *Brachiaria* species cannot be attributed to Aluminum (Al) toxicity (Singh, 2009).

2.2 Botanical description

Brachiaria forages are annual or perennial grasses, most lacking rhizomes except for *B. ruziziensis, B. brizantha* and *B. decumbens* having short rhizomes. The inflorescence has panicle branches composed of racemes and the entire plant usually do not grow taller than 1 m. The flowers are fleshy with 3 anthers and the plants are bisexual. Some members of the genus have a

prominent vein in the center of the leaf whereas others do not. Brachiaria are C4 plants which allows them to tolerate drier conditions. A spreading perennial with short rhizomes similar in habit to Para grass. The inflorescence consists of dense and spikelike racemes, the spikelets are all sessile and close together while the rachis of the racemes are winged, broad and over 3 mm wide (Watson and Dallwitz, 2008).

A tufted, creeping perennial with short rhizomes forming a dense leafy cover. Culms arise from many-noded creeping shoots and short rhizomes, growing to a height of 1.5 m when flowering. Leaves are soft but hairy and up to 25 cm long and 15 mm wide. Inflorescence consists of 3–9 relatively long racemes (4–10 cm), bearing spikelets in 1 or 2 rows on one side of a broad, flattened and winged rachis. Spikelets is hairy, 5 mm long with an average seed weight of 250,000/kg. *B. ruziziensis* is very closely related to *B. decumbens*, being differentiated morphologically on rachis shape, which is subfoliolate and 2–3.5 mm wide and flat in *B. ruziziensis* and 1–1.7 mm wide in *B. decumbens* and on the position of the lower glume, which is 0.5–1 mm distant from the rest of the spikelet in the former and very close to the upper glume in the latter (Rao *et al*., 1996).

2.3 *B. ruziziensis* as a forage crop

Brachiaria brizantha has been found to have similar characteristics with *B. ruziziensis* and can be heavily grazed if used as a monospecific sward and regularly fertilized with nitrogen. *Brachiaria brizantha* alone or in combination with Congo grass (*Brachiaria ruziziensis*) are considered as improved forages and recommended to farmers in South America (Payan, 2007). Other grasses such as *Brachiaria humidicola* or *Brachiaria dictyoneura* under more intensive grazing systems, creeping legumes such as *Arachis* spp., *Desmodium heterocarpon sub spp*.

ovalifolium, *Stylosanthes spp*., *Alysicarpus vaginalis*, *Leucaena leucocephala*, *Pueraria phaseoloides*, *Desmodium intortum* can be mixed with *Brachiaria brizantha* (Cook *et al.,* 2005).

Dry matter (DM) yields range from 8–20 t/ha/year, depending on soil moisture and fertilization. Pastures can be permanent (up to 20 years without replanting) or planted under crops such as rubber and coconut. Both *Brachiaria brizantha* and *B. ruziziensis* are well accepted by grazing animals. They are considered to be slightly more palatable than *Brachiaria decumbens* (Signal grass) though slightly less digestible. Most of the trials involving the species were carried out in Brazil.

2.4 Environmental requirements

2.4.1 *Soil requirements*

B. ruziziensis grass requires light to loam soils of moderately high fertility (pH 5.0–6.8) and cannot tolerate strongly acid conditions. Rao *et al.* (1996), in their reviews suggested that *Brachiaria* species can adapt to a wide range of soil types, from Oxisols and Ultisols (low-fertility acid soils) to Alfisoils and Mollisols which are high-fertility neutral soils. They perform, much better on acid soils than other grasses, such as *Panicum* species, they also perform well on moderately fertile to very fertile soils. Requirements for phosphorus, calcium, and potassium for growth of *B. humidicola* are much lower than those for other species. Greenhouse and field studies have demonstrated sticking responses in forage yield to phosphorus, but no response to lime or micronutrient applications. Rapid and reliable screening procedures are urgently needed to improve the efficiency of evaluation and genetic improvement of *Brachiaria* germ plasm (Rao *et al.* 1996).

2.4.2 *Moisture requirement*

B. ruziziensis is a grass for the lowlands and up to 2,000mm above sea level in the humid tropics, with a minimum of 1,200 mm average annual rainfall. However, it can tolerate a dry season of 4 months but will die out in extended dry conditions. Having poor tolerance to flooding, it thrives best on well-drained soils. *B. decumbens* is essentially a grass of the wet tropics, but it has good drought tolerance and is adapted to a dry season of four or five months. However, it prefers 1,500 mm or more of rain. It does not do well where the dry season is more than five months, but is more productive than *Digitaria decumbens, Panicum maximum* and *Brachiaria mutica* in the late dry season. In Australia Loch (1977) assessed *B. decumbens* as better adapted to the humid tropics, with a dry season of less than 4 months and an annual rainfall of more than 1,400 mm. However, in strongly seasonal climate of the isothermic savannas of the Brazilian Cerrados, *B. decumbens* cv. *Basilisk* is grown in areas where the dry season is as long as 7 months and rainfall as low as 1,300 mm. It extends further into drier zones than *B.humidicola. Brachiaria brizantha* is reputed to tolerate drought better than either *B. decumbens* or *B. humidicola* (Thomas and Grof., 1986). All three species grow well throughout the year in the piedmont of the eastern Cordillera of the Andes in Colombia, where rainfall is more than 4,000 mm (Fisher *et al*., 1996).

Fisher and Kerridge (1996) noted that at two sites, with contrasting soils, on the Caribbean island of Martinique, Gayalin (1994) compared the performance of *B. decumbens* with *Panicum maximum, Pennisetum purpeureum*, and *Tripsacum laxum* as forages for deferred grazing in the dry season. Although *B. decumbens* is widely grown by farmers for its drought resistance, it was out yielded by *T. laxum*, which retained three to seven times more green leaf, *P. purpeureum* yielded two to three times more total forage than *B. decumbens* and had between one and three times as much green leaf dry matter (DM). Obviously, farmers' perception of drought resistance

probably on the basis of the apparent proportion of green leaf in the standing forage was not a good guide to the amount of green leaf actually present in the forage.

2.4.3 *Temperature requirement*

Temperature for optimal growth of *B. decumbens* is 30-35°C. It is readily frosted, but its winter production is better than *Digitaria decumbens* in frost free areas. Low temperature depresses growth and hence, *Brachiaria* in general performs poorly at altitudes above 1,800m above sea level (Ndikumana and de Leeuw, 1996). The optimum temperature for growth of *B. ruziziensis* is 33°C during the day and 28°C during night, with a minimum night temperature of 19^{o}C. It is not frost tolerant (Dienum and Dirven, 1972). Low yields resulted from a 24^{o}C temperature during the day and 19°C temperature at night. Ludlow (1976) found this species of several tropical grasses to be the most affected by low temperatures. It is highly affected by heavy frosts, and spring re-growth is very slow after light frosts.

2.4.4 *Light requirement*

Radiation: Fisher and Kerridge (1996) reported that *Brachiaria* species are used as soil covers in many plantation crops, such as rubber and coconut, in Southeast Asia and the Pacific Islands. Their tolerance of shade is therefore of interest. In one experiment, thirty-five (35) forage grass accessions were grown under coconut on fertile soils in North Sulawesi and Bali, Indonesia, with light transmissions of 73% or 58%, respectively. Rainfall (amount and distribution) was confounded with light transmission, higher total rainfall and more even distribution occurred at the site with greater light transmission. *Brachiaria decumbens* cv. *Basilisk* was the top performer at the site with higher rainfall, less shade, and a 12-month growing season (Kaligis and

Sumolang, 1991). It was also one of the best species that performed very well at the site with lower rainfall, more shade, and a more marked dry season (Rika *et al.*, 1991).

Photoperiodism: *B. decumbens* is inferred to be a quantitative short-day plant, flowering everywhere in the longer days of the year, and more vigorously at high than at low latitudes (Hopkinson *et al.,* 1996). *B. ruziziensis* has moderate shade tolerance and is grown under coconut plantation.

2.5 Land preparation, establishment and management

A well-prepared seed-bed is recommended, but light disc-harrowing gives good results. Drill the seed into a well-prepared seed-bed. In Zaire it has been sown in rows 60 cm apart, or broadcasted over the land after scarification of the soil with a disc harrow or brushcutter, without burning the native pastures and grazed as soon as it is ready (Risopoulos, 1966). It will establish in rough seeds-beds but gives better results on a well-prepared seed-bed. Minimum tillage systems should be used, when established *Brachiaria decumbens* will suppress weeds very effectively.

The work of Boddey *et al*. (1996) also suggested that the environmental impact of a vigorously growing *Brachiaria* pasture is only positive. The grass provides good soil cover, facilitating water infiltration, preventing erosion and leaching of soluble nutrients is minimal. Nitrogen fixation associated with some *Brachiaria* genotypes may slow down pasture decline and the grass's deep, dense rooting system also sequesters much more atmospheric Carbon than native pasture. The large area occupied by *Brachiaria* pastures suggests that this may be an area of global significance for atmospheric carbondioxide (CO_2). Sustaining the productivity of pastures while improving animal production requires strategies for maintaining or even improving soil

fertility and one effective strategy is to introduce forage legumes. Surface sowing in moist soil and sowing should not be deeper than 2 cm in dry soil (Bogdan, 1964). In Zaire it is recommended to sow at a depth of 1-2 cm. Under humid conditions seeds lose their vitality after one year (Risopoulos, 1966).

2.6 Planting and sowing depth

B. ruziziensis will establish in rough seed-beds but gives better results on a well prepared seed-bed cleared of weeds, stones and dirts. Within three months a complete ground cover should be obtained. It has a long growing season with productive active growth from spring to late autumn. In Zaire, seed is sown into soil not deeper than 1 cm at a recommended seed rate of 30 kg/ha and rolling is only recommended after sowing. Best results are obtained when seed is sown during the wet season at a rate of 2-5 kg seed. After seed ripening, it takes 10 to 12 months to break dormancy. Treating the seeds for 10 to 15 minutes with commercial Sulphuric acid will improve germination of harvested seed by 33% and seedling vigour is excellent (Grof, 1969).

2.7 Establishment of *Brachiaria ruziziensis*

B. ruziziensis can be established from seed, which is often cheap but needs to be stored for at least 6 months after harvest to break its seed dormancy. Broadcast seed at 2.5–10 kg/ha (depending on seed quality) onto a well-prepared seedbed and lightly cover and seed should be sown not deeper than 2 cm. Infertile soils should be fertilised with NPK fertilizer to supply Nitrogen, Phosphorus and Potassium prior to planting and seedling growth is vigorous. *B. ruziziensis* grass can be established vegetatively from stem cuttings with rooting nodes and by seed sowing. Initially planted from vegetative material, it is now established mostly from seed after dormancy has been broken (Hare and Phaikew, 1997; Burke *et al*., 2003).

2.8 Growth vigour

B. ruziziensis gives a good early wet season growth up to eight weeks after the onset of rain and it seeds heavily in April at South Johnstone, north Queensland (lat. 17°36'S) (Falvey, 1976).

It forms a dense mat under grazing which withstands grazing well (Davidson, 1966). The yields of dry matter did not vary very significantly in Sri Lanka with monthly cutting at 2.5 cm or 7.6 cm but bi-monthly cuts yielded a little higher dry matter yield (Appadurai & Goonawardene, 1973). Within three months a complete ground cover can be obtained. It has a long growing season with productive active growth from spring to late autumn.

2.9 Weed control and fertility management

B. ruziziensis can tolerate pre-emergence application of atrazine herbicide at 2.5 kg of 80% product per hectare which will give good control of a wide range of weeds when it is established in the red latosolic soils of Atherton Tableland, Queensland (Loch, 1978; Hawton, 1979). *Unlike B. ruziziensis, Brachiaria brizantha* responds well to nitrogen (N) fertilization and may require repeated moderate applications. In cut-and-carry systems, nitrogen fertiliser should be applied after each cut for maximum production. If grown with a legume, the grazing system must favour the legume and adequate phosphorus (P) must be maintained (Fredericksen *et al*., 1980).

B. ruziziensis demands high fertility soils and adequate fertiliser to persist under grazing or cutting. It needs high phosphorus in the early growth on a wide range of soils. It responds well to nitrogen, either inorganic or from legumes, but its nitrogen requirement exceeds that of Guinea grass, which makes the latter more attractive (Mellor *et al*., 1973b). Risopoulos (1966) recorded an increased yield of 10.74t/ha from nitrogen application in Zaire. Added nitrogen is required to keep *B. decumbens* in active leafy growth. Frequent applications of nitrogen, up to six times per season, keep the grass in a very nutritious condition and improve live weight gain in animals

especially under high rainfall conditions. However, a selection of *Brachiaria decumbens* yielded over 4.0t DM/ha without nitrogen but with adequate phosphorus at Quilichao, Colombia (CIAT, 1978) and it was one of the best grasses for soil with low nitrogen and low phosphorus. In Honduras, mean annual production was 23.07t DM/ha with added nitrogen of 450 kg Sulphate of ammonia per hectare (Romney, 1961). At Korovinia, in Fiji's wet zone, it yielded 34.13t DM/ha over an 11 month period, while in Solomon Islands it produced up to 30t DM/ha per year under coconuts. On an oxisol at Carimagua, Colombia, it gave maximum yields at 50 kg P_2O_5/ha, responding much more to phosphorus than *Panicum maximum* and *Andropogon gayanus* while on an ultisol at Quilichao, Colombia, it gave a linear response to more than 400 kg N/ha (CIAT, 1978).

