PRODUCTIVITY AND QUALITY OF GRASS-LEGUME MIXTURES AND EFFECT OF SOWING DATE OF GRASS ON LEGUME SURVIVAL IN MIXTURES

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DECLARATION

I hereby declare that this work is the product of my research efforts undertaken under the supervision of Dr. Mohammed Baba and has not been presented anywhere for the award of a Degree or Certificate. All sources have been duly acknowledged.

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CERTIFICATION

This is to certify that the research work for this thesis and the subsequent write-up by Aminu Sani Ayuba (SPS/15/MAS/00014) were carried out under my supervision.

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DEDICATION

This research work is dedicated to my father Alhaji Karami Sani Maiturare, mother Hajia Rabiatu Gambo, step mothers, my wife Fatima Ahmad Musa and relatives.

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ABSTRACT

Two studies were conducted at the Livestock Teaching and Research Farm, Faculty of Agriculture Bayero University, Kano. The first study evaluated compatibility of *Panicum mombasa* grass with legumes (*Stylosanthes hamata, Stylosanthes guianensis, Centrosema pubescens, Centrosema pascourum and Alysicarpus vaginalis*).The treatments were monocultures of grass and legumes as well as mixtures of grass with each legume. Both mixtures and monocultures were sown on 1×1 m^2 plots replicated in four blocks in a randomized complete block design with mixtures sown at 2:2 sowing proportion. The second experiment evaluated the effect of sowing date of grass in grass-legume mixtures. The treatment consisted of mixtures of *Sorghum almum-Stylosanthes hamata*, *Sorghum almum-Centrosema pascourum* and *Sorghum almum-Centrosema pubescens* as well as four sowing dates of grass in mixture (0, 1, 2, and 3weeks after sowing of legume). Treatments were combined as 3×4 factorial in a randomized complete block design. Similar to experiment 1 seeds of grass and legumes were sown in 2:2 sowing proportion in an alternate arrangement. The result indicated that *Panicum mombasa-Centrosema pascourum* mixture produced higher dry matter yield (1973.3kg/ha). All mixtures recorded total relative yield value of greater than one suggestive of advantage of mixtures over monocultures. *Sorghum almum-Centrosema pascourum* (31707kg/ha) and *Sorghum almum-Centrosema pubescens* (26309kg/ha) had greater (P<0.05) cumulative dry matter yield than *Sorghum almum-Stylosanthes hamata* (19707kg/ha). Crude protein and digestible dry matter values fallowed a similar pattern. However, dry matter intake and relative feed values were superior (P<0.05) in *Sorghum almum-Centrosema pubescens.* Neutral detergent fiber declined with delayed sowing of grass in mixture while digestible dry matter increased. It can be concluded that *Sorghum almum-Centrosema pascourum* and *Sorghum almum-Centrosema pubescens* produced higher dry matter yields and proved better in quality. However, as a compromise between dry matter yield and quality, *Sorghum almum-Centrosema pubescens is recommended since it had better relative feed value, digestible dry matter and dry matter intake among the mixtures.*

CHAPTER ONE

1.0 INTRODUCTION

1.1BACKGROUND OF THE STUDY

Livestock production is a dominant subset of farming enterprise in the semi-arid and arid regions of Africa. However, livestock keeping in this region is challenged by low availability of grazing resources in terms of quantity and quality during dry season occasioned by cyclical variation in weather and climate. Sabiiti (1992) and (Minson,1982) reported that during the dry season in Nigeria, forage crude protein especially of grass declined to 3% which is below the critical level of 7% recommended by National Research Council (NRC, 1985) for efficient rumen function. This limits feed intake and digestibility with attendant low animal productivity.

Grasses generally have lower crude protein (CP) compared to legumes, the CP content gets even lower below the level that can sustain animal production, hence the need for intercropping grass with forage legumes. One way of improving the grazing potential of natural pastures is to integrate forage legumes into grass pastures, with the aim of increasing species diversity and at the same time increasing the amount of protein available for grazing animals as well as increasing nitrogen uptake by associated forage grass (Macharia, 2003).In recent years, the use of forage legumes in livestock production systems for ruminants in the tropics has increased with benefits such as serving as cover crop for the control of erosion, conversion of atmospheric nitrogen to forms of nitrogen which plants can take up and cycled within the plant-animal-soil system (Tarawali, 1991; Said & Tolera, 1993; Humphreys, 1995). Forage legumes can be grazed, harvested and fed fresh or preserved as hay or silage (Harricharan, Moris & Devers, 1983). A better way to improve the feeding value of these tropical pastures especially for the poor resource small holders is through intercropping grasses with forage legumes; Owing to the fact that use of fertilizers to improve forage yield and utilization of commercial concentrates as livestock supplements are limited as a result inability of farmers to purchase them (Sodeinde *et al*., 2006).The importance of forage legumes in increasing herbage production from grasses and enhancing the quality of feed produced has been recognized (Muinga, Mureithi, Juma & Saha,2007). Legumes benefit grasses by contributing nitrogen to the soil through atmospheric nitrogen fixation, decay of dead root nodules or mineralization of shaded leaves (Aderinola, 2007).

Intercropping forage legume with grasses has been reported to increase forage dry matter yield, forage quality in terms of crude protein content, voluntary feed intake and digestibility (Aderinola, 2007; Akinlade, 2012) as well as improved seasonal distribution of forage (Akinlade, 2012). Legume grown with grasses offer several advantages over grasses grown alone. Legume-grass mixtures have reduced weed encroachment and erosion and have led to greater stand longevity than legume or grass monoculture (Akinlade *et al*., 2003).

Inspite of the numerous advantages conferred by the inclusion of legumes in grass land Agriculture, the survival of legumes in mixtures with grass remains a serious problem in the tropics. This may be attributed to the fast growth rate of grass which enables grass to outcompete the legume leading to reduced growth and sometimes outright extermination. In the light of the foregoing, any attempt at intercropping legume with grass should take in to cognizance the nature of competition between grass and legume. Some of the competition indices employed in the study of competition include relative yield, relative crowding coefficient and aggressivity index. It was also thought that sowing date of grass in grass - legume mixture may determine the survival of legume in mixtures (Baba, Halim, Alimon & Abubakar, 2013).

The first experiment therefore aimed at evaluating the effect of competition on dry matter yield and morphological characteristics of mixtures of *Panicum mombasa* grass with the legumes *Stylosanthes guianensis*, *Stylosanthes hamata*, *Centrosema pubscense*, *Centrosema pascourum* and *Alysicarpus vaginalis* while the second experiment sought to evaluate the effect of sowing date of grass on dry matter yield and nutritive value of the three best mixtures from experiment.

1.2 PROBLEM STATEMENT

Survival of legumes in mixtures with grass remains a serious problem due to the fast growth rate of grass which enables it to out-compete the legume leading to reduced growth and to some extent may lead to total elimination of the legume. The impact of this development could be very debilitating on animal production especially in tropical environment where crude protein levels could be as low as 3% or even less during critical period. The impact on growth production of animal products, reproduction and health of animal is better imagined. Gramshaw *et al*., (1989) observed that the establishment of grass-legume mixtures had not been much of a success in the tropics, it was hypothesized that identification of compatible grass-legume mixtures will help alleviate the problem.

1.3 JUSTIFICATION FOR THE STUDY

Pastures deteriorate very fast due to continuous grazing by ruminants especially when there is no improvement. This leads to poor nutritional intake by ruminants and hence poor performance in terms of growth production and reproduction. One of the logical approaches to alleviate these problems is pasture improvement through incorporation of forage legumes into native grass swards or grass-legume mixed pasture. The potential of grass-legume forage resources in livestock nutrition cannot be over emphasized giving the numerous advantages conferred by mixtures. Mixture of forage grass with legume has been reported to increase forage dry matter yield, forage quality in terms of crude protein content, voluntary feed intake and digestibility (Aderinola, 2007). Dhima, Lithourgidis, Vasilakoglou and Dordas (2007); Lithourgidis, Dhima, Vasilakoglou, Dordas and Yiakoulaki (2007) and Javanmard, Nasab, Javanshir, Moghaddam and Jan Mohammadi (2009) reported that grass – legume mixtures have some advantages such as higher total yield and better land use efficiency, yield stability of the cropping system, better utilization of light, water and nutrient and a host of other advantages. Legume grown with grass offer several advantages over grass grown alone. Baylor (1994) noted that inclusion of legumes in pasture usually results in increased yield, higher quality and improved seasonal distribution of forage. Legume - grass mixtures have reduced weed encroachment and erosion and have led to greater stand longevity than legume or grass monoculture (Akinlade, *et al*., 2003).

1.4 OBJECTIVES OF THE STUDY

The main objective of the research is to determine the effect of competition and sowing date on productivity and quality of grass-legume mixtures with the following specific objectives

i. To determine the nature of competition between *Panicum mombasa* and five (5) legumes (*Stylosanthes hamata, Stylosanthes guianensis, Centrosema pascourum, Centrosema pubescence* and *Alysicarpus vaginalis*).

ii. To determine the effect of sowing date of grass dry matter yield and nutritive value of three (3) best performing grass legume mixtures from objective one.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 ***Panicum maximum*** **(cv. mombasa)**

2.1.1 Origin and Distribution

Guinea grass is indigenous to Africa and has been introduced, cultivated and now naturalized in many tropical and subtropical areas of the world (Aganga and Tshwenyane, 2004). It is widespread in moist soils throughout Southern Nigeria and in the wetter parts of the north. Olanite, Arigbede, Onifade, Jolaoso and Akinlade (2002) reported that *Panicum maximum* species are notable forages for animal production in Southwestern Nigeria. It is a perennial bunch grass, 0.5 to 4.5 m high. It thrives between temperature ranges of 15 to 38^0C.

2.1.2 Morphology Description

Guinea grass is a large tufted, fast-growing perennial grass. It has a broad morphological and agronomic variability, ranging in height from 0.5 to 3.5 m, with stems of 5 mm to 10 mm diameter. There are two main types: a tall/medium tussock type, taller than 1.5 m at flowering, and a short tussock type (Cook *et al.*, 2005). The root is a short creeping rhizome; culms are erect, hirsute at the nodes. Leaves are blade-shaped, glabrous to pubescent up to 35 mm broad. Inflorescence is a panicle, 15 to 50 cm long. Spikelets are 3-4 mm green to purple (Ecoport, 2009).

2.1.3 Ecological Requirement

It is naturally found in open grasslands, woodland and shady places within 16.3°N and 28.7°S. It grows best under an annual rainfall above 1000 mm with no more than a 4 to 5 month dry period. Average annual day-temperature should range from 19.1°C to 22.9°C. Small types are more tolerant of cooler temperatures than tall types. It prefers well-drained, moist and fertile soils (Cook *et al*., 2005). It is tolerant of light frost and low soil pH if drainage is good (FAO, 2009) and also of high Al_3^+saturation (Ecoport, 2009). It is well adapted to slopy, cleared land in rainforest areas (FAO, 2009). Drought tolerance depends on the cultivar, but should not generally exceed 4 or 5 months. Guinea grass can be sown with companion legumes such as *Centrosema pubescens*, *Leucaena leucocephala*, *Pueraria phaseoloides* or *Macroptilium atropurpureum* (Cook *et al*., 2005).

2.1.4 Dry matter Yield

Guinea grass yields an average of 30 t DM/ha/year (Cook *et al*., 2005). The yields depend on the cultivar and fertilizer application. For instance, unfertilized guinea grass yields around 7t DM/ha while N-fertilized pastures can yield up to 42t/ha (Hongthong, 2005). Guinea grass produces around 1.7-3.1 million seeds/kg (Ecoport, 2009).

2.1.5 Utilization

Guinea grass *(Panicum maximum* (cv *mombasa*)) is a perennial humid tropical grass that is grazed by ruminants and is characterized by a robust growth, high productivity, acceptability, palatability and persistence (Fajemilehin, Babayemi & Fagbuaro, 2008) and its used throughout the tropics for sown pasture, cut-and-carry, silage and hay. Guinea grass can be managed as a long-term pasture grass if grazed consistently, but it should not be grazed under 35 cm height and under very wet conditions (FAO, 2009). For silage and hay, a good cutting height is 60-90 cm, but for higher yields of acceptable quality it can be cut at up to 1.5 m, as it does not become coarse even if left to grow to that height (Hongthong, 2005). Better quality silage is obtained if Guinea grass is cut during pre-anthesis or anthesis (Sarwatt, Mussa & Katejile, 1989). Ensiled guinea grass has a good texture and it is possible to mix grass of different ages with no effect on silage quality (Babayemi and Bamikole, 2009). Guinea grass is well eaten by all classes of grazing livestock, with particularly high intakes of young leafy plants (Cook *et al*., 2005).

2.1.6 Digestibility

Reported OM digestibility values range from 53 to 79%. The best OM and DM digestibilities are obtained with young regrowth (Peiris & Ibrahim, 1995). Guinea grass is palatable to rabbits (Adehan, Kpodekon, Houenon, Ossenti & Lebas, 1994). Rabbits fed on guinea grass had a higher feed intake and Guinea grass voluntary intake was 75% of the overall intake (Taiwo, Adejuyigbe, Oshota & David, 2005). It has also a good fibre complement in water spinach-based diet (Khuc Thi Hue *et al*., 2006). However, it was reported to decrease digestibility coefficients when added at 25% of the diet (Gupta, Yadav, Gupta & Bujarbaruah, 1993). Replacing guinea grass with water spinach (*Ipomoea aquatica*) resulted in higher body weight gains in growing rabbits and higher milk yield and litter size in does (Tran Hoang , Ngo Tien, Dinh & Preston, 2005).

