EFFECT OF PLANTING PATTERNS AND CUTTING INTERVALS ON AGRONOMIC PERFORMANCE AND QUALITY OF PASTURE GRASS AND LEGUME

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EFFECT OF PLANTING PATTERNS AND CUTTING INTERVALS ON AGRONOMIC PERFORMANCE AND QUALITY OF PASTURE GRASS AND LEGUME

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A thesis submitted to the post-graduate committee of the Yezin Agricultural University as a partial fulfillment of the requirements for the degree of Master of Agricultural Science (Agronomy)

Department of Agronomy

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The thesis attached hereto, entitled **"Effect of Planting Patterns and Cutting Intervals on Agronomic Performance and Quality of Pasture Grass and Legume"** was prepared under the direction of the chairperson of the candidate supervisory committee and has been approved by all members of that committee and board of examiners as a partial fulfillment of the requirements for the degree of **Master of Agricultural Science (Agronomy)**.

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DECLARATION OF ORIGINALITY

This thesis represents the original work of the author, except where otherwise stated. It has not been submitted previously for a degree at any other University.

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DEDICATED TO MY BELOVED PARENTS,

U KO KO AND DAW MAY THIT

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ABSTRACT

This study was conducted as three experiments to determine the best performing pasture grass cultivar for the study area in experiment I, to examine the best performing pasture legume cultivar for the study area in experiment II, to evaluate the appropriate planting pattern and cutting interval for optimum herbage yield and quality of the tested pasture grass and legume and to determine the suitable combination of planting pattern and cutting interval for optimum crop performance and quality of the tested pasture grass and legume in experiment III. All experiments were conducted at the upland field of Department of Agronomy, YAU from October 2016 to August 2018. Experiment I was designed as randomized complete block design with 4 replications. Tested grass cultivars were Mombasa, Cayman and Mulato II. Experiment II was laid out as randomized complete block design with 4 replications. Tested legume cultivars were Desmanthus, Butterfly pea, Stylo and Burgundy. Experiment III was laid out as split plot design with 3 replications. In experiment III, main plot factor was planting patterns and sub plot factor was cutting intervals. Planting patterns included grass sole cropping, legume sole cropping and grass legume intercropping and cutting intervals consisted of 3-month cutting, 6-month cutting, 9-month cutting and 12-month cutting. There were 4 cuttings for 3-month cutting interval, 2 cuttings for 6-month cutting interval, 1 cutting each for 9-month and 12-month cutting intervals during the experimental period. Tested grass and legume cultivars were Mombasa and Butterfly pea. As agronomic characters, plant heights were measured every month after planting. Tiller numbers per hill for pasture grasses in experiment I and III were counted before cutting. Fresh weight and leaf area were measured after cutting and dry weight was recorded after cutting and oven drying. The dried samples were analyzed for total nitrogen (N) to calculate crude protein (CP) content (%), acid detergent fiber (ADF) content (%), neutral detergent fiber (NDF) content (%) and organic matter (OM) content (%). The results of experiment I showed, among tested pasture grass cultivars, plant height of Mombasa was significantly higher than those of Cayman and Mulato II. Higher plant height of Mombasa also leaded to heavier fresh and dry weight, resulting in increased forage yield of that cultivar compared to the remaining two cultivars. Increased forage yield of Mombasa could provide higher crude protein, relative feed value and organic matter yield. Therefore, Mombasa could be considered as the best performing grass cultivar for pasture grass farming in the study area and used as tested grass cultivar in experiment III. The findings of experiment II pointed that, among tested pasture legume cultivars, Desmanthus also leaded to larger fresh and dry weight increasing forage yield of that cultivar compared to the remaining three cultivars. However, that cultivar had slowly developed at early growth stage that cannot meet early forage demand and woody stem with increased age that cannot provide plenty of leafy portions for livestock production. Therefore, Butterfly pea was selected for experiment III due to leafy and more nutritious than other tested legumes after Desmanthus. In experiment III results, among cropping patterns, forage yield was the highest in grass sole cropping as the result of higher plant height, fresh weight and dry weight. Moreover, grass legume intercropping also produced higher plant height and dry matter yield which were not significantly different from those of grass sole cropping. Nutritive value such as CP, RFV and OM of grass legume intercropping was higher than those of sole croppings. Except from land equivalent ratio (LER) for 6-month cutting intervals, biomass yield and nutritional composition of each cutting intervals was greater than 1, indicating the yield benefit from intercropping. Among cutting intervals, forage yield and nutritive value such as CP, RFV and OM were highest under 3-month cutting interval. From the results, it can be recommended that grass legume intercropping with 3-month cutting should be adopted to improve not only for forage yield but also for nutritive value of pasture grass and legume farming in the study area.