2.10 Cropping systems and crop management practices

Brachiaria needs to be stocked heavily and added nitrogen is required to keep it in active leafy growth. Frequent applications of nitrogen-up to six times per season-keep the grass in a very nutritious condition and improve live weight gain especially under high rainfall conditions. Grazing at 42-day rotations gave the best balance with *Brachiaria decumbens and Pueraria phaseoloides* at Carimaqua, Colombia. At 56-day rotations, the *Brachiaria* seeded and new seedlings invaded the *Pueraria* while at 28-day rotations the *Brachiaria* maintained good stands. It is compatible with legumes such as *Stylosanthes spp., Centrosema spp. and Pueraria spp*. for a short time but these are soon suppressed by the vigorous grass (*Brachiaria decumbens*) to leave a pure grass sward. Hetero (*Desmodium heterophyllum*) has similar tolerance (Loch, 1978; Gutteridge and Whiteman, 1978) and *B. ruziziensis* withstands heavy grazing and trampling. CIAT (1978) recommend waiting for a month after the opening rains before establishing rainy-

season stoking rates. It is affected by burning but if the environment is dry enough, *Brachiaria decumbens* will take a fire and recovery after fire is usually satisfactory.

2.11 Compatibility with other grasses and legumes

Under light grazing, *B. ruziziensis* forms a dense cover and competes with weeds. The sward opens under heavier grazing, allowing broad-leaf weeds to establish and legumes to persist and will combine with a range of twining, erect and shrub legumes. Fisher and Kerridge (1996) reported that *Brachiaria* species are very aggressive and there have been difficulties in them forming long-term, stable associations with legumes. *Desmodium heterophyllum* and *D. ovalifolium* were reported to be more compatible with *Brachiaria* than species of *Centrosema* and *Pueraria*, which in turn were more compatible than *Stylosanthes guianensis*. Of the common cultivars of *Brachiaria, B. humidicola* is regarded as being the most aggressive, followed by *B. dictyoneura* CIAT 6133, then *B. decumbens*. There are no data, nor even an objective measure, for this ranking. Usually, few weeds invade a *Brachiaria* pasture unless it is grossly mismanaged through overgrazing.

Some legumes, grown in association with *B. decumbens*, have persisted over the long term, for example, at Carimagua, associations of *B. decumbens/Stylosanthes capitata* on a sandy soil. *Brachiaria decumbens/Pueraria phaseoloides* persisted for more than 10 years on a clay loam, even though in some years the vigor of *B. decumbens* was reduced by spittlebug infestation. At Pucallpa, Peru, associations of *B. decumbens/D. ovalifolium* have persisted for 8 years under lenient grazing (Fisher and Kerridge, 1996). Research in Costa Rica confirmed that *A. pintoi* is more persistent than other legumes in associations with *Brachiaria*. The proportion of *A. pintoi* increased with heavy grazing pressure, and fewer weeds grew in these than in the other

Brachiaria-legume associations. One mechanism for greater persistence was the greater half-life of *A. pintoi* plants (Fisher and Kerridge, 1996).

In summary, it is difficult to assess whether the poor persistence of legumes (other than *A. pintoi*) with *Brachiaria* species results from competition with the grass or from inherent characteristics of the legumes. Most other legumes have characteristics that do not favour persistence under heavy defoliation i.e easily removed growing points and low seed production. *Brachiaria decumbens* tolerates heavier grazing than other grasses and thus tends to be grazed more heavily which in turn puts greater pressure on the legumes. On the contrary, where growing points are not removed as with *A. pintoi*, the proportion of legume can increase under heavy defoliation (Fisher *et al*. 1996).

2.12 Pests and diseases

B. ruziziensis is found to be attacked by spittlebug (*Aeneolamia* spp., *Deois* spp. and *Zulia* spp.) in tropical America. The leaves are attacked by foliar blight (*Rhizoctonia solani*) in tropical America. Seed heads are attacked by a fungus (*Sphacelia* spp.) in Zaire. But generally, incidence of disease and pest are not common in *Brachiaria* and they are very resistant species (Lenne and Trutmann, 1994).

2.13 Nutritive value and digestibility of *B. ruziziensis*

*B. ruziziensi*s has a good nutritive value and is more palatable than most other *Brachiaria* spp. Its crude protein (CP) content commonly ranged from 7–13% and up to 20% with dry matter digestibility of 55–75%. For *B. ruziziensis* grass hay cut 45 days after seeding in northeast Thailand, the IVDMD, crude fibre, NDF and ME concentrations were 61%, 80.5%, 72.8% and 7.9 MJ/kg, respectively. Selective grazing, heavy grazing pressure and the need for high soil

fertility can result in the loss of *B. ruziziensis* grass (Schultze-Kraft and Teitzel, 1992). Photosensitization may occur and Abas and Sharif (1986) suggest that *B. ruziziensis* grass should not be fed to sheep, goats or young cattle.

The quality of *B. decumbens* (Signal grass) has been measured in many cutting experiments and feeding trials, together with other well-known grass species. Studies have shown that the *in vitro* (IVDMD) and *in vivo* digestibility of young leaf and mature (whole plant) Signal grass is similar or higher than those of other tropical grasses, such as *Panicum maximum* . The IVDMD of Signal grass ranged from 60% to 70% in young forage and 50% to 60% in mature forage, which is higher than the average (55%) for tropical forage grasses found by Minson (1990) and as in literature (Lascano and Euclides, 1996).

High temperatures have an adverse effect on digestibility, digestibility decreased in 18-day material from 78.4 percent at day/night temperatures of 24/18°C to 72.7 percent at 29/30°C and 69.5 percent at 34/30°C (Dienum & Dirven, 1972). Feeding value declined when it seeded heavily at South Johnstone, Queensland, in April (Mellor *et al*., 1973a). Scaut (1959) in Zaire, found fresh grass to contain 13.9 percent crude protein, 27.2 percent crude fibre, 9.0 percent ash, 2.3 percent ether extract and 47.6 percent nitrogen-free extract in the dry matter.

2.14 Production potential

2.14.1 Green and dry-matter yields

In Tanzania, *B. ruziziensis* grass yielded 21.16t DM/ ha (Naveh & Anderson, 1967). At South Johnstone, north Queensland it yielded 19.5t DM/ha under a six-week cutting interval and an input of 220 kg N/ha/year (Grof and Harding, 1970). In Sri Lanka yields of 16.81, 22.03 and 25.59t DM/ha per year with nitrogen applications of 112, 224 and 366 kg N/ha, respectively

(Appadurai, 1975). In French Guyana the yield was 20.58t DM/ha and 1.18 t/ha crude protein (Borget, 1966) and in Zaire yields of 31.35t/ha and 21.47t/ha green matter per hectare per year were obtained in successive years from 1958 to 1959, with 100 kg nitrogen and 100 kg superphosphate per hectare per year (Risopoulos, 1966). At Gualaca, Panama, it produced 11t DM/ha without fertilizer and 27t DM/ha when fertilized with 600 kg N/ha per year in a rainfall area of 3997 mm per year (Holmann *et al*., 2004).

B. ruziziensis is less productive than *B. decumbens* in Australia and South America although yields have exceeded 20 t/ha/year with high rates of nitrogen. In Sri Lanka, DM yields of 16.8, 22.0 and 25.6 t/ha/year were achieved with nitrogen applications of 112, 224 and 366 kg/ha, respectively. On an oxisol soil at Coronel Pacheco, Brazil, *B. ruziziensis* grass produced 6.0 t/ha DM without added fertiliser and 12.0 t/ha with 150 kg/ha N fertilizer (Rao *et al*., 1996). A selection of *Brachiaria decumbens* yielded over 4 tonnes of DM/ha without nitrogen but with adequate phosphorus at Quilichao, Colombia (CIAT, 1978). In Honduras, mean annual production was 23 tonnes DM/ha with 450 kg sulphate of ammonia per hectare (Romney, 1961). At Korovinia, in Fiji's wet zone, it yielded 34 tonnes DM/ha over an 11 month period, while in Solomon Islands it produced up to 30 tonnes DM/ha per year under coconuts.

2.14.2 Tillering and Seed production (seed yield, processing and storage)

The pattern of tillering and tiller development have been documented in well fertilised seed crops covering eight tropical grass species by Loch (1985). Both showed that maximum tillering occurred during early vegetative growth and then declined before inflorescences emerged due to some tillers dying without completing reproductive development. In the current study of *B. ruziziensis* grass, tiller development in both spaced-plant and miniature swards showed a

substantial increase over time after the appropriate cutting management had been applied. In fact, both frequency and intensity of defoliation management had a profound influence on tiller development. This was particularly apparent when different cutting treatments were compared. However, after the seed harvest (at final cutting) only plants in miniature swards had lowered tiller numbers of 5.19. The continued increase of tillers in spaced plants may simply reflect the longer period from closing to seed production and the extra space available for growth. The work of Loch (1985) suggests that for dual purpose use of *B. ruziziensis* pasture for herbage and seed. Production management emphasis should focus on how to encourage high tiller numbers during the vegetative stage and how to maintain a high proportion of tiller survival and reproductive development.

Seed crop management is mostly conventional, vigorous synchronized tillering is stimulated by use of nitrogenous fertilizer at times when rainfall, temperature, and sunshine are expected to favour unrestricted development. Ripe seed sheds readily and coupled with imperfect synchronization of crop ripening, tends to make conventional direct harvesting inefficient and its timing critical. Where possible, seeds are allowed to fall and accumulate, and then recovered. Seed yields range from more than 1,000 $kgha^{-1}$ of pure seed to less than 100 $kgha^{-1}$ (Grof, 1969).

Seed quality is heavily influenced by vitality and dormancy. Vitality depends mostly on maturity of seed at harvest, which is higher in accumulated fallen seed and much lower in directly harvested seeds. Dormancy is strongly developed in the genus and persists in most taxa at least into the season after harvest. This creates problems for germination testing and in the field use of fresh seed. Breaching the husk, most commonly by Sulfuric acid provides a partial solution (Hopkinson *et al.,* 1996*)*. Yields of 125–200 kg/ha pure seed have been achieved by combine harvesting and up to 700 kg/ha seed has been harvested by ground sweeping. Head emergence is

relatively uniform, supporting combine harvesting or sweating. In Thailand, hand-harvested seed heads are stacked about 1 m deep and allowed to sweat for about 3 days. The heads are turned daily to facilitate the separation of seed from the head and to prevent overheating. Alternatively, the "living sheath" method is used, where heads are tied together in groups and effectively sweated in the field for 1–2 weeks before harvest. The grouped seed heads are shaken into a large net every 2–3 days until all seed is collected. Main countries of seed production are Brazil and Thailand. Seed has a high percentage of dormancy following harvest (<20% germination). Primary dormancy is physiological, whilst long-term dormancy is mechanical, caused by a restriction of the seed coat. Dormancy may be broken by 6–9 months storage or by acid scarification (Phaikaew *et al*., 1993).

Fresh seed shows post-harvest dormancy and delayed germination. Fresh seed gave 20 percent germination in Queensland and after 12 months' storage this increased to 40 percent (Davidson, 1966). Dormancy can also be broken by treating the seed with concentrated Sulphuric acid for 15 minutes (Barnard, 1969) or mechanical scarification (Jones, 1973). All seed recovered directly from the crop must be dried after harvest because moisture contents can be as high as 60% and the usual target for storage is about 10%. The minimum germination and quality required for commercial sale are 15% germinable seeds with 50% purity (phaikaew and pholsen, 1993).

2.15 Genetics and breeding

The genus *Brachiaria*, tribe *Paniceae*, includes about 100 species, which occur in the tropical and subtropical regions of both eastern and western hemispheres, but mostly in Africa. Seven perennial species of African origin: *B. arrecta, B. brizantha, B. decumbens, B. dictyoneura, B. humidicola, B. mutica*, and *B. ruziziensis* have been used as fodder plants, particularly in tropical

America, and less so in Asia, the South Pacific, and Australia (Keller-Grein et al. 1996). As previously mentioned, it is difficult to separate closely related species and there is confusion regarding identification. Bogdan (1977) stated that *B. ruziziensis* and *B. decumbens* were regarded as closely related and not easily differentiated. At the Kitale Research Station, Kenya, *B. ruziziensis* and *B. brizantha* were not distinguished from each other for a long time. Maas (1996) suggested that the widely used cv. *Basilisk*, commonly identified as *B. decumbens* (Oram, 1990), is in fact *B. brizantha* because much of the *B. brizantha* germplasm overlaps morphologically with accessions of *B. decumbens*. Maas (1996) suggested that we continue identifying cv. Basilisk as *B. decumbens*, until the taxonomic status of the whole agamic complex, including *B. brizantha, B. decumbens*, and *B. ruziziensis*, is clarified.