2.2 ***Sorghum almum* (Columbus grass)**

2.2.1 Origin and Distribution

Columbus grass is thought to have originated in Argentina. It is now found worldwide within 25°N and 30°S and from sea level to an altitude of 700 m. it was introduced to Nigeria in 1967 and has been successfully tried in most ecological zones of Nigeria (Muhammad *et. al*., 2006).

2.2.2 Morphological Description

Columbus grass (*Sorghum almum*) is a robust, tussock, short-lived perennial. It has numerous tillers and thick short rhizomes. The leaves are 2.5-4.0 cm wide and 30-100cm long. The inflorescence is a large pyramidal panicle of 20-60cm long, loose, sessile spikelets ovate-lanccolate, with secondary and tertiary branches, generally drooping as seed ripens (Cook *et al*., 2005). Columbus grass is one of the most valuable summer forage and fodder crops in semi-arid and sub-humid areas (FAO, 2010).

2.2.3 Ecological Requirement

The optimal growing conditions are an annual rainfall ranging from 460 to 760 mm, average day-temperatures between 15°C and 22°C, on fertile, well-drained loamy soils or heavy clays, with soil pH ranging from 5 to 8.5. Columbus grass may withstand drought periods but has no tolerance of waterlogging or flooding (FAO, 2010; Cook *et al*., 2005). Its growth is impaired below 15°C but it can survive mild frosts if the stand is well established (Cook *et al*., 2005). Columbus grass is also one of the most salt-tolerant grasses, comparable to *Chloris gayana*, *Panicum coloratum*, *Pennisetum clandestinum* and *Digitaria eriantha* (FAO, 2010).

2.2.4 Forage Management

Columbus grass (*Sorghum almum*) provides valuable fresh forage used as pasture or in cut-and-carry systems. It should be cut down to 5 cm every 6 to 12 weeks (Ecocrop, 2010). It makes a good quality, though coarse, hay and silage, provided it is cut at the mature stage and the weather is not too wet (Cook *et al*., 2005).

Columbus grass is a fast-growing and high-yielding species that will weaken within 3 years. In Australia, it is usually grown in pure stands but also thrives when mixed with other grasses such as *Megathyrsus maximus*, *Cenchrus ciliaris* or *Chloris gayana*. Such pastures first benefit from the fast-growing Columbus grass and later from the other perennial species (Cook *et al*., 2005).

Columbus grass responds well to additional N, P and K fertilizers and generally yields 4-12 t DM/ha, sometimes up to 20 t DM/ha (Ecocrop, 2010; Cook *et al*., 2005). Seeds yield is between 0.3-1.6 t/ha (Cook *et al*., 2005).

2.2.5 Dry Matter Yield

In Nigeria Kallah *et al*., (1998) reported that the mean plant population of 94 culms/m^2 and culm height of 233cm were attained within 9 weeks and yields of 1.3-14.3t DM/ha were obtained in the study between the late vegetative to dough stages. Muhammad, Kallah, Tanko and Balarabe (2002 & 2006) reported the yield during full bloom stage of maturity for different ecological zones as follows: Sahel, 4.8-5.4t DM/ha; Sudan, 8.2t DM/ha; Northern guinea, 13.2-14.1t DM/ha; and Southern guinea, 13.6-14.6t DM/ha. Muhammad, Kallah, Tanko, Ahmed and Otchere (1994 &1999) reported that in northern Nigeria irrigated *Sorghum almum* yielded 5.5-12.5t DM/ha.

2.2.6 Nutritive Value

The nutritive value of Columbus grass is dependent on the age of regrowth and it provides good feed only on soils which are at least moderately fertile (Hacker, 1992; Cook *et al*., 2005). Between 6 and 14 weeks, crude protein decreased from 15.6 to 5.2% DM, NDF increased from 52 to 69% DM. Dry matter and nitrogen degradability decreased from 41 to 32% and 48 to 33% respectively (Lanyasunya, Mukisira, Ilatsia, Wang & Ondiek 2007b). Application of fertilizer improved the *in vitro* gas production, suggesting enhanced fermentation (Lanyasunya, Wang, Mukisira, Abdulrazak & Kibitok 2007a). It has moderate to high palatability but is not as readily eaten as annual sorghum (Pritchard, 1964 ; FAO, 2010).

It stands heavy stocking and will give several grazing in a season (up to 2-3 grazing per season for a rain-fed crop), but it does not stand heavy trampling and is therefore more suitable for rotational grazing. It should be grazed heavily once the crop is 50 cm high to prevent it from growing too coarse. For maximum regrowth, stubble is left at 15 cm (FAO, 2010).

2.3 ***Stylosanthes hamata* (cv. Verano)**

2.3.1 Origin and Distribution

Sylosanthes hamata originated from the Caribbean Islands, Southern Florida, Central America and South America, where it is mainly found in Colombia, Venezuela and Brazil (Edye & Topark-Ngarm 1992). It is now also found in India, West Africa and Northern Australia. It is best adapted to drier areas with pronounced dry season and can do better in areas with 700 to 900 mm rainfall (Cook *et al*., 2005; Cameron, 2010). *Stylosanthes hamata* is the most drought-resistant stylo species and has been found in Venezuela in areas with less than 300 mm rainfall (Coulibaly & Coulibaly 1996). Though Caribbean stylo landraces may have some water logging and flooding tolerance, many cultivars do not stand flooded conditions (Cameron, 2010). Caribbean stylo can grow on a wide range of soils, except heavy clays, with a pH ranging from 5.4 to 8 (Cook *et al*., 2005).

2.3.2 Morphological Description

Stylosanthes hamata (Verano) is native to North America and belongs to the family – fabaceae. It is an herbaceous perennial legume; semi-erect, mostly 30 – 75cm tall. Its stems are slender, multi-branched, non-determinate and pubescent on one side but the leaves are trifoliate; the central leaflet is 16 – 26mm long and 3 - 6mm wide and acute. The inflorescence is an axiliary or terminal oblong spike, 20mm long, with 8 – 14 yellow papilionaceous flowers. The single-seeded pods are erect and segmented. The upper segment is glabrous and hooked, 6-7 mm long including the length of the hook (Cameron, 2010; Cook *et al*., 2005).

Stylosanthes hamata is widely used to improve the flora of natural pastures and leys and for the creation of forage banks (Coulibaly & Coulibaly 1996). The Caribbean Stylo is relished by all classes of livestock (Cook *et al*., 2005). It is mainly used as permanent pasture but is also cut to be fed fresh in cut-and-carry systems. It may be used for hay provided it is cut before the plant sheds its leaves in the dry season. It can be easily over sown in pastures and is a valuable ley-legume.

2.3.3 Establishment

Stylosanthes hamata CV. Verano commonly known as stylo is widely used in Nigeria (Amodu, Adamu, Abubakar and Omokanye (2002). It has been recommended for large-scale use in sown pasture production as well as in range improvement and rehabilitation (Amodu *et al*., 2002). Over 95 per cent of the verano stylo grown in Nigeria came from 1kg of seed originally introduced from Queensland in 1975. Between 1977 and 1980 the annual Verano seed production was 15 tons from a farm near Shika (Amodu *et al*., 2002). Stylo has been successfully established in the Southern Guinea savanna at Mokwa by sowing into cultivated strips in rangelands (Agishi, 1971). In the northern Guinea savanna, where strip cultivation was limited to only disc-harrowing, establishment and performance were poor and were only improved when over sowing was repeated in the following year (Haggar, De Leeuw and Agishi (1971). Earlier studies by Foster (1961) showed that stylo could be introduced into the range by feeding seed to the grazing cattle, but application of this technique was limited by the high cost of stylo seed. The poor performance of verano stylo in Nigeria has been attributed to removal of most of the seed by ants and by shading from the existing vegetation (De Leeuw, 1975). Livestock farmers in Nigeria are becoming familiar with verano stylo and its success as a pasture in Shika was due to its rapid seed germination of 50 – 80 per cent within two days due to fast water uptake and rapid root growth (4 – 13 mm/day) leading to deep penetration in the soil (Amodu *et al*., 2002).

2.3.4 Dry Matter Yield

Once established, the Caribbean stylo can produce between 10 and 17 t DM/ha in pure stands under favourable conditions. When sown in mixed stands, it can yield 1-7 t DM/ha (Cook *et al*., 2005; Edye *et al*., 1992). In India, under rainfed conditions, *Stylosanthes hamata* cut at 80 days after sowing at 50% flowering yielded 8.6 t DM/ha (Nandanwar, Deshmukh & Patil 1991).

2.3.5 Nutritional Value

Stylosanthes hamata contains about 16% DM as protein (10-24% DM) and is, therefore, less rich in protein than other tropical legumes such as *Leucaena* or *Gliricidia*. Lower protein content has been observed in West Africa, 6-10% DM in sub-humid Nigeria, or 11% DM in the Sudano-Sahelian region (Coulibaly *et al*., 1996). Fibre content is variable and rather high, with an average of 33% DM as crude fibre (24-49% DM). Lignin content also tends to be high. Nutrient composition is likely to vary with the stage of maturity and the leaf:stem ratio. For instance, Caribbean stylo hay harvested at 90 days after sowing had a higher protein and nutrient digestibility in goats than hay harvested at 150 days (Singh *et al*., 2001).

2.3.6 Grazing Management

Grazing should be avoided within the first year of establishment in order to promote seed setting. Heavy, continuous or rotational grazing is beneficial to its growth at the expense of grass growth. When rotationally grazed or cut, four-week rest periods should be respected (Cook *et al*., 2005). Grazing is necessary for perennation, otherwise Caribbean stylo is more likely to behave as an annual (Cameron, 2010; Cook *et al*., 2005; Edye & Topak-Ngarm 1992). Even after leaf shedding under dry conditions, the Caribbean stylo remains well-grazed by livestock, which selects green stems, fallen leaves and seed heads.

2.4 ***Stylosanthes guianenensis*** **(Cook stylo)**

2.4.1 Origin and Distribution

Stylosanthes guianensis is native to Central and South America and was introduced to Nigeria around 1947 (FDA, 1980). It was formerly referred to as *Stylosanthes gracilis*. It is used in the manner of alfalfa. It was naturalized in many tropical and subtropical areas where it became popular legume forage (Cook *et al*., 2005; Mannetje, 1992). However, its cultivation largely ceased after an outbreak of anthracnose in the 1970s and only resumed in the 1990s, after anthracnose-resistant lines were developed and released commercially.

2.4.2 Morphological Description

Stylo is a short-lived, erect or semi-erect perennial legume that can reach a height of 1-1.5 m. Stylo has a strong taproot that is nodulated. The stems are many-branched and may be woody at the base. Stylo does not twin, unlike other legumes. Stylo is a leafy species that remains green under dry conditions. The leaves are trifoliolate with elliptical to lanceolate leaflets, 0.5-45 mm long x 20 mm broad. The inflorescence is a densely flowered spike, with up to 40 flowers/head. Flowers are yellow to orange with black or red stripes. The fruit is a one-seeded pod, 2-3 mm long x 1.5-2.5 mm wide. The seed are very small, pale brown or purple in colour (US Forest Service, 2014; Cook *et al*., 2005; Mannetje, 1992). There are 7 varieties of stylo, notably var. *guianensis* (common stylo) and var. *intermedia* (fine stem stylo) (Mannetje, 1984). Fine stem stylo has finer and shorter stems than the common stylo (1-2 mm in diameter and only 30 cm in height). Its inflorescence is a denser cluster and the seeds are yellowish brown (Cook *et al.*, 2005; Mannetje, 1984).

2.4.3 Ecological Requirement

Stylo is found from 20°N to 32°S, and from sea level up to an altitude of 2000 m (Cook *et al*., 2005; Mannetje, 1992). Stylo can grow in places where annual rainfall ranges from 700 to 5000 mm, but it does better between 1000 and 2500 mm for common stylo and between 600 and 1800 mm for fine stem stylo. It is a warm season growing legume that thrives in places where annual temperatures are between 23 and 27°C. However, stylo can survive light frost (0°C) and can remain productive down to 15°C. Stylo does well in most soils from sands to light clays (including those that are relatively infertile or deprived of P) provided they are well-drained. Soil pH ranging from 4 to 8.3 is acceptable to *Stylosanthes guianensis,* which also has some tolerance of aluminum and manganese. Stylo is not salt tolerant plant and it is a full light species (Cook *et al*., 2005).

2.4.4 Establishment

Stylo can be sown alone or mixed with companion species. In Australia, it is often oversown in native grasslands (Partridge, 2003). Stylo can be sown in plots (7-12 seeds/plot) and should not be buried as the seeds are very small. Stylo can be broadcast when overseeded in grassland. In humid areas, stylo can be sown at any time provided that there is no dry period during its establishment. In drier parts, it should be sown as soon as possible after the start of the rainy season, and at least two months before the rain stops (Husson *et al*., 2008).