Keller-Grein *et al.* (1996) reported that while *Brachiaria brizantha* is widespread in tropical Africa, occurring in open and wooded grasslands, along margins of woodlands and thickets and in upland grasslands, *Brachiaria decumbens* has a narrow natural distribution. However, except for cv. Basilisk no germplasm is available from Uganda where the species is very common and where numerous herbarium specimens were collected. In addition, no germplasm has been collected from westem Tanzania or Zaire, where the species also occurs naturally. It is found in deciduous bush land, grasslands, and at forest edges.

Four major and three minor collections of *Brachiaria* exist *ex situ*, holding a total of 987 distinct accessions of 33 known species. About 40% of existing accessions are of *B. brizantha*, and another 39% are of *B. humidicola, B. decumbens, B. nigropedata, B. jubata*, or *B. ruziziensis* (Keller-Grein *et al*., 1996). To minimize genetic drift, shift or erosion, proper maintenance of germplasm is essential. But conservation of *Brachiaria* germplasm as seed is extremely difficult because of problems in seed production and processing. Hence, most major genetic resource

centers maintain live field collections (Keller-Grein *et al*. 1996). Because most *Brachiaria* species are apomicts, problems of contamination of accessions by out-crossing during rejuvenation are limited. Current practices to avoid mechanical mixtures are adequate. Sexually reproducing biotypes would be better conserved *in vitro*. However, no conservation method has yet been developed for this (Keller-Grein *et al*., 1996).

2.16 Varieties and cultivars

Brachiaria decumbens and *B. brizantha* are tetraploid (2n = 4x = 36) and apomictic, that is the embryo is produced without fusion of male and female gametes. Sexuality has been found at the diploid level in these species and in *B. ruziziensis*, and is generally associated with regular chromosome pairing and division. As a breeding tool, apomixis offers several advantages, because it associates fixation of hybrid vigour with seed propagation. Apomictic hybrids breed true and superior genotypes can be rapidly increased by seed (Valle do and Savidan, 1996). Until 10 years ago, genetic improvement of *Brachiaria* species depended entirely on selection among naturally existing genotypes, genetic recombination being impossible because of prevailing apomictic reproduction. However, recent advances in understanding the genetics and cytogenetics of *Brachiaria* have opened the way for controlled genetic manipulation. Genetic recombination is now possible in the *B. ruziziensis/B. brizantha/B. decumbens* pool. Present breeding initiatives aim to create apomictic genotypes combining spittlebug resistance and edaphic adaptation with other desirable attributes (Miles and Valle do, 1996).

Probably the best known and most widely used *Brachiaria* cultivar is *B. decumbens* cv. Basilisk (signal grass). It derives from seed (CPI 1694) introduced into Australia from the Ugandan Department of Agriculture in 1930. It was approved for commercial release in Australia in 1966 and registered in 1973 (Oram, 1990). This cultivar is well adapted to infertile acid soils and

forms an aggressive, high-yielding sward that withstands heavy grazing and trampling. It is a palatable grass of good forage quality and gives good animal performance. However, its susceptibility to spittlebugs reduces its value as a pasture plant in areas where this pest is a major constraint, for example, in the neo-tropical savannas (Keller-Grein *et al*., 1996).

Improvement of protein concentration in *Brachiaria* seems feasible, as indicated by the variation in Crude protein (CP) among accessions of some important *Brachiaria* species grown at different sites. However, based on results with other grass species, GxE variance for CP in *Brachiaria* is likely to be greater than genetic variance (Vogel and Sleper, 1994). But, the large variation in IVDMD and the stability of this attribute across environments suggest that digestibility of *Brachiaria* species can be improved. Even small changes in digestibility in *B. decumbens* or *B. brizantha* could have a significant impact on animal performance, as was shown with bermuda grass (Hill *et al*., 1993, Lascano and Euclides, 1996).

2.17 Silage and hay utilization

Though *Bracharia brizantha* silage may result in low nutrient intake and thus lower animal performance, it may be a valuable alternative as a forage source in beef cattle diets. Its optimal use depends on the appropriate integration of pasture management and forage surplus conservation in the form of silage (Pereira *et al*., 2008). *Bracharia brizantha* grass/sorghum silage ratio of 67:33 fed to Nelore steers and resulted in similar intake and body weight gain compared to the diet containing only sorghum silage (Chizzotti et al., 2005). It made very good silage with *Stylosanthes guianensis* in Zaire with 1 percent molasses and without additives (Risopoulos, 1966).

Brachiaria decumbens hay can be combined with tree foliage. Moringa (*Moringa oleifera*) foliage included as a protein supplement to *Bracharia brizantha* (Bread grass) hay-based diet fed to dairy cattle increased DM intake and digestibility of the diet as well as milk production without affecting milk composition (Sanchez *et al*., 2006).

2.18 Animal production on *B. ruziziensis*

Brahman steers grazing *B. ruziziensis* grass at Utchee Creek, north Queensland, gave a poor winter performance on grass in association with legumes compared with the performance on Guinea grass, but nearly equalled Guinea grass when 27 kg N/ha was applied. *B. ruziziensis* grass/legume pastures produced 1157 kg/ha live- weight gain while *B. ruziziensis* grass plus 200 kg N/ha per year gave 1 513 kg/ha live-weight gain (Mellor *et al.,* 1973a). Live-weight gains exceeded 1,000 kg/ha/year on pastures of *B. ruziziensis* with legumes, and over 1,500 kg/ha/yr with 200 kg/ha N fertilizer and steers grazing *B. ruziziensis* on Brazilian savannas at 2 head/ha gained 285 kg/ha/year.

2.18.1 Grazing management of *Brachiaria ruziziensis*

B. decumbens, in combination with *Stylosanthes humilis* in northern Australia had to be grazed heavily to maintain the legume in the sward (Falvey, 1976). *B. decumbens* needs to be stocked heavily, grazing at 42-day rotations gave the best balance with *Brachiaria decumbens* and *Pueraria phaseoloides* at Carimaqua, Colombia. At 56-day rotations, the *Brachiaria* seeded and new seedlings invaded the *Pueraria*. At 28-day rotations the *Brachiaria* also maintained good stands. Other workers also reported that *Brachiaria* species show rapid re-growth and good persistence under heavy or frequent defoliation (Rika *et al*., 1991). *Brachiaria decumbens* ranked higher over 10 harvests under cutting, compared with the other species. Under grazing, *B.*

decumbens persisted longer than *Panicum maximum* and *Digitaria setivalva* (now *D. milanjiana*) under increasing stocking rates and heavy grazing pressure (Chen *et al*., 1981). As grazing pressure increased, the pasture of *P. maximum* was gradually invaded by *Paspalum conjugatum* , unlike that of *B. decumbens* pasture, which maintained high ground cover until it "crashed" under prolonged and heavy grazing at a stocking rate of 10 head/ha (Fisher *et al*. 1996).

Lascano and Euclides (1996) summarized results from experiments designed to measure live weight gain (LWG) of steers grazing signal grass under different types of management. In the humid environment of South Johnstone, Australia, live weight gain/ha/year on unfertilized signal grass was 50% higher than that recorded earlier at the same location with unfertilized common *P. maximum* (Grof and Harding, 1970), whereas on fertilized signal grass, live weight gain was almost 1000 kg/ha (Harding and Grof, 1978). In a drier environment (Cape York Peninsula, Australia), signal grass in association with legumes, produced more live weight gain in heavily stocked pastures than a common *P. maximum* association (Winter *et al*., 1977). In southeastern Queensland, Australia, signal grass fertilized with nitrogen and the improved *P. maximum* cv. Hamil produced similar live weight gain at both medium and high stocking rates (Whiteman *et al*., 1985). However, in Campo Grande, Brazil, animal gains on unfertilized signal grass were 20% to 30% lower than on improved *P. maximum* cultivars (Lascano and Euclides, 1996).

A long-term grazing experiment is being conducted on an Oxisol soil on the Colombian Llanos with signal grass fertilized every 2 years (10 phosphorus, 13 potassium 10 magnesium, and 16 sulphur kg/ha), under continuous grazing (1979 to 1994), and with seasonal adjustment of stocking rate (1 hd/ha in the dry season and 2 hd/ha in the wet season). During the first 9 years, the average seasonal live weight gain (LWG) was 125 kg/hd and 225 kg/ha, with minimum values of 48 kg/hd and 86 kg/ha in 1986 and maximum of 182 kg/hd and 328 kg/ha in 1981

(Lascano and Estrada, 1989). The low live weight gain in 1986 coincided with a season of unusually heavy rains (over 3,000 mm) and a severe spittlebug attack on the grass. Maximum live weight gain was recorded in a year with abnormal dry season rainfall (300 mm) (Lascano and Euclides 1996).

An analysis of the 16-year live weight gain data indicates that this pasture does not show signs of degradation, despite periodic spittlebug attacks. The annual live weight gain recorded in 1994 (140 kg/hd) was similar to that recorded in the first year after establishment. However, this should not be interpreted to mean that spittlebug is not a problem in *B. decumbens*. Results clearly indicate the large losses in live weight gain caused in a given year by spittlebug. Nevertheless, signal grass has been persistent in this long-term grazing experiment, probably because of careful management, seasonal stocking rate adjustment and maintenance fertilizer which is not practiced for most commercial pastures (Lascano and Euclides, 1996). Over grazing and lack of fertilization coupled with spittlebug infestation are probably responsible for the degradation and consequent low animal production of large areas of the Cerrados.

Live-weight gains on signal grass increase with improved management. Results from Mato Grosso do Sul, Brazil, showed that live weight gain on signal grass could be doubled (from 120 to 250 kg/ha/year) with phosphorus fertilization (44 kg/ha) (Schultze-kraft and Teitzel, 1992). On less fertile soils in the Cerrados, live weight gain on signal grass increased only by 60 kg/ha per year when the amount of phosphorus applied to the pasture was doubled (29 to 58 kg/ha) but animal performance was probably limited by low nitrogen levels in the soil (Lascano and Euclides, 1996). One effective way to increase the quality of *Brachiaria* pastures is through grass-legume associations. However, because of the inherent aggressiveness of most *Brachiaria* species, few associated legumes have persisted. Results from a short-term grazing study in

Campo Grande, Brazil, showed an 18% advantage in live weight gain from the association of signal grass with the legume *Calopogonium mucunoides*. In a long-term grazing trial in the Colombian Llanos, signal grass associated with *Pueraria phaseoloides* (Tropical kudzu) produced, on average, 40% more live weight gain than the grass alone over the first 9 years of grazing (Lascano and Estrada, 1989). Over a longer period (16 years), the signal grass-kudzu pasture has produced an average of 34% more live weight gain than the grass alone. The grass-legume pasture has shown a clear advantage over pure grass, giving a 67% higher live weight gain in the dry season and a 24% higher live weight gain in the wet season indicating both a direct (i.e., animal selection) and an indirect (i.e., Nitrogen cycling) contribution of the legume to animal performance (Lascano and Estrada, 1989; Lascano and Euclides 1996).

The excellent compatibility and persistence of *A. pintoi* cv. Amarillo with *Brachiaria* was documented in the Colombian Llanos by Grof (1970). Following these initial results, grazing experiments were established in the Llanos and in the humid tropics of Costa Rica to measure live weight gain on *Brachiaria* with and without *A. pintoi*. Associations gave substantially higher live weight gain than the pure grass pastures: 67% higher for *B. humidicola*, and 52% higher for *B. dictyoneura*. In the more favourable environment of a humid forest site at Guapiles, Costa Rica, live weight gain on heavily stocked pastures of *B. brizantha* cv. Marandu/*A. pintoi* has been exceptionally high, producing 30% more live weight gain over a 3-year period than the pure grass. At this site, the pure grass pasture is showing signs of nitrogen deficiency (Argel, 1994), which in the long term, will undoubtedly result in greater advantage in live weight gain because of the legume. Another legume compatible with *Brachiaria* is *Desmodium ovalifolium* (now *D. heterocarpon* subsp. *ovalifolium*). In a humid environment of Bahia, Brazil, pastures of *B. humidicola* and *D. ovalifolium* were relatively stable over time with adequate grazing

management (Pereira *et al*., 1992). However, because of the low quality of this legume (i.e., tannins), live weight gain on the grass-legume association did not differ from that on the pure grass (Pereira *et al*. 1992 and Lascano and Euclides, 1996).

2.18.2. Response to concentrate supplementation

Supplementing young grazing bulls with 0.5 kg/day of concentrate resulted in better economic outcome but did not achieve appropriate slaughter weight (Brito *et al*., 2008). Increasing the level of concentrate in fattening crossbred Nelore steers grazing *Brachiaria brizantha* pasture had a positive influence on daily live weight gain. Supplementation is therefore technically and economically viable, with better results at a level of 0.76 % of body weight (Baiao *et al*., 2005). With Santa Gertrudis and Simmental breeds the best results were obtained at 0.125 % live weight (LW) with an efficiency rate of 1.62 (Goes *et al*., 2005). Increasing the concentrate level up to 0.6 % LW increased daily weight gains linearly, but the best economical return was obtained at 0.4 % LW (Leao *et al.,* 2005). Maize and soybean meal supplementation (24 % crude protein) provided higher values of weight gain at 0.5 and 1.0 % live weight (LW) and higher efficiencies at 0.125 and 0.25 % live weight (Goes *et al*., 2005).