2.4.5 Association With Grasses

Stylo can be mixed with tropical grasses such as *Brachiaria* spp., *Andropogon gayanus*, *Chloris gayana*, *Digitaria eriantha*, *Heteropogon contortus*, *Hyparrhenia rufa*, *Melinis minutiflora*, *Pennisetum purpureum* or *Setaria sphacelata*. It can be out shaded when it is sown with guinea grass (*Panicum maximum*) (Cook *et al*., 2005). Stylo is not often sown with other legumes but it can be intercropped with rice, maize or cassava, depending on soil fertility (Husson *et al*., 2008).

2.4.6 Dry Matter Yield

Stylo is a high yielding forage legume that can produce 10-20 t DM/ha depending on soil fertility (Cook *et al*., 2005).

2.4.7 Utilization

Stylosanthes guianensis var. *guianensis* is widely used as forage, not only in its native South America but also in South-East Asia, Africa and Australia, where many cultivars had been developed to suit local Australian growing conditions (Mannetje, 1992).

Cook Stylo is particularly suited for forage in subhumid, tropical and subtropical areas with a marked dry season. It is used for hay, cut-and-carry systems and pasture (Cook *et al*., 2005). Stylo is fairly palatable to livestock when matured and can grow on relatively infertile soils. It can be intercropped with rice and oversown in natural grasslands. It is a valuable cover crop in coconut and palm oil plantations (Husson *et al*., 2008; Skerman *et al*., 1990; Göhl, 1982). While normally used for ruminant production, *Stylosanthes guianensis* is also used to feed pigs in South-East Asia (Khoutsavang, 2005).

Stylo can be grazed but it is sensitive to heavy grazing. It should not be grazed until 6-8 weeks after sowing. Rotational grazing is preferable with 4-8 week rest intervals (Skerman *et al*., 1990). Stylo has been used to improve the nutritive value of natural grasslands in Australia (Partridge, 2003). Stylo as fed is not very palatable when young as palatability increases with maturity and it is advised to wilt it to soften its bristles before offering it to the animals (Skerman *et al*., 1990).

Stylo can make valuable hay but should be handled carefully so that it does not shed its leaves. For sward longevity, stylo should not be cut below 20 cm and no more than once a year (Skerman *et al*., 1990). Stylo may be used as silage when ensiled with salts and molasses (FAO, 2014).

2.4.8 Nutritional Value

Stylosanthes guianensis has a variable protein content, which is usually moderate (about 14% DM) but can be as low as 6% or exceed 20% DM. The fibre content is quite high (more than 25% DM crude fibre). Stylo contains condensed tannins (Baloyi *et al.*, 2001; Thang *et al*., 2010). Fresh stylo is frequently used as a cut-and-carry fodder for rabbits by smallholders in Asia (Phaikaew *et al*., 2004), and Africa (Nigeria) (Odeyinka *et al*., 2007). Stylo with a moderate to low protein content (less than 15% DM) used as sole forage is not able to support maintenance or growth (Adegbola *et al*., 1985; Raharjo *et al*., 1986). On the contrary, when the protein level is high (19-20% DM), stylo can be used as sole feed for growing rabbits. In Nigeria, fresh *Stylosanthes guianensis* forage provided better growth rate (8.0 g/d *vs.* 6.7 g/d) than *Lablab purpureus* forage, or the fresh leaves of Mexican sunflower (*Tithonia diversifolia* Hemsl.) (Omole *et al*., 2007).

Dried stylo has been used safely in balanced diets for growing rabbits and breeding does. Inclusion levels were 25-30% for growth and reproduction (Fomunyam *et al*., 1984), or 40% for growth (Harris *et al*., 1981). Stylo is a source of calcium but its low phosphorus content requires supplementation with minerals or ingredients rich in phosphorus, such as wheat bran.

2.5 ***Centrosema pascuorum***

2.5.1 Origin and Distribution

The origin and natural distribution of this species is in tropical South and Central America, mainly in semi-arid regions in north-eastern Brazil, Venezuela, Guyana, Ecuador, Panama, Costa Rica, Honduras, Guatemala and southern Mexico. *C. pascuorum* also occurs naturally in the Brazilian Pantanal. It has been introduced recently to Australia (Northern Territory and Queensland) and to most countries in South-East Asia, including Indonesia, Malaysia, the Philippines and Papua New Guinea (Stockwell, Clements, Calder & Winter 1986). Tarawali (1991) reported that *Centrosema pascourum* was introduced to Nigeria between 1986 and 1987 and evaluated in central Nigeria.

2.5.2 Morphological Description

Centro is an annual, herbaceous plant with a twining or scrambling habit, producing roots on trailing stems in moist conditions. The Stem is cylindrical, glabrous to scarcely pilose, branched at the nodes, up to 2 m long. Leaf trifoliolate and often held erect; stipules narrowly triangular, 4-9 mm long; petiole 1.7-5 cm long including the upper rachis; leaflets long and narrow, 2-15 cm × 0.3-1.7 cm, glabrous to scarcely pilose, with acute to acuminate apices. Inflorescence racemose, with 1-2 peduncles per leaf axil; flower resupinate, singly or in pairs at the end of a short (0.5-2 cm) peduncle; pedicel 4-10 mm long, subtended by a single ovate bract 2-4 mm long with at the distal end two conspicuously paired bracteoles which are ovate, 4-6 mm × 2-4 mm, with acuminate apices; calyx tube 3-4 mm long, with 5 narrow teeth 3-7 mm in length; the lowest tooth (4-7 mm) is the longest; corolla wine red, 15-25 mm long and wide; the standard with a spur on the back towards the base. Pod linear, 4-8 cm × 3-4 mm, laterally compressed, with a dark longitudinal stripe near each suture, containing up to 15 seeds; the pod shatters at maturity. Seed ovoid to cylindrical, 4 mm long, slightly compressed laterally, greenish-yellow to brown, rarely mottled (Clement *et. al*., 1984).

2.5.3 Ecological Requirement

Centrosema pascourum is extremely drought tolerant and does well usually in areas receiving less than 100mm annual rainfall Clements *et al*., 1983. It was reported in Venezuela in areas with an annual rainfall of 1000 to 1500 mm, and an extended and reliable dry session of four to six months with 50 mm of rain during the dry season. It is found naturally on a wide range of soil with pH range from 6 to 8.5 and textures from sands to heavy clays Clements *et al*., (1983).

2.5.4 Dry Matter Yield

Annual DM yields of 4-6 t/ha are obtained from legume-dominant pastures in the semi-arid tropics. In small plots, yields of up to 9 t/ha have been measured in Thailand. Under favourable conditions, large quantities of seed are produced, exceeding 1 t/ha in pure stands (Stockwell *et. al*., 1986). When grown sole the yields vary, and in Brazil Buller *et. al.*, (1970) Centro yielded 3 to 5.5 t DM/ha. In Ghana, Tetteh (1972) reported a higher yield of 7.6t DM/ha. In Nigeria, Muhammad *et. al*., (2002) reported that Centro dry matter yield increased significantly with advancing maturity.

2.5.5 Utilization

C. pascuorum has potential for wider use as a pasture or hay legume in semi-arid tropical regions. Its ability to tolerate both drought and prolonged waterlogging is unusual in legumes. However, its proven area of adaptation in Australia is limited, and its variable performance in trials in South-East Asia suggests that its use may be restricted to a few areas in the drier parts of the region Clements *et al*., (1984).

2.5.6 Nutritive value

Centro is highly palatable to grazing animals as standing feed or hay. The CP content ranges from 18 – 20%, good hay has CP ranging from 12 – 14% CP with 79% digestibility (Nwargu and Egbunike, 2013).

2.6 *Centrosema pubescens*

Centrosema pubescens common name Centro or butterflypea, is a legume in the family Fabaceae, subfamily Faboideae, and tribe Phaseolae. It is native to Central and South America and cultivated in other tropical areas as forage for livestock. Although, this species has hitherto almost exclusively been referred to as *Centrosema pubescens*, its correct name is *Centrosema molle*. The former *C. schiedeanum* (incl. the released cultivar Belalto centro) is now *C. pubescens*.

2.6.1 Origin and Distribution

Centrosema pubescens, common name centro or butterflypea, is a legume in the family Fabaceae, subfamily Faboideae, and tribe Phaseolae. It is native to Central and South America and cultivated in other tropical areas as a forage for livestock. Although, this species has hitherto almost exclusively been referred to as *Centrosema pubescens*, its correct name is *Centrosema molle*. The former *C. schiedeanum* (including the released cultivar Belalto centro) is now *C. pubescens*.

2.6.2 Morphological Description

Centro is a perennial herb that can reach a height of 45 cm (17.5 in). The root system can reach up to 30 cm in depth, frequently in association with *Rhizobium*, nitrogen-fixing bacteria (Souza *et. al.,* 2011). Stems grow and branch rapidly, producing a dense mass of branches and leaves on the soil. Stems do not become woody until about 18 months after planting. Leaves are trifoliate, with elliptical leaflets approximately 4 cm × 3.5 cm (1.6 in × 1.4 in), dark-green and glabrous above but whitish and densely tomentose below. Flowers are generally pale violet with darker violet veins, born in axillary racemes. Fruit is a flat, long, dark brown pod 7.5–15 cm (3.0–5.9 in) long, containing up to 20 seeds. Seeds are spherical, about 4–mm (0.16–inches) in diameter, dark brown when ripe.

2.6.3 Ecological Requirements

Centro is propagated by seed, planted directly into the ground or broadcast over a field typically before the rainy season (Heuze & Tran, 2016). Centro grows well in soils without fertilizer since it is very adaptable to its environment. For optimal yields it is best to grow Centro in wet and humid soils, but it can grow in any soil type from a sandy to clay soil depending on its location. Centro grows best in a soil pH between 4.9 – 5.5, but will still survive in soils with a pH as low as 4. This plant is also able to endure soils with a high level of manganese (FAO, 2013)

The growing season for Centro ranges between 4–8 months, but the seeds typically mature within 4–6 months. Centro has versatile rainfall requirements, with its optimal range between 1500–1700 mm, but can still grow with a minimum of 800 mm and is able to withstand 3–4 month dry periods. However, it has a reasonable drought tolerance thanks to its deep root system, so it can take up water from a significant depth. It grows well in nutrient-poor soils (Heuze, 2016)

2.6.4 Establishment

Seeds of *Centrosema pubescens* have a mechanical dormancy that has to be broken by soaking the seeds for 3–5 minutes in water at 85 °C (Costa, Bendahan & Ribeiro 2009). After breaking the dormancy of the seeds, they can be inoculated with *Rhizobium* or any other inoculant. A typical seed planting depth is 2.5–5 cm. The shallower depth is used when the soil moisture is appropriate, but when the soil is dry the seed should be planted deeper to reach moisture (FAO, 2013). *Centrosema pubescens* is a promising forage in regions looking for an alternative to enhance the protein content of livestock feed. It is easy to manage and improves soil nitrogen levels. It does not require any special technology or equipment to plant.

2.6.5 Nutritional Value for Animal Feed

C. pubescens is a good source of protein, calcium and potassium for cattle, sheep, goats and rabbits as forage. It can be used to feed broiler chickens and broiler finishers as leaf meal in a quantity up to 20 g per day. More than that causes reduction in growth performance. This is a very cheap alternative to other sources of protein that are usually more expensive, like soybean (Nwargu and Egbunike, 2013).

2.7 ***Alysicarpus vaginalis***

2.7.1 Origin and Distribution

Alysicarpus is native to tropical Africa, Madagascar, Afghanistan, India, Pakistan, Vietnam and Indonesia. It is widespread throughout the tropics. *Alysicarpus vaginalis* usually grows in savanna and is also frequently found in croplands (as a weed) and fallow lands. It is common in Sudano-Sahelian countries where it grows in natural pastures with *Cenchrus biflorus* and *Zornia glochidiata* (FAO, 2010). *Alysicarpus* withstands drier conditions and heavier grazing than *Alysicarpus rugosus* thanks to its capacity to flower and set seeds very quickly (Grouzis, 1988). Optimal growth conditions are 200-600 mm annual rainfall on sandy soils. It grows from sea level up to an altitude of 900 m. It has medium drought tolerance (FAO, 2010; Mannetje, 2002).

2.7.2 Morphological Description

Alyce clover (*Alysicarpus vaginalis*) is an erect or spreading annual herbaceous legume (sometimes woody at the base) very variable in size (2-60 cm tall) and in shape (Mannetje, 2002; Jamnadass, Mace, Hiermaux, Muchugi & Hanson 2006). The stems are decumbent, slightly pubescent when young and almost glabrous with age. The single leaves are alternate; leaflets are oblong or narrowly lanceolate, 1-10 cm long × 0.5-3 cm broad. Inflorescences are pseudo racemes, sometimes panicles. Flowers are orange-buff to pink or reddish-violet. Fruits are indehiscent oblong pods of 18-25 mm; seeds are oblong-ellipsoid, 2.5 mm × 1.5 mm × 1.2 mm (Mannetje, 2002). Alyce clover is very similar to *Alysicarpus rugosus* or *Alysicarpus glumaceus* during the vegetative stages, thus difficult to identify (CIRAD, 2010).

2.7.3 Dry Matter Yield

Alyce clover does not tolerate wet lands and grows poorly on low fertile soils. Dry matter yield obtained in mixture with *Bracharia* using N and P fertilizer was 12.5tDM/ha in Sri Lanka. Grown in Florida with *Digitaria decumbens* but found to be one of the lower yielding legumes, although yielded 8.5t/ha compared to 5.2t/ha for grass alone (FAO, 2010).

2.7.4 Utilization

Alysicarpus vaginalis is a protein-rich fodder valuable for all types of livestock. It is available during the rainy season and in early stages of drought periods (FAO, 2010). It is very palatable to animals that graze in rangelands. It may be used as bush straw or bush hay in sheep diets (ICRISAT, 2005). In Niger, it is a valuable component of vegetation collected and traded as fodder (Mannetje, 2002). It is a weed in millet crops but exploited as a fodder (Lamers, Buerkert, Makkar, Von Oppen & Becker 1996). However, it was not cultivated until recently (FAO, 2010). An attempt was made in Burkina Faso to sow *Alysicarpus ovalifolius* in order to enhance the value of natural pastures and it proved to settle efficiently after sowing (Kiema, Oumou & Sanon 2006).

2.7.3 Nutritive Value

In Central Mali, the crude protein content of *Alysicarpus vaginalis* samples, collected from sites with different soils and rainfall regimes, varied from 9.4 to 21.8% DM, with 63% of the samples containing 12.5 to 15.6% crude protein (Breman, Van Keulan & Ketelaars 1984). In a survey in Niger of dried *Alysicarpus vaginalis* weeds (from millet crops) sold on local markets, crude protein varied from 14.1% to 31.1%, but decreased with increasing age of the plant at harvest.

2.8 PLANT COMPETITION AND INDICES OF MEASURING COMPETITION

Intercropping can be defined as growing of two or more crops on the same area of land. The main goal of intercropping is to produce a greater yield on a given piece of land by making better use of growth resources that would otherwise not be utilized by a sole crop. However, it is well established that different species growing together in the same place compete for nutrients, water and light (Ghosh, 2004). Several factors can affect the growth and yield of the species in mixture, particularly planting ratio, spatial arrangement, plant density, cultivar and competition between mixture components (Caballero *et al*. 1995; Dhima *et al*. 2007; Rezaei-Chianeh *et al*. 2011). Competition is one of the main factors having significant impact on growth rate and yield of plant species used in intercropping, compared with pure stands (Caballero *et al*. 1995). High yields are achieved with intercropping when inter-specific competition is lower than intra-specific (Zhang *et al.*, 2011).Competition behaviour of component crops across different intercropping systems and planting patterns are determined in terms of relative crowding coefficient (RCC), aggressivity index (AI), relative yield and competitive ratio (CR). Relative crowding coefficient (RCC) plays an important role in determining the competition effects and advantages of intercropping. According to Willey (1979), in an intercropping system each crop has its own RCC (K).

The term relative crowding coefficient (k) of plant species was proposed by Hall (1974). It gives a measure of whether that species has produced more, or less yield than expected. If a species has a coefficient less than, equal to or greater than one, it means it has produced less yield, the same yield or more yield than expected yield. To determine if there is a yield advantage of intercropping, the product of the coefficient is formed (K= ka * kb). If K greater than, equal or less than one, there is a yield advantage, no difference or yield disadvantage, respectively. Aggressivity (A) was proposed by McGilchrist (1965). It gives a simple measure of how much the relative yield increase in species a is greater than that for species b. An aggressevitiy value of zero indicates that both component species are equally competitive. Both species A and B have the same numerical value but the sign of the dominant species is positive and that of the dominated one is negative. The greater the numerical value the bigger the difference in competitive abilities and the bigger the difference between actual and expected yields. Relative yield (RY) shows the degree to which different species in a mixture share common resources (Ghosh *et al.*, 2006).

2.9 INFLUENCE OF GRASS-LEGUME MIXTURES ON FORAGE QUALITY

Grass grown with legume contain more protein than grass alone unless if heavily fertilized with nitrogen. Mixtures resist weed encroachment; remain productive longer than pure legumes stands and grasses reduce lodging by legumes, thus saving more leaves (Muhammad *et. al.*, 2007). Grass-legume mixtures improved forage yield, nutritive value and animal performance. High quality forage has high digestibility, low fiber content and high concentration of protein (McDonald, Edwards, Greenhalgh & Morgan, 2002). Forage quality is defined as the capacity of forage to provide the required nutrients to livestock (Adesogan *et al.*, 2006; Muir *et al.*, 2007; Newman *et al*., 2006). Determining the nutritional value of forages is important in livestock nutrition, because effective livestock production is related to the amount of nutrients in the forage (Schut *et al*., 2010).

Total digestible nutrient (TDN), crude protein (CP) and metabolizable energy (ME) are often used as indicators of forage quality (Pinkerton, 2005; White & Wight, 1984). France *et al.*, (2000) noted that the nutritional value of forage depends on the amount of proteins and digestible carbohydrates. The digestibility can be measured in two ways, the digestibility of the whole plant or the digestibility of the cell walls. The digestibility rate is lower for the cell wall than for the cell content. Consequently, as the proportion of cell wall of the digestible plant material increases the lower the digestibility rate will be. Animal performance mainly depends on the quality of forage available to livestock (Lazzarini *et al.*, 2009; Woolley *et al*., 2009). In addition, ash, lignin, cellulose, crude fibre, phosphorus, carotene and some other plant chemical compounds are also measured as indicators of forage quality (El-Waziry, 2007) and (Rhodes & Sharrow, 1990). Plant morphology for both cereals and legumes has three main plant parts, leaf, stem and grain. As a structural component of the plant, stems typically contain more fiber for supports. Leaves, on the other hand, provide a means for capture and utilization of energy from sunlight and tend to be lower in fiber content than stems (Wilman & Rezvani-Moghadam, 1998). Thus, stems usually are lower in digestibility than leaves, and stem digestibility declines more rapidly with increased plant maturity than that of leaves (Gebrehiwot *et al*., 1996). Differences between leaf and stem digestibility are normally greater in forage legumes than cereals (Buxton, 1996). Given the large difference between the digestible fiber content of stems and leaves, the proportion of leaf to stem in given forage plant relates directly to its forage quality (Ghanbari-Bonjar, 2000).

Thorvaldsson (1987) has investigated the effect of weather on the quality values of timothy. Weather affects forage quality both directly and indirectly through its effect on morphological development. Increasing radiation decreases crude protein content but enhances digestibility and increasing temperature decreases digestibility of grasses. Soil can also have an effect on forage nutritional value and drought has a negative effect, e.g. accelerating decline in crude protein content.

Legumes have higher nutritive value than grass species so growing mixtures of grasses and legumes can improve forage quality compared to grass monocultures (Sleugh *et al*., 2000; Zemenchik, Albrecht & Shaver, 2002). Benefits of growing legumes with grasses are that the rate of decline in digestibility with advancing maturity is less for legumes than for grasses. Digestibility of the commonly grown ryegrass can decline by 20 g kg-1 DM per week while digestibility of white clover declines by 10 g/kg DM per week at the most (Dewhurst, Delaby, Moloney, Boland & Lewis, 2009).

Cattle and sheep both eat grasses and legumes given opportunities of both but they prefer legumes over grasses and the legume content is about 70% of overall intake if they are given equal opportunities of feeding on grasses and legumes (Rutter, 2006). The animals maintained a mixed diet of grasses and legumes even though they preferred eating legumes. This may be to maintain effective rumen function.

2.10 INFLUENCE OF GRASS-LEGUMES MIXTURES ON FORAGE INTAKE AND DIGESTIBILITY

Most available ruminant feeds during dry season have been described as fibrous, resulting in low digestibility and poor livestock production (Richard *et al*., 1994). Protein supplementation of grass diets with forage legumes is essential to achieve high productivity in the animals. Forage legumes are known to have an important role in the nutrition of ruminants in terms of providing energy, protein, minerals element for chewing and ruminant (Ahmad, Ghafoor & Ali 2000; Ranibar, 2007). Protein supplementation affects voluntary feed intake and digestibility positively. The use of forage legumes such as lablab as feed supplements has been shown to enhance intake of poor quality forages, improve growth rates and increase production efficiency in ruminants (Orden *et al*., 2000). Feed intake increases as digestibility of energy increases and as crude protein content of the feed increases.Voluntary intake by cows was higher when fed legume silage compared to grass silage and cows fed legume silage had higher yields of milk and the milk contained higher levels of polyunsaturated fatty acids (linoleic acid, conjugated linoleic acid, and α-linolenic acid) that are considered to be beneficial for human health (Williams, 2000).

2.11 INFLUENCE OF GRASS-LEGUME MIXTURES ON ANIMAL PRODUCTIVITY

Grasses generally are typically known to have low crude protein that cannot solely sustain ruminant animals throughout the year, hence the need for intercropping with forage legumes. The importance of forage legumes in increasing herbage production from grasses and to enhance the quality of feed produced has been recognized (Muinga *et al*., 2007). Legumes benefit grasses by contributing nitrogen to the soil through atmospheric fixation, decay of dead root nodules or mineralization of shed leaves (Aderinola, 2007). Muinga *et al*. (2007) reported that inclusion of a legume in *Panicum maximum* based diet resulted on an improved animal performance in terms of milk production and weight gain because of their high nutrient contents. During the dry season, cows grazing grass-legume mixtures increased milk production by 23% in comparison with those grazing grass only, and by 12% in comparison with those grazing the grass-only pastures and receiving supplementation with the legume in a cut and carry system (Lascano *et al*., 2002).

2.12 INFLUENCE OF GRASS-LEGUME MIXTURES ON DRY MATTER YIELD

Grass–legume mixtures generally provide more consistent forage yield across a wide range of environments than grass or legume monocultures (Sleugh *et al*., 2000; Bélanger *et al*., 2014). Mixtures have also been shown to reduce weed invasion compared with monocultures (Tracy and Sanderson 2004; Picasso *et al*., 2008; Frankow-Lindberg *et al*., 2009; Sanderson *et al*., 2012; Finn *et al*., 2013; Bélanger *et al*., 2014). Nutritive value should also be considered because of its impact on animal productivity and meat and milk quality. Results of experiment in Canadian, have demonstrated that mixing grasses and legumes increases dry matter yield (Finn *et al*. 2013) with no negative effects on nutritive value (Sturlud ´ottir *et al*., 2013). Adding a legume into a grass sward has been shown to increase forage DM yield and crude protein concentration (Barnett and Posler, 1983) and improve forage nutritive value (Papadopoulos *et al*. 2001). Furthermore, mixing timothy (*Phleum pratense* L.) with alfalfa (*Medicago sativa* L.) has been shown to increase the non-structural carbohydrate concentration of forages (Bélanger *et al*., 2014), potentially resulting in a more efficient use of nitrogen by ruminants (Brito *et al*., 2009). Seo *et al*., (1997) studied grass-legume mixtures on yield and reported that mixtures with legume increased forge yield, nutritive value and animal performance. In a separate trial reported by Sleugh *et al*., 2002, yield of monoculture grasses were lower than those of grass-legume mixture or of the monoculture of legumes. Muhammad *et al.,* (2009) reported 12.50t/ha of total dry matter yield was obtained with treatment that had *Sorghum almum* plus *Centrocema pascourum*. Yield advantages have been recorded in many grass-legume intercropping systems, including soybean-sorghum (Ghosh *et al*., 2009) maize-cowpea (Eskandari & Ghanbari, 2009), wheat-fababean (Ghanbari, 2000). The reason of yield advantage of intercropping are mainly environmental resources such as water, light and nutrients can be utilized more efficiently in intercropping than in the respective sole cropping systems (Liu *et al*., 2006).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 DESCRIPTION OF EXPERIMENTAL SITE

The study was conducted at the Livestock Teaching and Research Farm of the Faculty of Agriculture, Bayero University Kano. Kano lies between latitude 9° 31´ and 12° 30´ North, longitude 9° 30´ and 8° 42´ East in the Sudan Savannah ecological zone of Nigeria. It is characterized by tropical wet and dry climate. Mean annual temperature ranges from 21°C to 39°C while annual rainfall ranges from 500 mm to 1000 mm (Knarda, 2001). The vegetation of Kano State is the tropical type composed of a variety of trees (such as *Adansonia digitata*, *Tamarindus indica*, *Khaya senegalensis*, *Vitex doniana* etc) scattered over an expanse of grass land (Ahmed, 1998). Commonly grown crops in the region include millet, sorghum, cowpea and groundnut while cattle, sheep, goats and poultry are the predominant livestock reared.

Experiment I: Assessment of competition between grass and legume

3.2 LAND PREPARATION AND FIELD CULTURE

The land was ploughed, harrowed and demarcated into plots of $1 \times 1m^2$ size. Seeds were procured from National Animal Production Research Institute (NAPRI) Shika, Zaria. Legume seeds were scarified using hot water at 80°C for 3 minutes to break seed dormancy in order to improve germination and enhance establishment (Baba *et al.*, 2011) and sown using drilling method at 1cm depth with a spacing of 1m between blocks and 0.5m within plots. Plots containing sole legumes and grass-legume mixtures were fertilized with Nitrogen, phosphorus and potassium fertilizers in the form of urea, Single Super Phosphate (SSP) and Muriate of

Potash (MOP) respectively at the basal rate of 50kg/ha each (Baba *et al.*, 2011). Weeding was done as and when due using hoe.

3.3TREATMENTS AND EXPERIMENTAL DESIGN

The treatments consisted of monocultures of *Panicum mombasa*, *Stylosanthes guiniensis*, *Stylosanthes hamata*, *Centrosema pubescens*, *Centrosema pascourum*, *Alysicarpus vaginalis* and mixtures of *Panicum mombasa* with each legume at 2:2 sowing ratio. There were eleven (11) treatments replicated in four blocks in a randomized complete block design.