Energy and protein supplementation during the rainy season results in higher economic profit (Barbosa *et al*., 2008). In Nellore-Blonde d'Aquitaine crossbred steers, supplementation increased animal weight gain from 0.77 to 1.06 kg/day/animal (Fernandes *et al*., 2010).

2.18.3 Response to protein supplementation

Due to its low crude protein content, *Brachiaria brizantha* has to be supplemented with protein-rich concentrates or with urea. Supplementation with increasing urea levels showed a quadratic

response to total DM intake and DM intake from pasture, with the best response at 1.6 % urea diet as fed (Acedo *et al*., 2007). Weight gains of 50-60 g/day could be obtained using only maize grain, urea and mineral mix in multiple supplements for finishing beef cattle (Sales *et al*., 2008). Supplementation with protein sources provided viable economic returns, regardless of the protein source evaluated in relation to the control group (Porto *et al*., 2009).

The supplementation frequency of steers on *Brachiaria brizantha* pasture did not affect the forage DM intake, total diet DM intake and DM degradability (Morais, 2009). Moreover, reducing supplementation frequency may decrease feeding and labour costs with no influence on steer performance during the dry season (Canesin *et al*., 2007; Goes *et al*., 2005). There are few published data on the use of *Bracharia brizantha* for milk production. Supplementation with an energy-protein concentrate in lactating cows fed with *Bracharia brizantha* during the beginning of the dry season was beneficial to the performance of calves and cows (Sampaio *et al.*, 2010). In a 12-24 months Santa Ines sheep grazing *Brachiara brizantha*, average daily gain was greater with animals that received also *Desmodium heterocarpon* subsp. *ovalifolium* hay (Magalhaes *et al*., 2005).

Few studies have measured milk yields of cows grazing *Brachiaria* pastures with or without legumes. In short-term grazing experiments at CIAT's experiment station at Santander de Quilichao (Cauca, Colombia), daily milk yield was greater on signal grass having 8 kg/cow than on *B. dictyoneura* with 6 kg/cow (Lascano and Euclides, 1996).

2.19. Toxic effect of *Brachiaria* species

A widespread but sporadic toxicity syndrome associated with *B. decumbens* is hepatogenous photosensitization, which can cause losses in live weight gain of up to 40% in severe cases

(Fagliari *et al*., 1991). Toxicity symptoms, mainly in young sheep, goats, and cattle, includes; skin lesions, facial edema, liver damage, ruminal stasis, neurological disorders, and even death if animals are not removed from the pasture (Abas *et al*., 1985; Salam *et al*., 1988). In most reports from Africa, Southeast Asia, or South America, photosensitization has occurred in animals on signal grass. However, toxicity has also occurred in sheep grazing mainly *B. brizantha* cv. *Marandu* (Magalhaes *et al*., 2005) and in horses grazing *B. humidicol*a (Schenk *et al*., 1991; Lascano and Euclides 1996).

Photosensitization with signal grass has been related to infestation of the grass by the saprophytic fungus *P. chatarum*, which produces spores thought to contain toxic sporidesmin (Andrade *et al*., 1978; Dobereiner *et al*., 1976; Nobre and Andrade, 1976). However, the cause-effect relationship between *P. chatarum* and photosensitization in signal grass has been challenged by researchers from Malaysia (Abas and Sharif, 1986; Salam *et al*., 1992) and New Zealand (Smith and Miles, 1993). The arguments put forward against the theory that *P. chatarum* alone is responsible for photosensitization in signal grass are: In South America, different strains of *P. chatarum* were isolated from *Brachiaria* pastures where cattle had exhibited toxicity, but no strain had produced sporidesmin (Brewer *et al*., 1989). In New Zealand, a high correlation between spore count in the pasture and toxicity (facial eczema) exists in sheep (Brook, 1969), but this does not appear to be the case in South America (Avcardi, 1994). In Malaysia, sheep developed photosensitivity when fed hay or fresh signal grass. However, liver damage was not observed when grass litter, ideal for fungal growth, was fed (Abas and Sharif, 1988). The pathology of animals poisoned with signal grass is similar to that found in animals grazing *Panicum species* not infected with *P. chatarum* (Graydon *et al*., 1991). Steroidal saponins were isolated from the rumen contents of poisoned sheep fed *B. decumbens* (signal grass) (Lajis *et al*. 1993; Salam *et al*. 1992). In

addition, steroidal saponins were identified in several plants known to cause photosensitization (Miles *et al*. 1993), and the toxicity symptoms were reproduced in sheep through oral dosing of crude saponins extracted from the plant *Tribulus terrestris* (Zygophyllaceae) (Kellerman *et al*. 1991 and Lascano and Euclides, 1996). Clearly, more study is needed on the role of steroidal saponins in hepatogenous photosensitization in livestock and their possible interaction with *P. chatarum* and other fungi (endophytes) that may be present in *B. decumbens* and other *Brachiaria* species. Even if photosensitization in ruminants and horses is not caused primarily by *P. chatarum*, the presence of fungal spores may exacerbate the toxicity (Smith and Miles, 1993; Lascano and Euclides, 1996).

2.20 Nutritional value of Cotton Seed Cake

The main by-product of interest in animal feeding obtained from the cotton plant is cotton seed cake, which is a by-product of cotton oil extraction from ginnery or oil extraction companies. Relative to groundnut cake, Cotton Seed Cake is cheaper as a standard protein supplement.

The nutrient content of Cotton Seed Meal or Cake varies depending on the process used in extracting the oil. Compared to those produced 25-30 years ago, cotton seed meals produced today are shown to be higher in crude protein, magnesium, potassium, copper, manganese and are lower in crude fibre. Generally speaking, the major effect of extraction process is on the fat content. As a rule, the mechanically extracted cotton seed meal tends to have higher residual oil content than either the pre-pressed solvent or direct solvent extracted cotton seed meal (Calhoun *et al*., 1995). The crude protein content of pre-pressed and direct solvent extracted cottonseed meal varies between 41 – 45% depending on the method of extraction (NRC, 1998). According to Tanksley (1990), the most common is 41% crude protein products even though some official feed definitions require a minimum of 36% crude protein for both the cake and meal cotton seed

products. Some workers have reported values between 24 and 26% crude protein content for undecorticated cotton seed cakes and meals (Balogun *et al*., 1990; Aduku, 1992; Lamidi, 2006). Cotton seed cake is high in lysine and it is also adequate in other essential amino acids. The following ranges of percentage values had been recorded for arginine-4.40-6.63, lysine-1.57-1.79, methionine-0.62-0.73, cysteine-0.64-0.78, tryptophan-0.51-0.57, threonine-1.44-1.52, iso-leucine, 1.27-1.56, leucine-2.50-2.74, histidine, 1.15-1.45, and valine-1.80-2.05% (NRC, 1998).

The energy content of Cotton Seed Cake depends on the method of oil extraction of the whole cotton seed, the meals produced by the mechanical oil extraction. The range values of 4200-4600 kcal/kg have been reported for gross energy of cotton seed meal samples (NRC, 1998; NCPA, 2002).

Analysis have shown that the fat and crude fibre contents of cotton seed meal samples ranged between 4.0-9.6% and 10.2-18.4% respectively, while the ash content is between 6.2 and 6.8% (NRC, 1998; NCPA, 1999). Cotton seed meal is said to be rich in phosphorus with values ranging between 1.14 and 1.20%. The values of various minerals recorded for samples of cotton seed meal are calcium-0.16-0.22%, magnesium-0.56-0.66%, Iron 0.01-0.03%, potassium 1.40-1.68% and sodium 0.04-0.14% (Ranjhan, 1990; NRC, 1998; NCPA, 1999). Its gossypol content ranged from 0.03 to 0.2 % which has a toxic effect on monogastric animals but less effect on ruminant animals.

2.20.1 Effects of processing of whole cotton seed and its gossypol content

Currently, there are three methods of processing cotton seed meal or cake from whole cotton seeds namely mechanical extraction (screw processing), pre-pressed solvent extraction and direct solvent extraction. These methods use different temperatures, pressures and cooking times. All the three forms of cotton seed meal produced have similar nutritional values (Jones, 1981;

Goetch and Owens, 1985). Jones (1981) and Roger *et al.*, (2002) stated that when cubed or pelleted, Cotton Seed Meal is also known as Cotton Seed Cake. The cake is the residue of mechanical extraction and retains higher oil compared to the meal. During processing, the rupture of the pigment glands containing the gossypol and other complex polyphenols allow the binding of these highly reactive compositions of gossypol which has combined with the sulphur containing amino acids in protein during condensation of gossypol which is known as bond gossypol while the remaining uncombined gossypol is called free gossypol (Bernard and Goldblatt, 1969).

2.20.2 Effects of mineral supplementation on toxicity of gossypol in Nutrition

Efforts have been made to minimize these effects by various treatments such as moist cooking, supplementing the diet with minerals and feeding high level of protein (Hale *et al.,* 1958). Results from previous studies indicated that calcium and Iron have some detoxifying effects on gossypol (Bressani *et al*., 1966). These effects according to Smith (1965) can be critically evaluated since methods are now available for the determination of free and bound gossypol in the tissues of animals. According to Phelp *et al*., (1965) and Brahma *et al*. (1967) several iron salts had been used successfully in counteracting the undesirable gossypol effect in earlier studies.

2.21 Palm Kernel Cake/ Meal

Two species of the *Elaeis* genus are cultivated for oil production, the African oil palm *Elaeis guineensis* Jacq. (West African origin) and the American oil palm, *Elaeis oleifera* (Kunth) Cortés (South or Central America). *Elaeis guineensis* is the most productive species (5-7 *vs* 0.5 t

oil/ha/year) and the one generally used for oil production, though some interspecific hybrids have been developed for this purpose (Prabhakaran Nair, 2010; Teoh Cheng Hai, 2002).

Palm kernel meal also known as palm kernel cake is an important feed ingredient and the by-product of the oil palm (*Elaeis guineensis* Jacq.), a palm tree cultivated for its oils rich in highly saturated vegetable fats. The palm oil extracted from the fruit flesh and the palm kernel oil extracted from the fruit kernel. Palm oil is both a major staple oil - a "poor man's cooking oil" common in Southeast Asia and tropical Africa - and an indispensable ingredient for the food industry (Prabhakaran Nair, 2010). It has also numerous non-food applications, including as biodiesel. Palm kernel oil, which is semi-solid at room temperature, is less important economically. The demand for palm oil, fueled by the growth of Chinese and Indian economies, has been growing fast since the 1990s: palm oil production doubled between 1996 and 2005 and increased yearly by 10% during the 2000s. Palm oil overtook soybean oil in 2004 to be the world's leading vegetable oil (45 million t in 2010). The production of palm kernel oil, while less important (5.6 million t in 2010) overtook that of groundnut oil in 2007 (FAO, 2012).

Fetuga *et al*. (1977), in detailed studies including chemical assays, described PKM as being a good source of methionine and cystine but marginal in lysine. Analysis at the Nutrition Laboratory of KNUST indicated that such dried PKM contains 91.04% dry matter, 19.02% crude protein, 23.3% fat and 5.68% ash. This shows that it could be a good source of protein and energy for poultry. Okai *et al*. (1994) observed that fresh PKM could easily go mouldy and rancid if it is not fed within a short time (about a week) because of its high moisture content.

2.21.1 Nutritional value of Palm Kernel Cake

Palm kernel cake is a common feed ingredient, particularly in ruminant feeding. It is the less nutritionally valuable of the major oil meals due to its low protein content (14-20% DM), lower than copra meal and its high quantities of cell wall constituents (crude fibre 14-28%; NDF 60-80%; ADF 35-50%; Lignin 10-18% DM). The range of values for mechanically extracted palm kernel meal are: lysine (2.0-3.8%), Methionine (1.0-2.7%), Cystine (0.7-1.0%), iso-leucine (2.9-4.2%) and leucine (5.3-7.2%) (NRC, 2002). The proportion of lignin in the cell walls of palm kernel meal (18% of NDF) is higher than in copra meal (13% of NDF). For those reasons, its nutritive value is inferior to that of the main oil meals notably soybean meal, groundnut meal and cottonseed meal. Unlike those products, palm kernel meal is often obtained from mechanical extraction (expeller meal) and its oil content is quite high (6-15 % DM). The less common solvent-extracted palm kernel meal contains less oil (about 3 % DM) and slightly more protein (19% *vs* 17% in average) than the expeller meal, but the cell wall constituents and minerals are only slightly affected by the extraction process.

Palm kernel meal is dry and gritty and is not readily accepted by ruminants and pigs. However, as it is mainly used in compound feeds, its lack of palatability is of less importance (Göhl, 1982). The following significant relationships between NDF, ADF, and crude fiber content have been established (the slopes are identical for palm kernel meal and copra meal but the intercepts are different as palm kernel is significantly richer in cell walls) (O'Mara *et al*., 1999, Carvalho *et al*., 2005).