3.4 HARVESTING

Harvesting was carried out just before flowering of *Panicum mombasa* and the fallowing parameters were measured.

i- Plant height: This was measured three times with the aid of measuring tape from the base of the plant to the tip of the flag leaf.

ii- Leaf area: This was determined using leaf area meter model YMJ – A.

iii- Leaf to stem ratio: This was achieved by dividing the weight of the leaf by that of the stem.

iv- Dry matter yield: This was measured by harvesting the forage material at a stubble height of 10cm above the ground and then fresh weight was measured using electronic scale Camry model: EK5350. The sub-sample of harvested materials were oven dried at 65°C for 72 hrs to obtain the dry matter yield.

v- Competition indices such as relative yield, relative crowding coefficient and aggressivity index were calculated from the dry weight obtained in monocultures and mixtures using the formulae of Ghosh, Mohanty, Bandyopydhyay, Painuli and Misra (2006) below:

Competition Indices

3.4.1 Relative yield (RY)

Relative yield (RY) shows the degree to which different species in a mixture share common resources.

Relative yield grass (RYG) = DMYGL/DMYGG ---------- 1

Relative yield legume (RYL) = DMYLG/DMYLL---------- 2

Total relative yield (TRY) = summation of formula 1 and 2

Where DMYGG = dry matter yield of grass grown in monoculture

DMYGL = dry matter yield of grass grown in mixture with legume

DMYLL = dry matter yield of legume grown in monoculture

DMYLG = dry matter yield of legume grown in mixture with grass (De Wit, 1960).

3.4.2 Relative crowding coefficient (RCC)

Relative crowding coefficient (RCC) is the relative competitive ability of one species over the other (De Wit, 1960).

RCCGL=DMYGL/(DMYGG – DMYGL)

RCCLG=DMYLG/(DMYLL – DMYLG)

Where RCCGL = Relative crowding coefficient of grass in mixture with legume

RCCLG = Relative crowding coefficient of grass in mixture with grass

3.4.3 Aggressivity Index (AI)

Aggressivity index (AI) is use to show the aggressor and aggressee in a relationship between two species (McGilchrist, 1965; McGilchrist and Trenbath, 1971).

AIGL=(DMYGL/DMYGG) – (DMYLG/DMYLL)

AILG=(DMYLG/DMYLL) – (DMYGL/DMYGG)

Where AIGL = Aggressivity index of grass grown in mixture with legume

AILG = Aggressivity index of grass grown in mixture with grass

Experiment II: Effect of sowing date on legume survival

3.5 TREATMENT AND EXPERIMENTAL DESIGN

The treatment evaluated were three grass-legume mixtures {*Sorghum almum*-S*tylosanthes hamata* (T_1), *Sorghum almum-Centrosema pacourum* (T_2) and *Sorghum almum*-C*entrosema pubescens* (T_3)} and four sowing dates of the grass in mixtures (0, 1, 2 and 3 weeks after sowing of legumes) combined as 3x4 factorial arrangement in a randomized complete block design

3.5.1 Land Preparation and Field Culture

The Experiment commenced in February 2018 and lasted up to July of the same year. The experimental land was ploughed, harrowed and demarcated into plots of 2×3m^{2,} distances between plot and blocks were maintained at 0.5 and 1m respectively. Fertilizer was applied at sowing at the rate of 50kg/ha P and K using Single Super Phosphate (SSP) and Muriate of Potash (MOP). Seeds of *Sorghum almum* and the legumes (*Stylosanthes hamata*, *Centrosema pascourum* and *Centrosema pubescens*) were sown in alternate arrangement in 4 replicate blocks at the rate of 5 seeds per sowing hole, taking into cognizance the respective sowing dates of the grass in mixtures. However, the legumes were treated for dormancy by immersing in hot water at 80°C for 3 minutes prior to sowing. Uniform cutting of all mixtures was done using sickle at about eight weeks post sowing of the legumes at a stubble height of 5 cm from the ground level to allow for regrowth.

3.5.2 Sampling

Sampling was done at four weekly intervals each time taking into cognizance sowing date of the grass in mixture. For instance, mixtures sown on the same day (0 week) were the first to be harvested followed by those in which the grass was sown 1 week after the legume had been sown and continued in that order, *a* total of 2 harvests were taken. During each harvest grass and legume stands at the middle of each plot within an area of $0.5 \times 0.5 m^2$ were harvested, fresh weights were taken using a digital balance. The plant materials were then put in an oven at 65°C for 72hr to determine the dry matter yield. Separate fresh samples were taken for determination of leaf to stem ratio and leaf area was determined using leaf area meter (model YMJ-A portable).

3.6 CHEMICAL ANALYSIS

Samples collected were oven dried according to the treatment evaluation in the field. The mixture was ground to pass through 2mm sieve and stored in plastic containers until used. The ground samples were subjected to proximate analysis to determine crude protein (CP), Ash, crude fiber, fat and nitrogen free extract according to procedure described by AOAC (1995). Neutral and acid detergent fibers (NDF and ADF respectively) were determined using the method of Van Soest *et al*., (1991). Minerals (Ca, Mg, K and P) were evaluated using atomic absorption spectrophotometer (AAS) and flame emission spectrophotometer (FES). Other nutritive value parameters were calculated as follows

DMI= 120/%NDF

DDM= 88.9-0.779* %ADF

RFV= DDM*DMI/1.20 (Harrocks and Valentine, 1999)

3.7 DATA ANALYSIS

All data collected were analyzed by ANOVA Using SAS (Version 9.2, 2009). Differences among means were separated using Duncan's Multiple Range Test (DMRT) at 5% probability.

Model for Experiment I

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

Where Y_{ij} = Any dependent variable

μ = Overall mean

T = Treatment (1, 2, 3, --------------11)

e_{ij} = Random error

Model for Experiment II

$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + e_{ijk}$

Where Y_{ijk} = Any dependent variable

μ = Overall mean

α_i = ith factor grass-legume mixture (1, 2, 3)

β_j = j^{th} factor dates of sowing (0, 1, 2, 3)

$(\alpha\beta)_{ij} = {}_{(I, j)}{}^{th}$ effect of interaction

e_{ijk} = Random error of the K^{th} observation from the ${}_{(I, j)}{}^{th}$ cell

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 RESULTS: EXPERIMENT I

4.1.1 Dry Matter Yield

The values of dry matter yield for grass and legume monocultures are shown in Table 1. Monocultures of grass and legumes were significantly different, however in absolute terms *Centrosema pascourum* had the highest dry matter yield (1403.30 kg/ha) while *Stylosanthes hamata* had the least (390 kg/ha). The total dry matter yield values were in` the order *Centrosema pascourum*>*Panicum mombasa*>*Stylosanthes guianensis*>*Alysicarpus vaginalis*>*Centrosema pubsescens*>*Stylosanthes hamata*.

Table 1: Dry matter yield of grass and legumes grown monocultures

Treatment	DMYG (kg/ha)	DMYL (kg/ha)	TDMY (kg/ha)
T1 (*P. mombasa*)	1356.7	-	1356.7[a]
T2 (*S. hamata*)	-	390.00	390.00[d]
T3 (*S. guianensis*)	-	820.00	820.00[b]
T4 (*C. pascourum*)	-	1403.3	1403.30[a]
T5 (*C. pubescence*)	-	510.00	510.00[c]
T6 (A. *vaginalis*)	-	806.70	806.70[b]
SEM	114.0	324.7	198.00
P value	0.911	0.255	0.565

[abcd]Means within the same column with different superscripts are significantly different ($P<0.05$), P= *Panicum,* C= *Centrosema,*S= *Stylosanthes*, DMYG= dry matter yield of grass, DMYL= dry matter yield of legume and TDMY= total dry matter yield, P= *Panicum,* S= *Stylosanthes*, C= *Centrosema* and A= *Alysicarpus*

Dry matter yields of grass and legumes in mixtures were significantly different (Table 2), similarly for total dry matter yield of mixtures, however grass in mixture with *Centrosema pascourum* produced the highest value (1356.7 kg/ha) while the grass in grass *Alysicarpus vaginalis* mixture recorded the least dry matter yield (930 kg/ha). In the case of legumes in mixture *Centrosema pascourum* was observed to produced higher yield (606.70 kg/ha) while *Alysicarpus vaginalis* had the least (206.7 kg/ha). Comparatively, the total dry matter yields of mixtures were in the order *Panicum mombasa – Centrosema pascourum >Panicum mombasa – Centrosema pubsescens>Panicum mombasa – Stylosanthes guianensis>Panicum mombasa – Stylosanthes hamata>Panicum mombasa – Alysicarpus vaginalis*.

Table 2: Total Dry Matter Yield of Grass and Legume Grown in Mixture

Treatment	DMYG (kg/ha)	DMYL (kg/ha)	TDMY (kg/ha)
P. mombasa-S. hamata	1066.70^{b}	143.30^{e}	1210.00^{c}
P. mombasa- S. guianensis	1290.00^{a}	353.30^{c}	1643.30^{b}
P. mombasa- C. pascourum	1366.70^{a}	606.70^{a}	1973.30^{a}
P. mombasa –C. pubescens	1353.30^{a}	463.30^{b}	1816.70^{b}
P. mombasa- Alysicarpus	930.00^{c}	206.70^{d}	1136.70^{c}
SEM	266.5	15.90	277.8
P value	0.911	0.255	0.032

^{abcde}Means within the same column with different superscripts are significantly different (P<0.05), P= *Panicum,* C= *Centrosema*,S= *Stylosanthes*

4.1.2 Morphological Characteristics

Leaf area of grass in mixtures (Table 3) was observed to be the highest in absolute term in the *Panicum mombasa-Stylosanthes guianensis* mixture (162.47) while that of legume was higher (P>0.05) in *Panicum mombasa-Centrosema pascourum* mixture (27.46).

Table 3: Leaf Area of Grass-Legume Mixture

Treatment	LAG (cm^2)	LAL (cm^2)
P. mombasa-S. hamata	145.46^{bc}	20.77^{bc}
P. mombasa- S. guianensis	162.47^{a}	18.88^{c}
P. mombasa- C. pascourum	142.42^{c}	27.46^{a}
P. mombasa –C. pubescens	121.84^{d}	23.00^{b}
P. mombasa- Alysicarpus	147.40^{b}	17.75^{d}
SEM	7.97	2.77
P value	0.705	0.585

^{abcd}Means within the same column with different superscripts are significantly different (P<0.05). LAG= Leaf Area Grass, LAL= Leaf Area Legume, P= *Panicum*, C= *Centrosema*,S= *Stylosanthes*

4.1.3 Competition Index

Relative yield

Relative yield values for grass and legumes in mixtures were significantly different (P<0.05) with highest in *Panicum mombasa – Centrosema pubsescens* mixtures (1.11 and 1.69, respectively) similarly for relative yield total (2.79).

Table 4: Relative yield of grass – legume mixture

Treatment	RYG	RYL	TRY
P. mombasa-S. hamata	0.7393[b]	0.3482[b]	1.0875[d]
P. mombasa- S. guianensis	1.1000[a]	1.2726[a]	2.3726[b]
P. mombasa- C. pascourum	0.9708[ab]	0.4402[b]	1.4110[c]
P. mombasa –C. pubescens	1.1109[a]	1.6968[a]	2.7977[a]
P. mombasa- Alysicarpus	0.6892[b]	0.3029[b]	0.9921[d]
SEM	0.255	0.516	0.271
P value	0.8484	0.3989	0.1628

[abcd]Means within the same column with different superscripts are significantly different ($P<0.05$). RYG= relative yield grass, RYL= relative yield legume and TRY= total relative yield, P= *Panicum*, C= *Centrosema*,S= *Stylosanthes.*

Relative crowding coefficient

Relative crowding coefficient of grass in mixture was greatest in *Panicum mombasa – Stylosanthes hamata* (8.472) mixture followed by *Panicum mombasa – Alysicarpus vaginalis* (4.03), *Panicum mombasa – Centrosema pascourum* (1.80) and *Panicum mombasa – Stylosanthes giuanensis* (0.55). In the case of legumes in mixtures with grass, *Centrosema poscourum* had numerically the highest relative crowding coefficient.

Table 5: Relative crowding coefficient (K) of grass – legume mixture

Treatment	RCCG	RCCL
P. mombasa-S. hamata	8.472[a]	0.570[ab]
P. mombasa- S. guianensis	0.548[c]	0.309[b]
P. mombasa- C. pascourum	1.802[c]	0.893[a]
P. mombasa –C. pubescens	-2.938[d]	-1.233[c]
P. mombasa- Alysicarpus	4.030[b]	0.508[ab]
SEM	0.303	0.050
P value	1.190	0.352

[abcd]Means within the same column with different superscripts are significantly different (P<0.05). RCCG= Relative Crowding Coefficient grass, RCCL= Relative Crowding Coefficient legume, P= *Panicum*, C= *Centrosema*,S= *Stylosanthes*.

Aggressivity index

The grass in *Panicum mombasa – Stylosanthes hamata* (0.39), *Panicum mombasa – Centrosema pascourum* (0.53) and *Panicum mombasa – Alysicarpus vaginalis* recorded positive aggressivity index compared to their legume counterpart, in the case of legume *Stylosanthes giuanensis* and *Centrosema pubsescens* were more aggressive than their grass counterpart.

Table 6: Aggressively index of grass – legume mixture

Treatment	AIG	AIL
P. mombasa-S. hamata	0.3911[b]	- 0.3911[b]
P. mombasa- S. guianensis	-0.1726[c]	0.1726[a]
P. mombasa- C. pascourum	0.5305[a]	-0.5305[c]
P. mombasa –C. pubescens	-0.5759[c]	0.5759[a]
P. mombasa- Alysicarpus	0.3862[a]	-0.3862[b]
SEM	0.768	0.768
P value	0.8353	0.8353

[abc]Means within the same column with different superscripts are significantly different (P<0.05). AIG= aggressivity index grass, AIL= aggressivity index legume, P= *Panicum*, C= *Centrosema*,S= *Stylosanthes.*

RESULTS: EXPERIMENT II

4.1.4 Main Effects of Grass-Legume Mixtures and Sowing Date on Dry Matter Yield

The effects of mixtures and sowing date are shown in Table 7. At harvest 1, the grass in *Sorghum almum-Centrosema pubescens* mixture produced significantly higher dry matter yield (P<0.05) than *Sorghum almum-Stylosanthes hamata*, the grass in *Sorghum almum-Centrosema pascourum* and *Sorghum almum-Centrosema pubescens* were significantly different. In the case of legumes in mixtures, *Centrosema pascourum* produced significantly higher (P<0.05) yield than *Stylosanthes hamata* and *Centrosome pubescens*. Total dry matter yield values for mixtures at harvest 1 indicated that *Sorghum almum-Centrosema pascourum* and *Sorghum almum-Centrosema pubescens* had significantly higher (P<0.05) yield than *Sorghum almum-Stylosanthes hamata*. At harvest 2, there were significant differences among the grass in mixtures irrespective of the species combination. The legumes were however significantly different. *Centrosema pascourum* produced superior (P<0.05) yield than stylo and *pubescens*. Total dry matter yield was significantly different among mixtures, but *Sorghum almum-pascourum* mixture produced higher dry matter yield than other mixtures. Cumulative dry matter yield values also indicated greater (P<0.05) yield values for mixtures of *Sorghum almum-Centrosema pascourum* and *Sorghum almum-Centrosema pubescens* compared to *Sorghum almum-stylosanthes hamata*.

The results indicated that *Sorghum almum-Centrosema pascourum* mixture produced higher cumulative total dry matter yield compared to *Sorghum almum-Stylosanthes hamata* and *Sorghum almum-Centrosema pubescens*. In terms of the effect of sowing date, sowing grass and legume on the same day (0 week) produced higher (P<0.05) dry matter yield of grass compared to staggered sowing of grass in mixture (1, 2 and 3 weeks after legume). In the case of legumes, sowing of grass 2 and 3 weeks after legume produced higher (P<0.05) dry matter yield values than same day sowing and sowing 1 week after the legume. Total dry matter yield for mixtures was significantly (P<0.05) the highest when grass and legumes were sown on the same day compared to other sowing dates. At harvest 2, there was no significant effect of sowing date on dry matter yield of grass. However, dry matter yield of legume was significantly affected by sowing date. The dry matter yield of legume was significantly the highest (P<0.05) when the grass was sown 1 week after the legume. There were no significant effects of sowing date on total and cumulative dry matter yields of mixtures at harvest 2. However, in absolute terms, mixtures sown on the same day produced higher cumulative dry matter yield. The yield declined with delayed sowing of grass in the mixture in the order1>2>3.

Table 7: Main Effects of Mixtures and Sowing Date on Dry Matter Yield

	Harvest 1					Harvest 2					
Mixtures	DMYG	DMYL	TDMY	% Grass	% Legume	DMYG	DMYL	TDMY	% Grass	% Legume	Cumulative TDMY
	Kg/ha					Kg/ha					Kg/ha
SA-SH	4983.0[c]	940.0[b]	5923.0[b]	84.12	15.87	12432.0[c]	1251.7[b]	13783.0[c]	90.19	9.08	19707[c]
SA-CPA	6817.0[b]	3150.0[a]	9967.0[a]	68.39	31.60	19157.0[a]	2583.3[a]	21740.0[a]	88.11	11.88	31707[a]
SA-CPU	8833.0[a]	985.0[b]	9818.0[a]	89.96	11.15	15829.0[b]	661.7[b]	16419.0[b]	96.40	4.03	26309[b]
SEM	526.05	124.38	500.83	NA	NA	1307.5	172.35	1391.8	NA	NA	1648.6
P value	0.0235	0.0001	0.0045	NA	NA	0.1416	0.0005	0.0815	NA	NA	0.242
SD(Weeks)											
0	11044[a]	1473.3[b]	12518.0[a]	88.22	11.77	18538.0[b]	960.0[b]	19498.0[b]	95.08	4.92	32016[a]
1	4800[c]	1384.4[b]	6184.0[b]	77.62	22.38	20167.0[a]	2673.3[a]	22840.0[a]	88.29	11.70	29024[b]
2	5711[b]	2311.1[a]	8022.0[b]	71.19	28.80	12624.0[c]	957.8[b]	13582.0[c]	92.94	7.05	21604[c]
3	5956[b]	1597.8[ab]	7583.0[b]	78.54	21.06	12028.0[c]	1404.0[b]	13432.0[c]	89.50	10.45	20985[c]
SEM	526.05	124.38	500.83	NA	NA	1307.5	172.35	1391.8	NA	NA	1648.6
P value	0.0015	0.0001	0.0012	NA	NA	0.0878	0.0055	0.0660	NA	NA	0.0669

[abc]Means within the same column with different superscripts are significantly different ($P<0.05$). SA= *Sorghum almum*, CPA=*Centrosema pascourum* CPU= *Centrosema pubescens*, DMYG=Dry matter grass, DMYL= Dry matter legume, TDMY= Total dry matter yield, SD= Sowing Date, NA= Not Applicable.

4.1.5 Main Effects of Grass-Legume Mixtures and Sowing Dates on Leaf Area and Leaf to Stem ratio

Mean leaf area of grass (Table 8) was not significantly affected by mixtures although the grass in *Sorghum almum-Centrosema pascourum* had numerically higher mean leaf area. Similarly, the leaf area of grass in mixture was not significantly affected by sowing date. In the case of legumes, mean leaf area was greater ($p<0.05$) in *Sorghum almum-Centrosema pubescens*. Sowing date did not significantly influence the mean leaf area of legumes.

Mean leaf to stem ratio of grass (Table 8) was not significantly different among mixtures but sowing date significantly influenced the mean leaf to stem ratio. The grass in mixture sown on the same day with legume had higher ($P<0.05$) leaf to stem ratio compared to 2 weeks. A significant difference was found among legumes in mixtures sown at 0, 1 and 3 weeks preceding the grass, albeit the leaf to stem ratio of legume in *Sorghum almum-Centrosema pascourum* and *Sorghum almum-Centrosema pubescens* tended to be numerically higher. In the same connection, the leaf to stem ratio of legumes in mixtures was not significantly affected by sowing date.

Table 8: Main Effects of Mixtures and Sowing Dates on Leaf Area and Leaf to Stem ratio

Mixtures	Leaf area grass (cm^2)	Leaf area legume (cm^2)	Leaf to stem ratio grass	Leaf to stem ratio legume
SA-SH	158.05	1.93^c	0.51	0.55
SA–CPA	204.53	7.98^b	0.44	1.72
SA-CPU	189.26	10.10^a	0.55	1.72
SEM	0.1581	0.5467	0.064	0.292
P value	0.2674	0.0001	0.4181	0.2671
SD(weeks)				
0	191.77	6.11	0.64^a	1.20
1	193.37	6.37	0.48^{ab}	1.63
2	192.42	7.80	0.33^b	1.46
3	158.23	6.42	0.50^{ab}	1.77
SEM	0.2674	0.0001	0.064	0.292
P value	0.5533	0.5533	0.0552	0.8845

^{abc}Means within the same column with different superscripts are significantly different ($P<0.05$). SA= *Sorghum almum*, CPA=*Centrosema pascourum* CPU= *Centrosema pubescens*

4.1.6 Main Effects of Mixtures and Sowing Date on Proximate, Fiber and other Nutritive Value Indices of Mixtures and Their Interactions

Table 9 depicts that mixtures were not significantly different (P>0.05) in terms of percentage ash. Similarly, sowing date did not significantly influence the ash content.

In contrast to the effect of mixtures on ash content, crude protein content of mixtures was significantly different. *Sorghum almum-Centrosema pascourum* (22.33%) and 3 (22.75%) recorded higher (P<0.05) crude protein compared to *Sorghum almum-Stylosanthes hamata* (20.84%). Similarly, sowing date influenced the crude protein content of mixtures significantly. Mixtures sown on the same day exhibited higher (P<0.05) crude protein content (23.24%) than those in which legumes preceded the grass by 1, 2 and 3 weeks. Interaction between mixtures and sowing date on crude protein (Fig 1.) revealed significant difference (P<0.05) among mixture sown on the same date and those in which the grass was sown 1 week after the legume with *Sorghum almum-Stylosanthes hamata* and *Sorghum almum-Centrosema pubescens* having higher CP, respectively. No difference was observed among mixture in the other sowing dates

With regards to crude fiber, *Sorghum almum-Stylosanthes hamata* had significantly higher (P<0.05) crude fiber (41.99%) than *Sorghum almum-Centrosema pascourum* (39.79%) and *Sorghum almum-Centrosema pubescens* (35.10%). Crude fiber in mixtures was significantly affected by sowing date. Mixtures sown on the same day had greater (P<0.05) Crude fiber than those in which the grass was sown 1, 2 and 3 weeks after legume.

Mixtures were significantly different in terms of ether extract content. *Sorghum almum-Centrosema pubescens* had superior (P<0.05) ether extract value (6.35%) followed by *Sorghum* *almum-Stylosanthes hamata* (5.8%) and *Sorghum almum-Centrosema pascourum* (4.55%). Sowing date did not significantly affect the ether extract composition of mixtures.

In the case of nitrogen free extract, significantly higher (P<0.05) value was obtained in *Sorghum almum-Centrosema pubescens* (29.91%) compared to *Sorghum almum-Centrosema pascourum* (27.66%) and *Sorghum almum-Stylosanthes hamata* (26.23%) while mixtures in which the grass was sown at 1, 2 and 3 weeks after legumes had higher (P<0.05) NFE than same day sowing.

Both ADF (Acid detergent fiber) and NDF (Neutral detergent fiber) were significantly superior (P<0.05) in *Sorghum almum-Stylosanthes hamata* compared to *Sorghum almum-Centrosema pascourum* and *Sorghum almum-Centrosema pubescens*, no significant difference was found between treatments *Sorghum almum-Centrosema pascourum* and *Sorghum almum-Centrosema pubescens*. Sowing date of grass at 1 week after legume led to significantly greater (P<0.05) ADF compared to 2, 3 weeks and same day sowing of grass and legume. However, same day sowing of grass and legume produced higher ADF than 2 and 3 weeks. Interaction between mixtures and sowing date on ADF (Fig 2.) indicates that *Sorghum almum-Stylosanthes hamata* had significantly higher (P<0.05) ADF among mixtures sown on the same date, similarly for mixtures in which the grass was sown one week after legume. No significant difference was found at 2 weeks while ADF was highest in *Sorghum almum-Centrosema pubescens* at 3 weeks. In a somewhat similar fashion, the NDF values in mixtures sown on the same day and those in which the legume preceded the grass by 1 week were significantly the highest (P<0.05) compared to other dates. Interaction between mixtures and sowing date on NDF (Fig 3.) shows that *Sorghum almum-Stylosanthes hamata* had significantly (P<0.05) higher NDF across all sowing dates followed by *Sorghum almum-Centrosema pascourum* with *Sorghum almum-*

Centrosema pubescens the least. Furthermore, NDF decreased with delayed sowing date in *Sorghum almum-Stylosanthes hamata*.

Other nutritive value indices such as dry matter intake as a percentage of body weight, digestible dry matter and relative feed value (DMI, DDM and RFV, respectively) were significantly different among mixtures. DMI was significantly higher ($p<0.05$) in *Sorghum almum-Centrosema pubescens* (2.37%) followed by *Sorghum almum-Centrosema pascourum* (2.12%) and *Sorghum almum-Stylosanthes hamata* (1.76%). Grass sown at 3 weeks after legume recorded higher ($P<0.05$) DMI (2.24%) compared to other dates. Interaction between mixtures and sowing date on DMI (Fig 4.) reveals significantly higher ($p<0.05$) DMI in *Sorghum almum-Centrosema pubescens* across all sowing dates followed by *Sorghum almum-Centrosema pascourum* and *Sorghum almum-Stylosanthes hamata*, the highest DMI value was obtained in *Sorghum almum-Centrosema pubescens* when the grass was sown 2 weeks after the legume. Digestible dry matter was also significantly different among mixtures with *Sorghum almum-Centrosema pubescens* (61.45%) and *Sorghum almum-Centrosema pascourum* (61.13%) having greater values than *Sorghum almum-Stylosanthes hamata* (56.84%). Interaction between mixtures and sowing date on DDM (Fig 5.) indicates significantly higher ($P<0.05$) DDM in *Sorghum almum-Centrosema pascourum* and when mixtures were sown on the same day. DDM was also observed to have increased with increase in sowing date of grass in mixture.