- NDF = 63.3 + 0.49 x CF (N = 150, RSD = 6.1% DM)
- ADF = 31.9 + 0.65 x CF (N = 138, RSD = 4.8% DM)

2.21.2 Digestibility and energy value of Palm Kernel Cake

The in *vivo* organic matter (OM) digestibility of palm kernel has been found to be extremely variable (OMD = 68.6 ± 5.3%, N=22 from data pooled by Feedipedia). Tables have proposed diverse estimations for the in *vivo* OM digestibiltiy of expeller meal, including 68% (INRA-AFZ Tables, Sauvant *et a*l., 2004), 73% (Schiemann, 1981) and the quite high 77% (Jentsch *et al*., 2003). The expeller meal, possibly due to its higher oil content, is generally considered to be more digestible than the solvent-extracted (73 *vs* 67%, Schiemann, 1981; 77 *vs* 75%, Jentsch *et al*., 2003). Somewhat imprecise relationships between OM digestibility, NDF and ADF can be established by pooling together samples of palm kernel and copra meal (the regression coefficients are not significantly different between the two products) (Carvalho *et al*., 2005).

- OMD = 100.6 - 0.418 NDF % DM (n=27, R^2= 0.40, RSD=4.7)
- OMD = 94.4 - 0.510 ADF % DM (n=26, R^2= 0.59, RSD=4.0)

These OMD values result in ME estimates of 11.6 and 10.7 MJ/kg DM for expeller and solvent-extracted palm kernel meal respectively. Compared with copra meal, corn distillers dried grains and corn gluten feed, the low energy value of certain palm kernel meal could limit its inclusion in diets for high-performance ruminants (Carvalho *et al*., 2005).

The prediction of palm kernel meal digestibility by *in vitro* methods is not accurate and underestimates *in vivo* digestibility including with procedures involving enzymes (gammanase) or rumen fluid (Dowman, 1993; O'Mara *et al*., 1999). This problem is due to the presence of galactomannans which are not readily hydrolyzed by the enzymes in the cellulase preparation. Palm kernel meal is after guar gum, the feed ingredient that is the richest in non-starch polysaccharides (NSP) and galactomannans. This may also explain the fact that palm kernel meal

studied *in sacco* in the rumen has a particularly long lag phase which can exceed 10 hours before the onset of cell wall degradation (Sauvant *et al*., 1986; Hindle *et al*., 1995; Chapoutot *et al*., 2010). This fermentation pattern suggests that the effective ruminal digestion of palm kernel meal is particularly sensitive to transit outflow rates. After the lag phase, cell wall degradation becomes important and palm kernel meal can be considered to be a source of highly digestible fibre, like copra meal, soybean hulls and maize bran (Sauvant *et al*., 1986; Chapoutot *et al*., 2010). The rumen undegradable fraction of cell wall components varied between 23 to 37% as reported by Steg *et al*. (1993) but a higher value (47%) has been proposed by (Chapoutot *et al*., 2010).

Due to its low degradation rate in the rumen, palm kernel meal is not considered to be acidogenic and its inclusion up to 55% of DM intake had no detrimental effect on rumen conditions in goats (Chanjula *et al*., 2009). Moreover, the supplementation of low quality hay with palm kernel meal or copra meal improved the production of microbial proteins in the rumen (Marsetyo, 2007).

2.21.3 Protein value of Palm Kernel Cake

Although Palm Kernel Cake supplies both protein and energy, it is looked upon more as a source of protein. The fraction of rapidly fermentable N in the rumen is low (15-16%) (Sauvant *et al*., 2004; Woods *et al*., 2003a) and the effective degradability of protein generally considered to be low, in the 40-50 % range (Carvalho *et al*., 2009; Sauvant *et al*., 2004; Woods *et al*., 2003a; Hindle *et al*., 1995; Umunna *et a*l., 1994) or even lower (34%) (Promkot *et al*., 2007). The intestinal digestibility by-pass protein, which is generally lower than 80%, is not particularly high compared to other feeds (Carvalho *et al*., 2005; Sauvant *et al*., 2004; Woods *et a*l., 2003b)

though higher values (83-92%) have been proposed (and correlated to *in vitro* pepsin digestibility (Steg *et al*., 1993).

2.21.4 Copper toxicity in sheep fed with Palm Kernel Cake supplement

Palm kernel meal contains 20-30 ppm of copper (APOC, 2006). Sheep are very sensitive to copper and levels as low as 25 ppm in the diet can be toxic to them (Schoenian, 2009). Palm kernel cake is fed in excess (90% dietary level) to sheep is known to cause chronic copper toxicity and death due to hepatic necrosis. When palm kernel cake is fed at lower levels (60% dietary level) to rams, it results in spermatogenesis problems and other reproduction deficiencies (Yaakub *et al*., 2008). Supplementing diets with sodium molybdate may alleviate copper toxicity since Mo forms insoluble complexes with Cu and prevents copper absorption (Schoenian, 2009; Akpan *et al*., 2005). Zinc is another antagonist to copper absorption but zinc supplementation may result in high zinc concentration in blood, liver and kidneys. Phytase supplementation may be a complementary way of preventing copper toxicity as it enhances zinc availability in sheep (Akpan *et al*., 2005).

2.21.5 Supplementation of Palm Kernel Cake to sheep

Palm kernel meal is mostly used to feed ruminants. In spite of a nutritional value lower than that of other meals, it remains a source of protein and energy and its cost may make it particularly attractive when compared to more expensive ingredients such as maize grain and soybean, and it can often partially replace them when economic conditions allow it. Supplementation with up to 30% of palm kernel meal in sheep fed koronivia grass (*Brachiaria humidicola*) did not induce any physiological or nutritional damage and increased ADF digestibility (Costa *et al*., 2010). The partially substitution of maize grain and soybean meal with palm kernel meal was found to be

suitable in sheep fed ammoniated elephant grass silage (*Pennisetum purpureum*) (Silva *et al.*, 2007). In growing sheep fed native hay, increasing the inclusion rate of palm kernel meal in the supplement diet up to 90% did not significantly affect performance and decreased the feed cost, making the substitution of maize grain and oil meals by palm kernel meal economically attractive (Umunna *et al*., 1994). In grazing hair ewes, including up to 30% palm kernel meal in the supplement in partial substitution of maize grain did not alter reproductive performance (Luna Palomera *et al*., 2010). Supplementation with zinc and phytase prevented chronic copper toxicity West African Dwarf sheep fed palm kernel meal (Akpan *et al.*, 2005).

2.22 Brewers Dried Grains (BDG)

Brewers dried grains, brewer's yeast, and distillery wastes after fermentation of substrates are available as by-products of breweries and distilleries. Brewers Dried Grain (BDG) is solid waste from the brewery industries. It is available and cheap but difficult to dry to low **moisture content** for easy storage and use, especially during the wet seasons. Brewer's grains are the most extensively used brewers' by product and potential feed source for livestock keepers residing near breweries (Ulfina *et al*., 2013). Brewer's grains are considered to be good sources of un-degradable protein and water-soluble vitamins. They have been used in feeding ruminant and monogastric animals (Blezinger, 1998). Brewers dried grains are bulky in the wet form, high in crude fibre (about 21%) and moderate in protein (about 22%), they are also highly digestible and may be used for all classes of farm animals (Kwari *et al*., 1999; Oluponna *et al*., 2002). Brewers grains are the solid residue left after the processing of germinated and dried cereal grains (malt) for the production of beer and other malt products (malt extracts and malt vinegar). Though barley is the main grain used for brewing, beers are also made from wheat, maize, rice and sorghum. In the brewing process, grains are soaked in water until they germinate and then dried

to produce the malt (malting). The malted grain is milled and steeped in hot water so that enzymes transform the starch into sugars (mashing/saccharification). The resulting sugar-rich liquid (wort) is then boiled, filtered and fermented to produce beer. Brewers grains are collected at the end of the mashing process, once all sugars have been removed from the grain. The remaining product is a concentrate of proteins and fibre that is suitable for animal feeding, particularly for ruminants (Crawshaw, 2004). Brewers grains are a highly variable byproduct whose composition and nutritional value depend on the grain used, on the industrial process (temperature, fermentation...) and on the method of preservation. Brewers grains are sold wet or dried and can be ensiled (Blezinger, 2003).

2.22.1 Distribution of Brewer's Dried Grain

Brewer's grains have a long history in animal feeding. Before the industrial revolution, farms and monasteries in Europe brewed their own beer and fed their livestock with the resulting byproducts. These practices changed with the industrialization of brewing and animal feeding and brewer's grains began being used by the feed industry (Crawshaw, 2004). In 2011, world beer production was about 185 million t (21% in the EU) (FAO, 2013). Since brewery by-products represent about 20% of beer production (Mussatto *et a*l., 2006), world brewer's grains production should be in the range of 35-40 million tons (8 million t in the EU). These estimates are relatively imprecise, as conversion ratios between grain, malt, beer and brewer's grains depend on the type of beer and on the process. In temperate countries, brewer's grains are mostly produced during the warm season, when beer consumption is higher. This means that they are less available for livestock in the colder months when feed supplementation is more needed. Drying or ensiling is therefore necessary to defer the utilisation of brewers grains (Boessinger *et al*., 2005).

2.22.2 Nutritional attributes of Brewer's Dried Grains

Brewer's Dried Grains are used to feed ruminant and monogastric animals. They are palatable and readily consumed when in good condition. There is wide variability in the **proximate composition** of BDG depending on the brewery that produced it (Oyediji, 2001). Breweries in Nigeria presently use maize and sorghum in combinations, which vary from one brewery to another (Oluponna *et al*., 2002). This, therefore, has resulted in the production of BDG with variable physical and **chemical composition** (Oluponna and Balogun, 1996). BDG contains about 19-25% **crude protein** (Kwari *et al*., 1999; Oluponna *et al*., 2002), 10-22% crude fibre (Kwari *et al*., 1999; Oluponna *et al*., 2002), ME of 7.38 MJ/kg (Dogari, 1985) and gross energy value of 3030-3170 kcal/kg (Oluponna *et al*., 2002).. The protein value can be affected by the heat applied during the brewing process, which can be beneficial to ruminants but tend to be detrimental for monogastric animals. Brewer's grain are also relatively rich in fibre (ADF 17-26% DM), which makes them suitable for ruminants fed concentrate-rich diets, but less so for pigs and poultry (Crawshaw, 2004).

2.22.3 Digestibility and energy value of Brewer's Dried Grains

Values of organic matter (OM) digestibility found in the literature are quite variable and range from 55 to 75%. Feed tables from different regions report OM digestibilities from 59% to 67% (Sauvant *et al*., 2004 ; Beyer *et al*., 2003; MTT, 2013; Volden, 2011). It should be noted that chemical composition is not a significant predictor of OM digestibility in brewer's grains (Sauvant, 2013). Dried brewer's grains are sometimes reported to have a lower OM digestibility than wet brewers grains (59 *vs* 63%, MTT, 2013; 64 *vs* 66-67%, Beyer *et a*l., 2003), which is

probably due to the heat treatment. On the other hand a higher drying temperature (240° *vs* 180°) was found to slightly increase the *in vitro* digestibility of brewers grains (Mesgaran *et al*., 2011).

The energy value for dried brewer's grains, expressed as Net Energy for lactation, ranges from 5.8-6.0 MJ/kg DM (Sauvant *et al*., 2004; MTT, 2013) to 6.4-7.0 MJ/kg DM (Volden, 2011), or even 7.8 MJ/kg DM (NRC, 2001). As a consequence, the value of brewer's grains relative to other feeds is itself variable. For instance, feed tables usually consider brewer's grains as a better ingredient than tomato pomace (Beyer *et al*., 2003; NRC, 2001) but one study found the opposite (Aghajanzadeh-Golshani *et al*., 2010).

2.22.4 Protein value of Brewer's Dried Grains

Brewers grain have a good protein value for ruminants and their protein is less ruminally degradable than that of other plant-derived feeds. Brewer's grains are thus often used in ruminant productions with high requirements in by-pass protein, such as high-yielding dairy cows. The effective nitrogen degradability of brewer's grains reported in feed tables and in the scientific literature is about 41-49% (Sauvant *et al*., 2004 ; Batajoo *et al*., 1998 ; Nishiguchi *et al*., 2005 ; Volden, 2011 ; Promkot *et al*., 2007). These values are lower than those of soybean meal and cereal by-products (Sauvant *et al*., 2004; Volden, 2011; Nishiguchi *et al*., 2005), though in one case the protein of distillers dried grains was found less degradable (Batajoo *et al*., 1998). Nitrogen degradability depends on the amount of heat used during the drying process: in one experiment, the amount of protein by-pass doubled when temperature rose from 50° to 135°C (Pereira *et al*., 1998). Heating also decreases protein solubility while increasing the insoluble ADF-bound nitrogen fraction (Enishi *et al*., 2005). Values for the intestinal digestibility of nitrogen range from 74% (Yue Qun *et al*., 2007) to 84% (Sauvant *et al*., 2004), which is much

lower than the values reported by these authors for soybean meal, corn gluten meal and maize distillers grains (> 90%). As usual for cereal grains and their by-products, lysine is the first limiting amino acid in brewers grains used for high yielding ruminants, so it needs to be blended with sources of by-pass protein richer in lysine.