Similar to DMI, higher values of DDM were recorded in mixtures in which the legume preceded grass by 3 weeks, and the value was not different from 2 weeks but same day sowing and 1 week were inferior to 2 and 3 weeks.

Relative feed value was superior ($P<0.05$) in *Sorghum almum-Centrosema pubescens* (112.86) followed by 2 (100.51) with *Sorghum almum-Stylosanthes hamata* (76.73) the least. Similar to DDM and DMI, mixtures in which the legume preceded the grass by 3 weeks had better ($P<0.05$) RFV value (106.15) compared to other dates.

Table 9: Main Effects of Mixtures and Sowing Date on Proximate, Fiber and other Nutritive Value Indices of Mixtures (%)

Mixture	Ash	CP	CF	EE	NFE	ADF	NDF	DMI	DDM	RFV
SA-SH	5.26[c]	20.84[c]	41.99[a]	5.8[b]	26.23[c]	41.15[a]	70.56[a]	1.73[c]	56.84[c]	76.73[c]
SA–CPA	5.60[b]	22.33[b]	39.79[b]	4.55[c]	27.66[b]	35.64[b]	56.64[b]	2.12[b]	61.13[b]	100.51[b]
SA-CPU	5.64[a]	22.75[a]	35.10[c]	6.35[a]	29.91[a]	35.24[c]	50.75[c]	2.37[a]	61.45[a]	112.86[a]
SEM	0.009	0.098	0.304	0.049	0.386	0.221	0.236	0.009	0.172	0.403
P value	0.187	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
SD(weeks)										
0	5.55	23.24[a]	41.45[a]	5.8	24.40[b]	36.87[b]	63.15[a]	1.96[c]	60.18[b]	93.13[c]
1	5.75	22.28[b]	36.75[b]	5.5	29.61[a]	40.48[a]	62.62[a]	1.96[c]	57.36[c]	87.85[d]
2	5.67	20.89[c]	40.24[b]	5.48	27.72[a]	36.6b[c]	57.58[b]	2.13[b]	60.39[ab]	99.66[b]
3	5.48	21.48[c]	37.41[b]	5.47	30.01[a]	35.42[c]	53.92[c]	2.24[a]	61.31[a]	106.15[a]
SEM	0.009	0.098	0.304	0.049	0.386	0.221	0.236	0.009	0.172	0.403
P value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Interaction	NS	**	**	NS	**	**	**	**	**	**

[abc]Means with different superscripts within the same column are significantly different ($P<0.050$). SA= *Sorghum almum*, CPA=*Centrosema pascourum* CPU= *Centrosema pubescens*

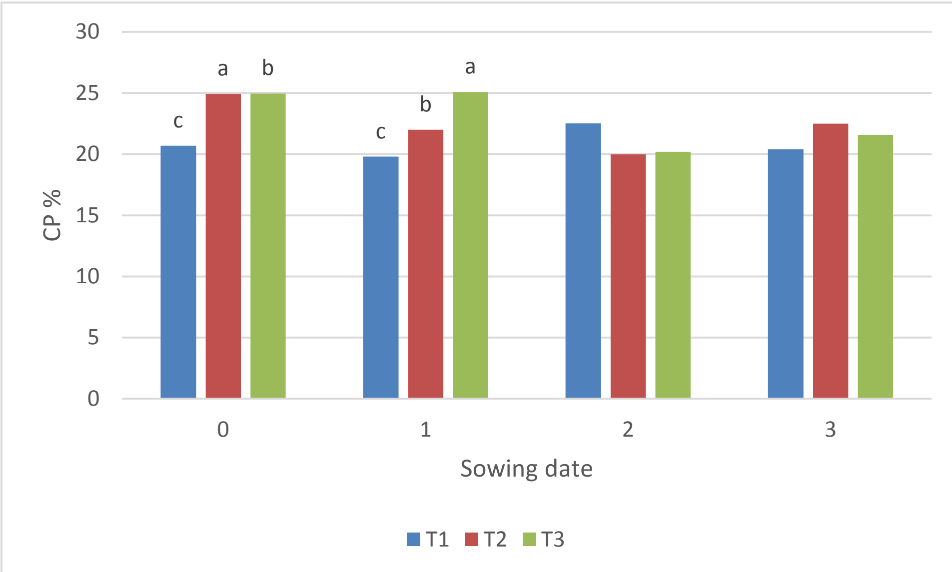

Fig 1. Interaction between grass-legume mixtures and sowing date on CP content at 4 weeks interval

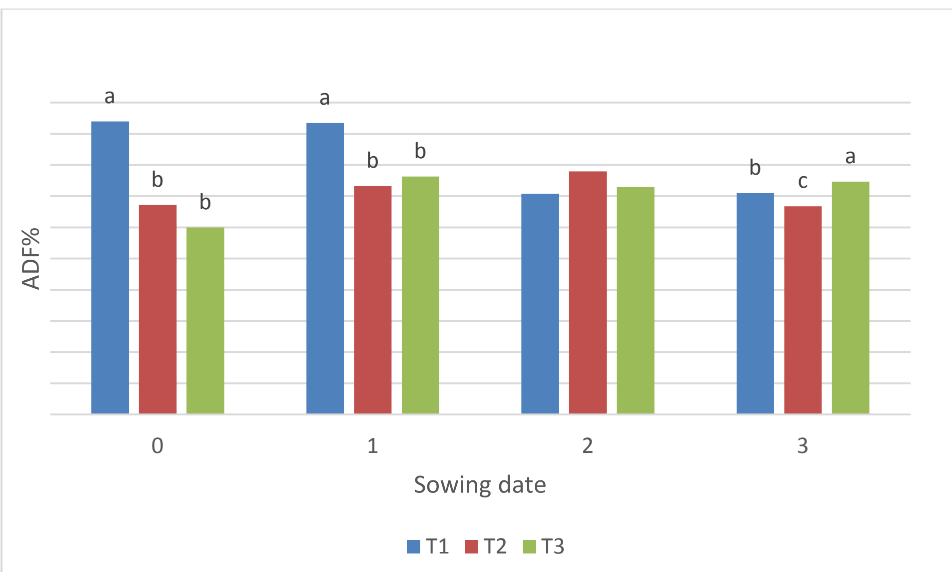

Fig 2. Interaction between grass-legume mixtures and sowing date on ADF content at 4 weeks interval

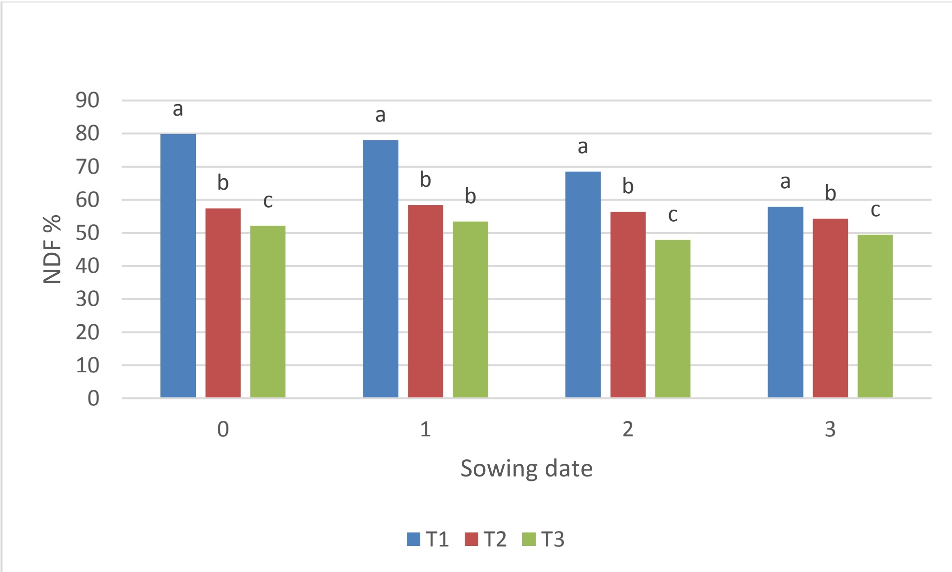

Fig 3. Interaction between grass-legume mixtures and sowing date on NDF content at 4 weeks interval

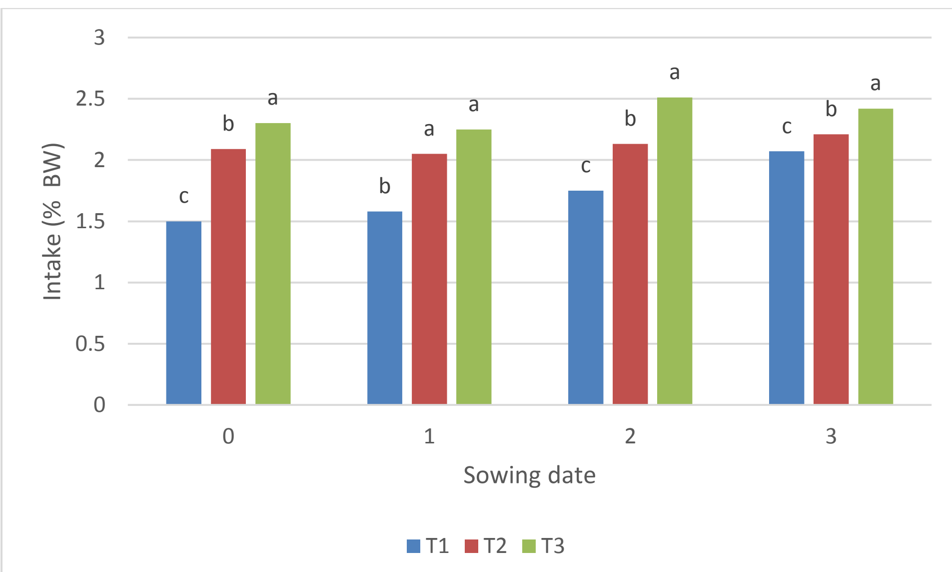

Fig 4. Interaction between grass-legume mixtures and sowing date on dry matter intake (% body weight)

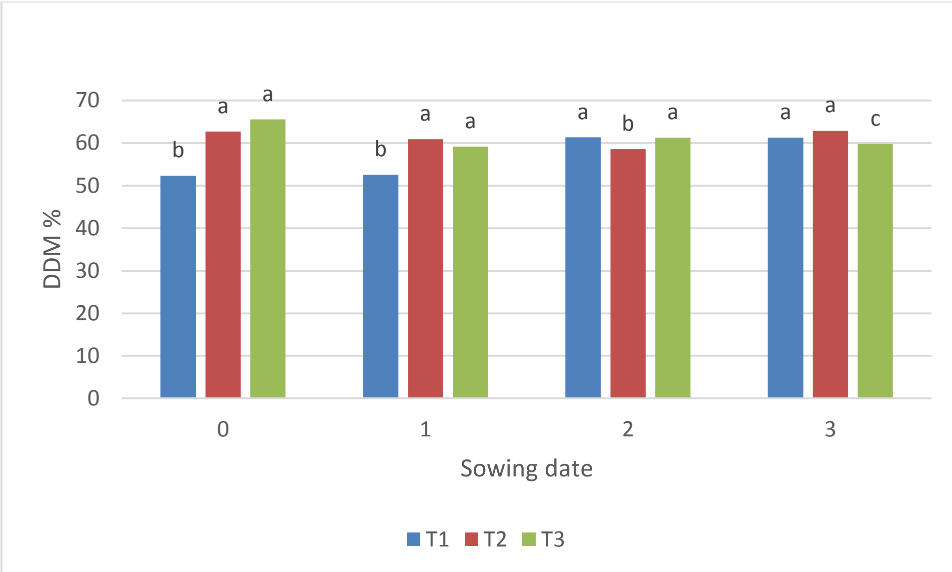

Fig 5. Interaction between grass-legume mixtures and sowing date on DDM

4.1.7 Main Effects of Mixtures and Sowing Date on Mineral Composition of Mixtures

Mixtures were not significantly different in terms of magnesium and phosphorus contents (Table 10). However, values for calcium and potassium were significantly different (P<0.05). Percentage calcium was higher in *Sorghum almum-Centrosema pascourum* compared to *Sorghum almum-Stylosanthes hamata* and *Sorghum almum-Centrosema pubescens* while potassium was higher (P<0.05) in *Sorghum almum-Centrosema pubescens*. In the same vein, sowing date significantly influenced the mineral composition of mixtures. Values for phosphorus, calcium and potassium were superior in mixtures with grasses sown 1 week after legume, same day with legume and 3 weeks after legume, respectively. There was no effect of sowing date on the magnesium content of mixtures. Significant interactions were observed between mixtures and sowing date on phosphorus, calcium and potassium.