2.22. 5 Feeding sheep with Brewer's Dried Grain

Recommended inclusion rates of brewers dried grains in lambs depend on the source. While some authors discourage it's use (Ewing, 1997), the scientific literature is more positive. In Italy, feeding dehydrated brewers grain to lambs up to 40% of the diet (diet DM) resulted in good growth performance, feed conversion ratio and in fatter carcasses (Bovolenta *et al*., 1998). In tropical and subtropical areas, high inclusion rates have been used in growing sheep without depressing performance or digestibility: 50% of dried brewers grains in the concentrate in Irak (Baghdassar *et al*., 1986), 60% (diet DM) of wet brewers grains in Mexico (with no change in ruminal pH and molar proportions of VFA) (Aguilera-Soto *et al*., 2007), 67% of wet brewers grains associated with Bermuda grass (*Cynodon dactylon*) hay in Brazil, though it decreased DM intake (Cabral Filho *et al*., 2007).

In Nigeria, the inclusion of 64% of dried sorghum brewers grains resulted in higher growth performance than a diet based on maize bran, but adding urea to the latter diet gave similar performance (Olorunnisomo *et al*., 2006). In another Nigerian trial, the optimal inclusion rate was 45%, as a 60% rate reduced intake and caused digestive problems (Anigbogu, 2003). In Brazil, wet brewers grains included at 30%, partially replacing maize grains, resulted in lower performance and feed efficiency than dehydrated citrus pulp (Gilaverte *et al*., 2011).

CHAPTER THREE

3.0 MATERIALS AND METHODS

EXPERIMENT 1

3.1 Experimental site

Experiment 1 was carried out at the National Animal Production Research Institute (NAPRI), Shika, Zaria. Shika is located at 22km North-west of Zaria, in the Northern Guinea savanna and lies between latitudes (11^0 and 12^0N) and longitudes (7^0 and 8^0E) with an altitude of 660m above sea level (Ovimaps, 2012).

3.2 Climate

Shika has characteristics of the Northern Guinea savanna ecological zone with a well defined dry and wet season. The wet season starts from April or early May and ends in late September or early October. The long-term total annual rainfall ranges from 1,110 to 1,580mm. Most of the rain falls between July and September. The maximum temperature for the period (April to October) recorded at Samaru about 10km northeast of Shika showed that the highest maximum temperature of about 30^oC. The relative humidity in the months of July and August is about 70% (I.A.R, Samaru weather station, 2012).

3.3 Soil samples of the Experimental plot

A composite soil sample was taken from the experimental plots using a soil auger to collect soil samples to a depth of 15-20cm. The soil samples was analysed for texture, particle size, nitrogen, phosphorus, soil pH and cations exchange capacity (CEC) (NAPRI field study, 2013).

3.4 Experimental design for *B. ruziziensis*

Experiment 1 was laid out in a Completely Randomized Design (CRD) with six replicates. *B. ruziziensis* grass was planted as a sole crop, at an intra row spacing spacing of 1m and inter row spacing of 0.5m. The pasture was sampled at 4, 6, 8, 12, 18 and 24 weeks post-emergence to determine various agronomic parameters.

3.5 Data collection and parameters taken

I) ***Establishment*:**

Seedling counts were made 4 and 8 weeks after the first rain to give an estimation of emergence.

1. The total number of seedlings in a row was counted to determine plant density per square meter.
2. Estimate of the soil cover (percentage of the plot covered by the plants).

II) ***Fresh fodder yield/Biomass production*:**

1. At 6, 12, 18 and 24 weeks after the first rain, the number of plants was counted and samples of the plant were cut at 10-15cm above the ground.
2. Prostrate species were cut at a height of 5-10cm and erect or semi-erect species 10-15cm above the soil.
3. Total fresh weight of the material cut was weighed immediately (Tot F.W.) to determine the biomass/fresh fodder yield.
4. Accurately weighing of 150-200g sub-samples of fresh material (FWss), oven dry it at 65^{o}C and re-weighed (DWss) to give an estimate of the dry matter production during the period.

Dry matter production was calculated as:

$$Dry\ matter(\ kg/ha) = \left[\text{Tot. FW} \times \left(\frac{\text{DWss}}{\text{FWss}}\right)\right] \times 10$$

Where:

Tot. FW= Total fresh weight from $1m^2$ in g

DWss = Dry weight of the sub-samples in g

FWss = Fresh weight of the sub-samples in g

Experiment 2

3.6 Feed intake and Nutrient utilization by Yankasa sheep

In Experiment 2, the feeding trial and nutrient digestibility study was conducted at SAJ Integrated Farms Limited, Kudungi, Shika-Zaria. Sixteen animals (16) comprising 8 males and 8 females were randomly allotted to 4 treatments diet with 4 animals per treatment (2 males and 2 females) in a Randomized Complete Block Design (RCBD).

The treatments diets were;

Treatment 1 (grass *ad libitum* + Cotton Seed Cake 250g),

Treatment 2 (grass *ad libitum* + Palm Kernel Cake 450g).

Treatment 3 (grass *ad libitum* + Brewers Dried Grain 400g) and

Treatment 4 (grass *ad libitum* only).

3.7 Animals and their management

Experimental animals were allowed 14 days to adjust to feed and confinement before the actual start of the experiment. Sixteen (16) Yankasa sheep weighing between 18.5 and 21.5kg and aged 9-12 months were used. During the adjustment period, the animals were de-wormed with *Albendazole* de-wormer against internal parasites. The animals were fed supplements at 3% body weight, while *Brachiaria ruzizensis* hay, water and mineral *salt lick* were provided *ad libitum.*

3.8 Growth study and data collection

The animals were kept in individual pens with sufficient ventilation. Each animal was offered supplement daily in 2 allocations, at 8:00 a.m and at 6:00 p.m. The supplements were fed 30 minutes before the basal feed was given and thereafter, the basal feed was fed *ad libitum*. The left-overs were collected the following morning and weighed before fresh feed was offered to determine the feed intake. Animals were provided with fresh drinking water in a graduated plastic container. The amount of water consumed by each animal daily was also measured and recorded.

The animals were weighed at the beginning of the experiment and subsequently at weekly intervals up to the 10^{th} week using a Walk in weigh-bridge. Feed and water intake were determined by calculating the difference between quantity offered and the left over.

3.9 Chemical analysis

Dry samples of *Brachiaria ruzizensis* and supplements were analysed at the National Animal Production Research Institute (NAPRI) Central Laboratory for the determination of proximate composition. Samples collected were oven-dried to a constant weight at 105^0C to determine the

dry matter and thereafter the sample was ground to pass through 1-mm sieve for later use. Crude protein, crude fibre, ether extract and ash content of *B. ruziziensis* and the protein supplements were determined by (AOAC, 2001). The crude protein was calculated (by multiplying the Nitrogen value in feedstuffs by 6.25% protein co-efficient) and the crude fibre component was determined by the method of (Van soest, 1991).

3.10 Digestibility study

The Digestibility study commenced at the end of the feeding trial. The trial was done in two batches (due to shortage of the crates) following a 7 days adjustment and 5 days collection period bringing the duration of the digestibility studies to 21 days. In each batch, eight (8) rams, two rams from each treatment were selected and confined in a metabolic crate. Feed offered and left over were weighed daily, the urine was collected daily in a plastic containing 2ml of 0.1M of concentrated sulphuric acid (diluted) while the total faecal output was collected daily, weighed and sub-sample taken for chemical analysis.

Feed samples collected were oven-dried at 70^0C to constant weight. The samples were ground using a hammer mill which will pass through 1-mm sieve. The samples were preserved in sealed bottles and kept in a dessicator. Proximate composition: Crude protein (CP), crude fibre, ether extract and ash were carried out using the method of AOAC (2001).

3.11 Statistical analysis

Data collected was analyzed using Analysis of Variance (ANOVA) by General Linear Model (GLM) Procedure of Statistical Analysis System (SAS) version 9 (SAS, 2005). The treatment means were separated and compared using Duncan's Multiple Range Test. Using the procedures for regression of SAS (2005), the Co-efficient of various parameters measured (plant height

(cm), tiller number per plant, leaf number per tiller and per m^2, leaf-stem ratio, dry and fresh forage yield) as well as the prediction equation for various weeks were computed. A simple linear regression model was used and is given as;

$y = a + bx$

Where y= Parameters measured (Response variable)

a= Intercept

b= Slope and

x= Co-efficient or explanatory variable (weeks)

The model of the experiment is;

$X_{ijk} = \mu + \alpha_i + \beta_j + e_{ijk}$

Where X_{ijk}= Any observation

μ= Population mean

α_i= Treatment effect

β_j= Block effect

e_{ijk}= Random error

3.12 Cost benefit analysis

The cost of *Brachiaria ruzizensis* forage per kilogram was estimated based on the total expenditure used in production of the grass, including fertilizer, pesticide and labour cost. *B. ruziziensis* was harvested from a 0.5ha land area. After drying, 28 bags were obtained from the harvested grass, each bag weighed 12kg, making a total of 336kg dry weight of *B. ruziziensis* harvested. This was divided by the total cost of production (□4000) from 0.5ha of *Brachiari*a *ruziziensis* to obtain □12 as the cost per kg of *B. ruziziensis* grass. CSC, PKC and BDG at the time of this study were purchased at □50, □40, □35 per kg, respectively

The current market cost of the various feed ingredients was used to compute feed cost per kilogram, while the cost of total feed consumed and cost per kilogram gain were calculated. The cost of feeding an animal in Naira (□) was calculated from the total dry matter intake (kg) of both the basal diet (*B. ruziziensis*) and the protein supplement put together for the whole period of the experiment (90 days). The total basal dry matter intake (kg) per animal for the period of the study was multiplied by the cost per kg of *B. ruziziensis* (□12) while the total supplement intake (kg) per animal for the period of the study multiplied by the cost per kilogram (□) of the supplement taken in each treatment to determine the cost of feeding an animal in each treatment for the study period..

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Shika Climate

Shika has characteristics of the Northern Guinea savanna ecological zone with a well defined dry and wet season, the wet season starts from April and ends in early October. Table 1 shows the climate for year 2012 preceding the year of the study (2013). The review by Loch (1977) implicates a humid tropical climate with 1400mm rainfall annually and not more than a 5 months dry season as most suitable for signal grass. Yet of the promising introduced grasses at Shika, Signal grass has remained green longest and certainly past five (5) of the characteristic 7 months dry season (Akinola, 1981).

Table 1: Temperature, relative humidity and rainfall distribution of the experimental site.

	Max. Temp (^{0}C)[a]		Relative Humidity(%)[a]		Rainfall(mm)[b]	
Months	2012	(2002-2011)	2012	(2002-2011)	2012	(2002-2011)
April	37.8	38.0	20.7	22.8	13.9	41.9
May	35.3	35.2	47.2	51.5	123.3	125.9
June	32.3	31.8	61.1	63.3	162.5	145.9
July	30.2	30.5	70.8	69.5	223.9	229.1
August	30.3	29.6	72.2	73.9	239.9	310.9
September	31.9	31.3	68.2	67.1	113.9	181.7
October	34.0	32.9	64.4	51.6	54.0	68.7
Total	232.8	229.3	404.6	399.7	917.0	1104.1
Mean	33.2	32.7	57.8	57.1	131.1	157.7

Sources: [a] Samaru (Lat. 11^{0}11'N, Long. 07^{0}38'E, Altit. 687m).

[b] Shika (Lat 11^{0}12'N, Long. 07^{0}33'E. Altit. 667m)

(Samaru weather station, I.A.R, 2012)

4.2 Soil characteristics of the study area

Table 2 showed both the soil physical and chemical properties of the study area, National Animal Production Research Institute (NAPRI), Shika, Zaria. The soil analysis was done prior to the start of the study in 2013 at the laboratory of the Department of Soil science, Faculty of Agriculture, Ahmadu Bello University, Zaria.

Table 2: Soil physical and chemical properties of the study area

Properties	Value
Physical properties:	
Particle size:	
Clay (%)	16.01
Silt (%)	9.5
Sand (%)	75.3
pH:	
H_2O	5.74
$Cacl_2$	4.62
Chemical properties:	
Total N (%)	0.084
Organic carbon (%)	0.89
Zn (ppm)	94.1
P (ppm)	8.58
Exchangeable cations (meg/100g of soil):	
Ca^{++}	2.00
Mg^{++}	0.80
K^{+}	0.30
Na^{+}	0.09

NAPRI field study, 2013

4.3 Agronomic studies

4.3.1 Establishment of *Brachiaria ruziziensis* grass

As shown in Table 3, the establishment count for *B. ruziziensis* made at 4 weeks post-emergence showed that there were 54 plants/m^2 and 50 plants/m^2 was recorded at 8 weeks post emergence within a row. Percentage at 4 and 8 weeks were 40% and 65%, respectively ($P<0.05$). The Percentage soil cover at 4 weeks post emergence was 45%, which later increased to about 80% at week 8 ($P<0.05$). Ekanayake *et al*., (1998) reported a marked increase in size of successive leaves (broader leaves) as plant matures, thereby increasing the surface area of soil covered by the leaves.