Table 10: Main Effects of Mixtures and Sowing Date on Mineral Composition (%) of Mixtures

Mixtures	Ca	K	Mg	P	Ca : P
T1	0.03^{b}	0.24^{c}	0.08	0.05	0.6
T2	0.04^{a}	0.29^{b}	0.07	0.05	0.8
T3	0.03^{b}	0.42^{a}	0.08	0.06	0.5
SEM	0.003	0.004	0.005	0.001	NA
P value	0.0001	0.0001	0.756	0.127	NA
SD (weeks)					
0	0.04^{a}	0.24^{d}	0.82	0.05^{b}	0.8
1	0.03^{b}	0.36^{b}	0.07	0.06^{a}	0.6
2	0.03^{b}	0.29^{c}	0.07	0.05^{b}	0.6
3	0.03^{b}	0.40^{a}	0.09	0.05b	0.6
SEM	0.003	0.004	0.005	0.001	NA
P value	0.0002	0.0001	0.359	0.010	NA
Interaction	**	**	NS	*	

[abc]Means with different superscripts within the same column are significantly different (P<0.05), SD= Sowing Date, SA= *Sorghum almum*, CPA=*Centrosema pascourum* CPU= *Centrosema pubescens*

4.2 DISCUSSION (Experiment I)

Animal production is a function of pasture productivity. The relatively higher dry matter yield recorded by monoculture of *Centrosema pascourum* could be due to its semi-erect growth habit which might have enabled the plant to position itself towards the direction of solar radiation for optimum photosynthesis. The same explanation may hold for the performance of *Centrosema pascourum* in mixture with *Panicum mombasa.* In addition the seemingly higher total dry matter yield recorded by the aforementioned mixture may be due to the numerically higher dry matter yields of *Centrosema pascourum* in comparison to other legumes. This might have translated in to higher nitrogen fixed by the legume via nitrogen fixation for the uptake of both the grass and legume. Lithourgidis and Dordas (2010) reported that cereal– legume intercropping may improve yield in a farm land area by making more efficient use of the available growth resources, in the same vein. Zhou and Wu (2011) reported increased biological activities in the soil when cucumber was produced in mixture with Onion or Garlic. Moreover, the contribution of both the *mombasa* and *pascourum* in mixture were the highest compared to other legumes. From a physiological point of view, the seemingly higher leaf area recorded in *Centrosema pascourum* may have provided the legume with the added advantage of absorbing more solar radiation for photosynthesis hence the higher yield value.

Relative yield indicates the extent to which species in a mixture share common resources, all mixtures had relative yield total of above 1.0 suggesting advantage in having the mixtures than monoculture (Tessema & Baars, 2006) except *Panicum mombasa – Alysicarpus vaginalis* mixture which had close to 1.0 indicating that the species in this mixture shared resources equally.

It further buttress the fact that one specie aided the growth of the other in the manner of the legume aiding the growth of grass through nitrogen fixation or better still, species may have been taking their resources from different layers of the soil thereby avoiding competition for soil resources altogether.

The higher relative crowding coefficient value recorded by *Panicum Mombasa* in almost all mixtures may be explained in the context that *Panicum mombasa* was more competitive than the legumes. This could be due to its fibrous root system that absorbs water and nutrient faster from the soil coupled with it being a C_4 plant with higher photosynthetic ability in warm climate.

Aggressivity index gives an indication of the aggressor and aggressee in a mixture. Species that have positive values are the aggressors while those with negative values are the aggresses. In this context *Panicum mombasa* displayed some degree of aggressiveness in the following mixtures *Panicum mombasa- Stylosanthes hamata, Panicum mombasa- Centrosema pascourum* and *Alysicarpus vaginalis* whereas *Stylosanthes guianensis, and Centrosema pubescence* were found to be more aggressive than their counterpart grass

4.4 DISCUSSION (Experiment II)

In the case of experiment II, the results of analysis of variance indicated that treatment 2 (*Sorghum almum-Centrosema pascourum* mixture) gave higher cumulative total dry matter yield compared to *Sorghum almum-Stylosanthes hamata* and *Sorghum almum-Centrosema pubescens*. This could be attributed to the fact that the total dry matter yield of mixtures in *Sorghum almum-Centrosema pascourum* was consistently the highest at both harvest 1 and 2, perhaps as a result of the higher yield of the legume in *Sorghum almum-Centrosema pascourum*. Higher yield of grass in grass-legume mixture connotes higher amount of nitrogen made available to the grass via the process of nitrogen fixation. One of the major advantages conferred by mixture of grass and legume is that of increased productivity through enhanced soil fertility. Rasmussen, Eriksen, Jensen, Esbensen, and Hogh-Jensen (2009) reported that transfer of nitrogen to companion non fixing species can contribute substantially to their nitrogen supply with estimates ranging from 0-68% of the nitrogen in the companion crop. Similarly, Jorgenssen *et al*. (1999) observed an estimated 1.7-7.5 g Nm^{-2} nitrogen transferred from clover to perennial rye grass. Furthermore, the superior yield recorded in *Sorghum almum-Centrosema pascourum* could be linked to the greater leaf area recorded by the grass in *Sorghum almum-Centrosema pascourum* which signifies better ability to absorb solar radiation for photosynthesis due to higher leaf surface area. The superior yield of grass in mixtures sown on the same date could be explained by the fact that the grass tillers, rhizomes, stolons etc being more competitive in the acquisition of resources for growth had the initial advantage of suppressing the growth of the legume early enough hence remained dominant in the mixture. Almost similar reason could be proffered for the higher dry matter yield of legumes in mixtures sown at 2 and 3 weeks ahead of the grass. Although in this case the legumes may not have been more competitive but had the initial advantage of being alone and cornered resources that favored their growth and thus led to the high yield.

The seemingly higher ash content in mixtures in which the grass was sown 1 and 2 weeks after the legume may be due to higher proportion of the legume components as legumes have higher amount of mineral occasioned by higher cation exchange capacity of the roots of legumes compared to grass. Furthermore, legumes are lovers of phosphorus fertilizer. Carling, Riehle, Brown, and Johnson (1978) reported that leguminous crops have comparatively higher inherent potential for phosphorus utilization because they require phosphorus in massive amount during nodulation. Graciano, Goya, Franji and Giamet (2006) reported increased values of N, P, K and Ca and attributed it to the role of phosphorus in bettering the absorption of additional nutrient in the soil.

As regards crude protein content of mixtures, the higher value observed in *Sorghum almum-Centrosema pascourum* than *Sorghum almum-Stylosanthes hamata* could be as a result of the comparatively higher dry matter yield of legume in the mixture. Carr, Martin, Carton and Poland (1998) indicated that a significant proportion of legume is required in intercrop mixture in order to increase the intercrop protein yield. In the same connection, the superior CP values obtained from mixtures sown on the same day may be as a result of the relatively higher proportion of leaf to stem ratio of the legume component since leaves have higher amount of protein than stem. The relatively greater crude fiber value of mixtures sown on the same day may not be unconnected with the higher proportion of the grass in the mixtures, grass has more fiber than legumes. The higher value for NFE observed in *Sorghum almum-Centrosema pubescens* could be linked to the higher value of RFV in the same treatment. Lithourgidis *et al*., (2006) posited that forage nutritive value (RFV) index could be used to predict intake and energy value of forages.

Acid and neutral detergent fibers were observed to be lower in *Sorghum almum-Centrosema pascourum* and *Sorghum almum-Centrosema pubescens*. This may be explained by the higher proportion of legume at all harvest in *Sorghum almum-Centrosema pascourum* and the higher mean leaf to stem ratio in *Sorghum almum-Centrosema pascourum* and *Sorghum almum-Centrosema pubescens*. Chapko, (1991) reported that cereal forage could have lower NDF and ADF content in cereal-legume intercropping.

Mineral composition of mixtures evaluated indicates that the values were lower than those recommended for different classes of ruminants (Ca 0.3%, (NRC 1984), Mg 0.12-0.27% (NRC 1985) K 0.8% (ARC 1980) and P 0.30-0.40% (NRC 2001)). This may be attributed to the age of the plants at harvest coupled with the low proportion of legumes in mixtures.

Other nutritive value parameters such as DMI were superior in *Sorghum almum-Centrosema pubescens* and *Sorghum almum-Centrosema pascourum* the reason may not be farfetched as the NDF values were lower in the same treatments. Caballero *et al*., (1998) reported negative relationship between NDF and DMI when NDF was high, the forage quality and DMI were low (Horrocks & Vallentine, 1999). The greater value for DMI recorded in mixtures sown at 3 weeks apart was probably due to the observed least NDF value in the mixtures. The reason for the higher digestible dry matter values observed in *Sorghum almum-Centrosema pascourum* and *Sorghum almum-Centrosema pubescens* could be due to lower ADF values in the aforesaid mixtures. Same reason might be advanced for the higher DDM values of mixtures sown at 2 and 3 weeks apart. Relative feed value reflects the quality of feed. The higher the value the better the quality of feed. In the light of the foregoing therefore, Albayrak (2012) classified relative feed value of feed into prime (151 and above), premium (125-150), Good (103-124) fair (87-102) and poor (75-86) based on the aforementioned ranking, only *Sorghum almum-Centrosema pubescens* met the criteria for goodness of feed while *Sorghum almum-Centrosema pascourum* came a distant second (fair) and *Sorghum almum-Stylosanthes hamata* the least (Poor). In the case of sowing date, mixtures sown at all the sowing dates fell in the category of fair with relative feed values ranging from 87.85 to 106.15.

CHAPTER FOUR

5.0 SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 SUMMARY

Two studies were conducted to evaluate the nature of competition between *Panicum mombasa* with 5 forage legumes (S. *hamata*, S. *guianensis*, C. *pascourum*, C. *pubescens* and A. *vaginalis* as treatments) Competition indices analyzed included relative yield (RY), relative yield total (RYT), relative crowding coefficient (k) and aggressivity index (AI) and effect of sowing dates (0, 1, 2 and 3) on grass-legume mixtures of three (3) best performing mixtures from experiment I (*Sorghum almum-Stylosanthes hamata*, *Sorghum almum-Centrosema pascourum* and *Sorghum almum-Centrosema pubescens*) in terms of morphological characteristics, yield and nutritive value. The experiment was conducted at Teaching and Research Farm of the Faculty of Agriculture, Bayero University, Kano.

The experimental design was randomized complete block design with plot size of $1m^2$ for experiment I and larger plots (2*3 m) for experiment II in a 3*4 factorial arrangement (3 mixtures with 4 different sowing dates) as treatments replicated 3 times.

The results shows that legume monoculture (*Centrosema pascourum*) recorded significantly higher total dry matter yield ($P<0.05$) than monoculture of grass and other legumes Mixtures were not significantly different but *Panicum mombasa-Centrosema pascourum* mixture tended to produced numerically higher yield than other mixtures (1973.3 kg/ha). Total relative yield values of all mixtures were not significantly different but were observed to be greater than 1 suggesting advantage of mixture over monoculture. Relative crowding coefficient of

Centrosema pascuorum was numerically the highest (0.8932) indicating higher competitive ability of the companion legume among other legumes in mixture.

In the second study it was observed that mixtures of *Sorghum almum-Centrosema pascourum* (31,707kg/ha) and *Sorghum almum-Centrosema pubescens* (26,309kg/ha) produced significantly higher (P<0.05) cumulative dry matter yield and %CP and DDM values than *Sorghum almum-stylosanthes hamata* (19,707kg/ha). *Sorghum almum-Centrosema pascourum* and *Sorghum almum-Centrosema pubescens* had similar crude protein and digestible dry matter values but higher (P<0.05) than those of *Sorghum almum- stylosanthese hamata*. Dry matter intake and relative feed value were superior (P<0.05) in *Sorghum almum-Centrosema pubescens* compared to other mixtures. Neutral detergent fiber decreased with delayed sowing of grass in mixture while digestible dry matter increased.

Mineral composition of mixtures evaluated indicates that the values were lower than those recommended for different classes of ruminants (Ca 0.3%, (NRC, 1984), Mg 0.12-0.27% (NRC, 1985), K 0.8% (ARC, 1980) and P 0.30-0.40% (NRC, 2001)). This may be attributed to the age of the plants at harvest coupled with the low proportion of legumes in mixtures.

5.2 CONCLUSION

From the result of this study, it can be concluded that:

Dry matter yield of *Centrosema pascourum* was 3% and 72% higher than in *Panicum mombasa* and *Stylosanthes hamata*, respectively. The relative yield total (RYT) of *Panicum mombasa- Centrosema pubescens* mixture was 65% higher than in *Panicum mombasa-Alysicarpus vaginalis* mixture. The relative crowding coefficient of legume (RCCL) and grass (RCCG) were 38% and 65% higher in *Centrosema pascourum* and *Stylosanthes hamata* than in

Panicum mombasa- Centrosema pubescens mixture, respectively. The aggressivity index of legume (AIL) and grass (AIG) were 33% and 67% higher in *Panicum mombasa- Centrosema pubescens* and *Panicum mombasa- Centrosema pascourum* mixtures than in *Panicum mombasa- Alysicarpus vaginalis* and *Panicum mombasa- Stylosanthes hamata* mixtures, respectively.

Total dry matter yield (TDMY) of *Sorghum almum-Centrosema pascourum* mixture was 61% higher than in *Sorghum almum- Stylosanthes hamata*. The TDMY of grass-legume mixture planted on the same day was 53% than intercropping grass in legume 3 weeks later. The relative feed value (RFV) of the mixture was 21% and 47% higher in 3 weeks date of planting grass in legume than 1 week and *Sorghum almum-Centrosema pubescens* mixture than in *Sorghum almum-Stylosanthes hamata*, respectively.

5.3 RECOMMENDATIONS

As a compromise between dry matter yield and quality, *Sorghum almum-Centrosema pubescens* is recommended as the best mixture having a better relative feed value, digestible dry matter and dry matter intake among the mixtures.

Furthermore, sowing grass 3 weeks after legumes in mixtures improved quality parameters and reduced fiber fractions (NDF and ADF) significantly. In the light of this, it is recommended that date of sowing of grass and legume in mixtures should be staggered with the legume sown ahead of the grass by 3 weeks.

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