The height of *B. ruziziensis* at 4 weeks post-emergence was 20cm, which later increased significantly ($P<0.05$) to 60cm at 8 weeks of age. Hazrat *et al*., (2004) found that plant height generally depends on internode expansion which caused increase in height with increase in water depth resulting in taller plant. The result obtained for the number of tillers as shown in Table 3 showed that there were 7 and 9 tillers per plant at 4 and 8 weeks post-emergence ($P<0.05$). The number of tillers recorded at week 4 was 182 while 225 tillers were recorded at week 8. Each tiller at 4 weeks had 1 leaf and at 8 weeks of age had 3 leaves ($P<0.05$). The number of tillers per plant and the number of leaves per tiller were all significantly higher in *B. ruziziensis* grass at 8 weeks post-emergence. Narongrit (1999) reported that the numbers of tillers in plants usually show a general increase at the initial growth stage and then declines at the final growth stage.

There was a difference ($P<0.05$) in percentage greenness between *B. ruziziensis* grass at 4 and 8 weeks post-emergence. Niinemets (2004) reported that leaf greenness tends to increases as the plant age increases due to increase in chlorophyll pigment in leaves. He also reported that plant structural and functional characteristics changes continuously with relative age.

Table 3: Estimation of percentage emergence and establishment of *B. ruziziensis* at 4 and 8 weeks post-emergence.

	Period of estimation		
Parameters	4 weeks	8 weeks	SEM
Greeness (%)	40*	65*	0.21
Soil cover (%)	45*	80*	1.76
Plant height (cm)	20*	60*	0.56
No of plant/m^2	54	50	0.54
No of tillers/ plant	7	9	0.91
No of tillers/0.5m^2	182*	225*	1.76
No of leaves/tiller	1	3	0.05

*= Means significant at P<0.05

4.3.2 Yield components of *Brachiaria ruziziensis* grass

Table 4 shows the result of yield components of *B. ruziziensis* at 6, 12, 18 and 24 weeks post-emergence. The result showed that plant height of *B. ruziziensis* ranged from 30 to 135cm at 6 weeks and 24 weeks post-emergence, respectively (P<0.05). The number of tiller per culm was highest at week 24 and lowest at week 6 (P<0.05). The number of leaves per culm at both week 6 and 12 did not differ significantly (P>0.05) from each other, but differed significantly from values obtained for week 18 and 24. The value for percentage green leaves per total leaves ranged from 60 to 95% at week 6 and week 24, respectively. The percentage of green leaves in week 18 and week 24 were not significantly different (P>0.05). The increase in green leaves was due to the defoliation frequency decrease due to increase in weeks post-emergence (Narongrit, 1999). The leaf-stem ratio was highest at week 6 (1.5:1) and lowest at week 18 and 24 (1.2:1).

The leaf to stem ratio was highest (P<0.05) at week 6 and declined (P>0.05) to 1.3 at week 12 and further to 1.2 at weeks 18 and 24 as shown in Table 4.

The results obtained for fresh fodder and dry matter yield showed a significant increase (P<0.05) in yield of *B. ruziziensis* grass from week 6 to week 24 post-emergence. Fresh fodder yield ranged from 8.0 ton/ha to 32 ton/ha in week 6 and week 24 respectively while the dry matter yield was lowest at week 6 (5.71t/ha) and highest at week 24 (11.58t/ha). The dry matter yield at week 24 was significantly (P<0.05) higher than the yields at week 6, 12, and 18, respectively. This indicated that the stage of growth influenced the yield of plant (Mickan, 2006) and hence, the increase in dry matter yield as the plant age increased. The result for dry matter yield obtained in this study at 24 weeks was higher than 4.2t/ha obtained by Ezenwa *et al*., (1996) for *Brachiaria ruziziensis* grown in a sole stand with Nitrogen fertilization when harvested at 24 weeks and was within the range of 7.66-11.59t/ha obtained by Pizzaro *et al*., (2013) for Brachiaria hybrids harvested at the same harvest period (week 24).

Table 4: Yield components of *B. ruziziensis* at 6, 12, 18 and 24 weeks post-emergence.

	Period of Estimation				
Yield component	6	12	18	24	SEM
Plant height (cm)	30^{d}	100^{c}	120^{b}	135^{a}	0.03
Tiller (No. /culm)	8^{c}	9^{bc}	10^{b}	12^{a}	0.20
Leaf (No. /culm)	3^{b}	3^{b}	5^{a}	5^{a}	0.20
Green (% of total leaves)	60^{c}	85^{b}	95^{a}	95^{a}	0.18
Leaf-stem ratio	$1.5:1^{a}$	$1.3:1^{b}$	$1.2:1^{b}$	$1.2:1^{b}$	0.02
Fresh fodder yield (t/ ha)	8.0^{d}	20^{c}	25^{b}	32^{a}	0.02
Dry matter yield (t/ ha)	5.7^{d}	6.9^{c}	9.6^{b}	11.6^{a}	0.01

a, b, c= Means in the same row with different superscripts differ significantly (P<0.05)

4.4 Regression analysis for various parameters measured

In Table 5, equations to predict the plant height, tiller/plant, leaf/tiller, tiller/m^2, Leaf-Stem ratio, dry matter and Biomass production of *B. ruziziensis* for various weeks after emergence of *Brachiaria ruziziensis* are given. The regression co-efficient (R^2) ranged from 0.90 for plant height to 0.93 for Biomass production. The Regression analysis summary shows a positive relationship between the parameters measured and weeks post-emergence of *Brachiaria ruziziensis*, indicating that there was a progressive increase in all the parameters measured as the week increased (advancement in period) up to week 24 in the study except for tiller number per plant and leaf-stem ratio which began to decline after week 12. The increase in other parameters relative to week advancement is because plant matures more with changes in rainfall, temperature and sunlight (Minson, 1990). The significant correlation of forage yield with week advancement is attributed to age of plant establishment (Mathias *et al*., 1973) which is also due to increase in photosynthetic rate relative to respiration rate (Mickell *et al*., 1969).

Table 5: Prediction equation for growth and yield of *B. ruziziensis* at various weeks of establishment.

Estimation	Equation	Adjusted R^2	LOS
Plant height (cm)	Y=6.61+5.88x	0.90	*
Tiller/plant	Y=6.40+0.22x	0.72	*
Leaf/tiller	Y=1.04+0.18x	0.72	*
Tiller/m^2	Y=140.7+9.48x	0.85	*
Leaf-stem ratio	Y=1.52-0.014	0.46	*
Dry matter (kg/ha)	Y= 3282.28+346.60x	0.94	*
Biomass (t/ha)	Y=2.48+1.21x	0.93	*

x= Week of sampling, **Y**= Parameter estimated, *= Significant at $p<0.05$

4.5 Feed intake and nutrient utilization studies

4.5.1 Daily ration of feed fed to Yankasa sheep

Table 6 showed the experimental diet rations fed to Yankasa sheep. Crude protein (CP) and digestible dry matter (DDM) are the most important components of a feed (Afzal and Ullah, 2007). Crude protein content from all the diets analyzed met the minimum requirements for production in ruminant animals i.e., for sheep, crude protein requirement is 9.6 % for maintenance, 11.2% for pregnant ewe, 14% for lactation, 11.7% for lamb finishing and 9.1% for feeding of yearlings (NRC, 2007).

Table 6: Experimental diet rations fed to Yankasa sheep during the experimental period

	Treatments			
Feed components	T1	T2	T3	T4
B. ruziziensis	*Ad libitum*	*Ad libitum*	*Ad libitum*	*Ad libitum*
Cotton seed cake (g)	250	-	-	-
Brewer's dried grain (g)	-	-	400	-
Palm kernel cake (g)	-	450	-	-
Bone (g)	0.05	0.05	0.05	0.05
Mineral salt lick	*Ad libitum*	*Ad libitum*	*Ad libitum*	*Ad libitum*
Water (l)	*Ad libitum*	*Ad libitum*	*Ad libitum*	*Ad libitum*
Crude protein (%)	14	14	14	7.58

T1=Treatment 1, **T2**=Treatment 2, **T3**= Treatment 3, **T4**= Treatment 4

4.6.2 Nutrient composition of the basal diet and protein supplements

In Table 7, the dry matter content for the protein supplements ranged between 88.6 and 90.83% while that of the wilted *Brachiaria ruziziensis* was 90.5%. The highest dry matter content in CSC indicates a higher concentration of nutrients for animals on the supplement (CSC). The CP content of PKC used in this experiment was within the CP content range (14.5-19.6%) as reported by (Alimon, 2006).

The crude protein content for cotton seed cake (CSC) was the highest (25.1%) and was similar to the CP of 25.05% obtained by Arigbede *et al.,* 2006 but lower than 36.5% obtained by Nyako *et al*., 2012. The nutritional value of cotton seed cake is affected by plant variety, geographical source, weather, processing conditions and level of endogenous substances (Adegun and Aye, 2013). The lowest crude protein from supplements (18.6%) was recorded for palm kernel cake (PKC) with *Brachiaria ruziziensis* having 7.6% crude protein. Ether extract content obtained from PKC was high (8.20%) and lowest (2.13%) in *B. ruziziensis*. Brewer's Dried Grain (BDG) had the highest ash content (9.2%), which was lowest in PKC (4.53%). The highest Ash content found in BDG supplement shows that the supplement (BDG) is richer in mineral content than other supplements (Chiba, 2009). *B. ruziziensis* grass in this study had an ash content of 6.61%. Linn and Martin (1999) reported that most forage generally has ash content ranging from 3-12%. The highest crude fibre content of 36.2% from this nutrient analysis was obtained in *B. ruziziensis*, followed by BDG (15.82%) while the lowest value of 10.33% was obtained for CSC.

Table 7: **Chemical composition of experimental diets (%) fed to Yankasa sheep.**

	Basal	Supplements		
Chemical component (% DM)	*B. ruziziensis*	BDG	PKC	CSC
Dry matter (%)	90.5	90.00	88.6	90.83
Crude protein	7.58	19.51	18.6	25.05
Ether extract	2.13	6.50	8.20	6.53
Crude fibre	36.2	15.82	12.34	10.33
Nitrogen free extract	58.48	48.97	56.33	51.89
Ash	6.61	9.2	4.53	6.2

CSC= Cotton Seed Cake, **BDG**= Brewer Dry Grain, **PKC**= Palm kernel Cake.

4.5.3 Nutrient and body intake from the experimental diets

Table 8 shows the DM and other nutrients intake of Yankasa sheep fed *B. ruziziensis* with different protein supplements. The dry matter intake (DMI) obtained from *B. ruziziensis* in this study showed that animals on *B. ruziziensis* (control) had the highest ($P<0.05$) DMI (796.4g/day), followed by CSC (769.25g/day) while those on BDG had the lowest DMI (705.9g/day). Values obtained from the consumption of supplements ranged between 180 for BDG to 227.08g/day for CSC and were significantly different ($P<0.05$) from each other. The total DMI from both grass and supplement was lowest (796.4g/day) for sheep on *B. ruziziensis* and highest (996.33g/day) for animals on CSC supplement. Dry matter intake from *B. ruziziensis*, supplement as well as the total dry matter intake for animals on CSC, PKC, BDG were significantly different from each other ($P<0.05$). Crude protein intake from *B. ruziziensis* was between 51.32 for BDG and 55.93g/day for CSC and was not significantly different from each other ($P>0.05$). However, protein intake from supplement (62.63g) as well as total crude protein intake of 118.56g was significantly highest ($P<0.05$) for the animals on CSC followed by

intake of animals on PKC supplement (44.64g and 97.28g) and least for those fed BDG supplement (39.02g and 90.34g) respectively. The crude fibre intake from grass as well as total crude fibre intake was significantly influenced by the treatment. The highest crude fibre intake from supplement ($P<0.05$) was recorded for animals on BDG (31.64g), which was followed by those on PKC supplement (29.62g) while the lowest was recorded for animals on CSC (25.83g). According to Topps (1996), fibrosity of forages indicates the extent to which it can be degraded by rumen micro-organisms.

Nitrogen free extract intakes from grass ranged from 378.14g in BDG to 426.62g in *B. ruziziensis*. Nitrogen free extract intakes from supplement was highest in PKC (135.19g) and lowest in BDG supplement (97.94g) while animals on CSC supplement had the highest total nitrogen free extract (NFE) intake (541.81g) which subsequently declined to 523.03g in PKC and 476.08g in BDG group, *B. ruziziensis* had the lowest total NFE intake (426.62g). The nitrogen free extract intake from grass, supplement as well as the total NFE intake were significantly different from each other. ARC (1984) reported that supplementation of protein based supplement enhances intake and growth performance.

Increase in protein intake will enhance the intake of other nutrients until another factor becomes limiting and this informs the increased intake results obtained by (Abubakar *et al.,* 1998). In this experiment, protein intake for animals on CSC was the highest (118.56g) which was followed by PKC (97.28g) and this must have enhanced DMI in both treatments. The highest DMI of CSC supplementation (996.33g) and also 936.64g for PKC can be explained by the fact that CSC and PKC did not only provide essential nutrients to maintain optional rumen activity but was also more rapidly degraded in the rumen. Low feed intake in animals on BDG (885.9g) could be as a result of low crude protein intake (90.34g) and higher fibre content of BDG (15.82%).

Supplementation of poor quality forages was reported to increase dry matter intake and performance of animals. The increase in dry matter intake by the animals due to increased protein intake as a result of protein supplementation gave higher live weight gain (Ferdous *et al*., 2011). Also, Bailey and Sim (1998) reported a significant ($P<0.05$) increase in organic matter intake (OMI) of sheep supplemented with cotton seed meal than sheep fed only hay.

Daily water intake of rams fed with *B. ruziziensis* grass with different supplements is summarized in Table 8. The results of water intake (1.92-2.27litres) obtained in this study did not agree with the report of Hicks *et al.* (1998) that water consumption increases with increase in DMI. The water intake was similar in all the treatments and is within the range reported by NRC (2007) and Owen (1993) for water intake of rams under varying environmental conditions.

Table 8: Nutrient intake and utilization of Yankasa sheep fed *B. ruziziensis* with protein supplements.

	Treatments Diets				
Parameters	CSC	PKC	BDG	Grass	SEM
DMI from *B. ruziziensis*	769.25^{b}	724^{c}	705.9^{d}	796.4^{a}	0.41
DMI from supplement	227.08^{a}	212.64^{b}	180^{c}	-	1.18
Total DMI	996.33^{a}	936.64^{b}	885.9^{c}	796.4^{d}	0.06
CPI from *B. ruziziensis*	55.93^{b}	52.64^{b}	51.32^{b}	57.90^{a}	0.14
CPI from supplement	62.63^{a}	44.64^{b}	39.02^{c}	-	0.32
Total CPI	118.56^{a}	97.28^{b}	90.34^{c}	57.90^{d}	0.27
CFI from *B. ruziziensis*	307.7^{b}	289.6^{c}	282.36^{d}	318.56^{a}	0.03
CFI from supplement	25.83^{c}	29.62^{b}	31.64^{a}	-	0.03
Total CFI	333.53^{a}	319.33^{b}	314^{c}	318.56^{b}	0.54
NFEI from *B. ruziziensis*	412.08^{b}	387.84^{c}	378.14^{d}	426.62^{a}	0.01
NFEI from supplement	129.73^{b}	135.19^{a}	97.94^{c}	-	0.01
Total NFEI	541.81^{a}	523.03^{b}	476.08^{c}	426.62^{d}	0.10
Water intake (litres/d)	1.92^{b}	2.27^{b}	2.0^{b}	2.0^{b}	0.20

a, b, c= Means in the same row with different superscripts differ significantly (P<0.05)

DMI= Dry matter intake, **CPI**= Crude protein intake, **CFI**= Crude fibre intake and NFEI= Nitrogen free extract intake

4.5.4 Digestibility studies in Yankasa sheep fed *B. ruziziensis* with protein supplements

In Table 9, digestibility of nutrients was high in all the treatment, this could be as a result of adequate protein supplementation in each of the treatments. Abubakar *et al.,* (1998) reported that protein supplementation enhanced digestibility of feeds in animals. Dry matter digestibility was best (P<0.05) in animals on CSC (66.8%) while it was worst for animals on *B. ruziziensis* grass (56.85%). For animals on CSC, digestion of crude protein (71.9%), crude fibre (63.2%) was best

and was significantly higher ($P<0.05$) than values obtained for digestion of animals on other supplement while the lowest crude fibre digestibility (52.9%) was in the control group (*B. ruziziensis*) without any supplement.

Better digestibility in animals on CSC could be as a result of higher crude protein intake while animals on *B. ruziziensis* grass had the lowest digestibility of dry matter (DMD), crude protein (CPD), Crude fibre (CFD) and Nitrogen retention in the body. This could be as a result of its lowest crude protein content and also its highest crude fibre percentage. McDonald *et al.,* (2011) reported that digestibility is much reduced when a ration contains little protein in proportion to the amount of readily digestible carbohydrate, also Nsinamwa *et al*. (2005) concur on the fact that the higher the fibre fractions, the lower the digestibility.. Nitrogen intake and nitrogen retained in the body of animals were highest ($P<0.05$) for animals on CSC (18.97 and 11.8g/day) and lowest for those on *B. ruziziensis* grass (9.26g and 5.12g/day) because of the crude protein intake from the diets.

Table 9: Digestibility Co-efficient of nutrients and nitrogen balance in Yankasa sheep fed protein supplements.

	Treatment Diets				
Parameter	CSC	PKC	BDG	B. ruziziensis	SEM
DMD (%)	66.8[a]	62.38[b]	61.3[c]	56.85[d]	0.01
CPD (%)	71.9[a]	69.03[b]	67.06[c]	66.97[d]	0.01
CFD (%)	63.2[a]	61.0[b]	55.7[c]	52.9[d]	0.07
Nitrogen balance:					
Nitrogen intake (g/day)	18.97[a]	15.56[b]	14.45[c]	9.26[d]	0.01
Faecal nitrogen (g/day)	5.32[a]	4.82[b]	4.76[c]	3.06[d]	0.003
Urinary nitrogen (g/day)	1.85[b]	1.92[a]	1.29[c]	1.08[d]	0.01
Nitrogen retained (g/day)	11.8[a]	8.82[b]	8.40[c]	5.12[d]	0.01

a, b, c= means in the same row with different superscripts differ significantly (P<0.05).

DMD= Dry matter digestibility, **CPD**= Crude protein digestibility and **CFD**= Crude fibre digestibility.

4.5.5 Performance of Yankasa sheep on *B. ruziziensis* with different protein supplements

In Table 10, weight gain was highest (P<0.05) in animals placed on CSC (2.55kg), this could have been due to the highest protein intake obtained from CSC. The live weight gain obtained for CSC in this study was however lower than 3.7kg obtained by Nyako *et al*., (2012) when CSC was fed in combination with *Digitaria decumbens* (pangola grass). Animals on PKC were second in live weight gain (1.9kg), while animals on *B. ruziziensis* had the lowest weight gain (0.91kg). This agrees with Ferdous *et al.,* (2011) who reported that higher levels of concentrate supplementation increases live weight gain. Also, ARC (1984) reported that supplementation of protein based supplement enhances intake and growth performance. For feed conversion ratio, the lower the better and in this study the feed conversion ratio was significantly lowest in

animals on CSC (29.15) and highest in *B. ruziziensis* (52.50), this indicates better efficiency of converting feed to flesh. Cotton Seed Cake contained higher quality protein and crude protein content than the other protein supplements as was obtained from the nutrient and chemical analysis done in this study as shown in Table 7.

Table 10: Growth performance of Yankasa sheep fed *Brachiaria ruziziensis* grass with different protein supplements

	Treatments Diets				
Indices/parameter	CSC	PKC	BDG	*B. ruziziensis*	SEM
Initial live weight (kg)	21.63	22.23	22.19	22.19	1.01
Final live weight (kg)	23.68	24.13	23.74	23.1	1.01
Total Live weight gain (kg)	2.50^{a}	1.9^{b}	1.65^{c}	0.91^{d}	0.07
Daily live weight gain (g)	41.67^{a}	31.66^{b}	27.5^{c}	15.17^{d}	1.12
Feed conversion ratio	29.15^{a}	29.58^{b}	34.30^{c}	52.50^{d}	0.16
Protein efficiency ratio	0.29^{ab}	0.33^{c}	0.29^{ab}	0.26^{a}	0.01

a, b, c= Means in the same row with different superscripts differ significantly ($P<0.05$).

4.6 Economic analysis of *B. ruziziensis* with protein supplements fed to Yankasa sheep

The results in Table 10 show the cost of feeding per animal in the various treatment group during the experimental period (60 days). The cost of feeding an animal differ ($P<0.05$) significantly across the treatments, with CSC group having the highest cost (₦896.82k) which was followed by PKC group (₦812.42) and lowest for animals on BDG supplement (₦746.71k). The highest cost of feeding per animal for the period of the research in animals fed with cotton seed cake supplement can be attributed to the high cost per kilogram of the supplement compared to the

price of the other protein supplements used (PKC and BDG) and also the amount of feed consumed.

The cost of ₦358.73k was spent in attaining a kilogram weight gain for animals in CSC group at the end of the experiment. For animals on PKC supplement, ₦427.59k was spent to attain a kilogram weight gain, while ₦452.55k was spent for animals on BDG supplement in this study.

The cost analysis showed Cotton Seed Cake (PKC) to be cheaper than other protein supplements used in this experiment. The economic analysis showed that while ₦896.82k was spent to achieve a weight gain of 2.50kg in CSC group (treatment 1) for the period of the experiment, ₦1,068.98k would be spent to achieve the same weight gain of 2.50kg for animals on PKC supplement and ₦1,131.38k would be spent per animal on BDG supplement group for 60 days.

Therefore, CSC from this study was found to be more economical in feeding Yankasa sheep to obtain better performance than other protein supplements. This was similar to the result obtained by Nyako *et al*., 2012 when Pangola grass (*Digitaria decumbens*) was supplemented with Cotton seed cake, brewer's waste and maize bran supplements in the diets of Yankasa rams.

Table 11: Economic analysis of feeding different protein supplements to Yankasa sheep

	Treatments diets				
Indices/parameter	CSC	PKC	BDG	*B. ruziziensis*	SEM
DMI from *B. ruziziensis* (g/d)	769.25[b]	724[c]	705.9[d]	796.4[a]	0.41
DMI from supplement (g/d)	227.08[a]	202.64[b]	180[c]	-	1.18
Total DMI (g/d)	996.33[a]	936.64[b]	885.9[c]	796.4[d]	0.06
Total Live weight gain (kg)	2.50[a]	1.9[b]	1.65[c]	0.91[d]	0.07
Daily live weight gain (g)	41.67[a]	31.66[b]	27.5[c]	15.17[d]	1.12
Cost/kg feed (□)	55	40	35	12	0.07
Cost of feeding (□/Animal)*	896.82[a]	812.42[b]	746.71[c]	295.5[d]	5.18
Cost of feed/kg gain (□/kg)	358.73[b]	427.59[c]	452.55[d]	324.0[a]	29.26

*= Cost of feeding an animal for the period of 60 days.

a, b, c= Means in the same row with different superscripts differ significantly (P<0.05).

CSC= Cotton Seed Cake, PKC= Palm Kernel Cake, BDG= Brewer's Dried Grain, DMI= Dry matter intake

CHAPTER FIVE

5.0 SUMMARY AND CONCLUSION

Brachiaria ruziziensis grass has a rapid growth especially in the wet season, it has the ability to grow so well in low fertility acid soils and still able to produce highly nutritious forage for many ruminants (Singh, 2009). In addition, the relative freedom and resistance of *Brachiaria* species from pest and diseases account for much of the current interest in the grass (Lenne and Trutmann, 1994). In general, studies on animal performance and digestibility show that Congo grass (*Brachiaria ruziziensis*) is good quality forage. Those positive attribute of signal grass together with its fast establishment and good seed yield which is viable for planting (a unique attribute which differentiate it from other *Brachiaria* species) could explain its popularity among pastoralist and graziers.

This study has shown that higher forage production potential, higher dry matter yield and biomass production of *B. ruziziensis* are obtained as plant age increased (Mickan, 2006). The dry matter and biomass yield was lowest at the start of the sampling (at week 6) and progressively increased till end of experiment at week 24 post-emergence which had the highest value for both dry matter and biomass yield (11t/ha and 32t/ha respectively). It also showed that cotton seed cake, palm kernel cake and brewers dried grain can be used efficiently as a good source of energy and protein for Yankasa sheep fed with *B. ruziziensis* grass, cotton seed cake supplementation with *Brachiaria ruziziensis* enhanced performance of Yankasa sheep better than PKC, BDG and *B. ruziziensis* without any supplement which was similar to the result obtained by Arigbede *et al*. (2006) when CSC, PKC and BDG supplement was fed in combination with

Panicum maximum basal diet to West African dwarf goats. This indicates a good approach in exploiting the use of local feed resources for ruminant production.

Also, an average daily weight gain of 41.67g was obtained for Yankasa sheep fed *B. ruziziensis* with cotton seed cake supplement compared to 15.17g for those in the control group (fed *B. ruziziensis* grass only). This showed an increase in weight gain (daily and total live weight gain) by 63.59% for animals on CSC supplement over those fed Ruzi grass alone. This would bring about greater economic gain in terms of profit to Yankasa sheep farmers due to increased total live weight gain (TLWG) when animals are supplemented with cotton seed cake relative to lower total live weight and economic gain when fed Congo grass (*B. ruziziensis*) only without any supplement.

5.1 RECOMMENDATION

From the results and findings of this study, it is therefore recommended that *Brachiaria ruziziensis* be harvested as from week 24 after planting for higher dry matter yield and biomass production. Also, *Brachiaria ruziziensis* should be supplemented with cotton seed cake at a rate of 250g/day in two allocations (morning and evening) for better growth and live weight gain in Yankasa sheep. It is also recommended that *Brachiaria ruziziensis* should not be fed in excess to prevent the occurrence of photosensitization in the animals (Abas *et al*., 1983, Salam *et al*., 1988 Fagliari *et al.*, 1991, and Magalhaes *et al*., 1996).

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