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CHAPTER I
INTRODUCTION

Myanmar is an agricultural country and more than 70% of the population lives in rural areas. Almost those people depend on agricultural activities and livestock breeding. Crop-livestock farming system plays a multi-purpose role in developing country and is essential for the livelihood of the rural population. Regarding livestock breeding activities, cows and buffalo are utilized for agricultural activities and animal-products especially meat. Most rural households raise livestock which contributes significantly to household protein and supports the farm economy through draught power, meat and milk (MOAI & MLFRD, 2015).

Although cattle are very important in agricultural works, fodder needs and demands have challenges including low quality feeds in Myanmar, most of the fodders consist of poor quality grasses and a limited range of edible shrubs. During prolonged dry period, grazing animals subsist on dry mature fodder of poor quality. A simple and effective way to improve livestock production is the development of good quality pasture production in Myanmar (Kywe & Aye, 2007). Increased productivity of livestock is required to meet the increasing demand for animal products and to improve the livelihood of farmers. In most developing countries, natural pastures and crop residues are the main feed resources for livestock. Poor quality natural pasture and crop residues cannot support the effective livestock production and even maintain current productivity because of their inherent nutrient deficiencies, low digestibility and limited intake capacity for bulky feeds (Van Soest, 1965).

Forage is an essential part of ruminant animal diet and an important factor in a profitable farm business. Pasture grass is one of the most important sources of nutrients for ruminants (Taweel et al., 2005). Herrera (2004) reported that grass pasture turns on to be an appropriate source of food for ruminants, mainly in tropical countries. There are many grass species used for pasture due to their high dry matter yield (DMY) potential and good animal feed quality. Mombasa (*Panicum maximum* cv. Mombasa) is one of the most widely used pasture grass for cattle (Correa & Santos, 2003) and it was introduced to Thailand in 2007 and commercial seed production commenced in 2008 because of a demand for seed in Central and South America (Hare et al., 2013).

In Indonesia, there are many species of improved grasses that have a high production potential and have adapted to local conditions. One of them is *Panicum maximum* and used as cut or grazing grass. Although its dry matter is not as high as elephant grass, its protein yield and dry matter intake are higher than elephant grass (Man & Wiktorsson, 2003). Moreover, Inyang et al. (2010) stated that Cayman and Mulato II grass are suitable for grazing, hay, fresh in feeding troughs and its quality and production also make it adequate for use as silage and persistence under grazing. Otherwise, Mulato II is promoted as a suitable grass for dairy farmers because of its high protein levels, high palatability and high digestibility compared to other tropical grasses in Vietnam.

Maintaining high soil fertility can be achieved through fertilizer application and introduction of legume into the pasture. Application of fertilizer to increase dry matter yield and nutritive value had been suggested to be one method to improve animal production in developing countries (Peyard & Astigarraga, 1998). However, the high price of commercial fertilizer makes it unaffordable for most subsistence farmers. Besides, the use of inorganic nitrogen can increase environmentally related problems due to excessive release of nitrogenous compounds. The high applied rate of nitrogenous chemical fertilizer on pasture lands in Western Europe has been becoming hazardous impacts by the release of nitrous oxide (NO_2) and ammonia (NH_3) into the atmosphere (Mannetje, 2002).

A good understanding of the specific management requirements for tropical perennial grasses is needed; particularly for nitrogen management and the implications of grass legume companion cropping. Such cropping pattern provides nitrogen to grass and improves seasonal pasture growth, pasture quality, animal intake and livestock growth rates (Harris et al., 2014). The introduction of legume into *Panicum maximum*, pasture may be the promising alternative way to improve pasture production because it may be cheaper source of nitrogen and do not harm environment by nitrogenous fertilizer. While legume is more nutritious than grass, guinea grass has been reported to combine well with *Centrosema pubescens* (Centro) (Baba et al., 2011).

Intercropping forage legume with grasses has been reported to increase forage dry matter yield, forage quality in term of crude protein content, voluntary feed intake and digestibility (Aderinola, 2007). Legume grown with grass gives several advantages over grass only. Alalade et al. (2014) reported that mix of legumes in the pasture usually results in improved herbage yield, higher quality and 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).

Some legumes such as Stylo, Butterfly pea, Desmanthus and Burgundy are high in crude protein and are well adapted to varying weather and ecological soil conditions. Apart from being relished by ruminants, farmers often use these legumes for soil reclamation (Babayemi & Bamikole, 2006). Among the group of potential forage legumes, the butterfly pea (*Clitoria ternatea*), a perennial plant that is tolerant to drought and resistant to competition from weeds, has production values ranging between 30000 and 40000 kg ha^{-1} and provides a fixing rate of up to 1200 kg ha^{-1} of soil nitrogen (N) (Collins & Grundy, 2005).

Production and composition of grass herbage is strongly affected by cutting management. Cutting is the main agronomic factor that effects morphology and the expression of yield potential and determines nutritive value (Santis et al., 2004). The yield of grasslands and other perennial herbage crops are greatly influenced by the total number of cutting intervals during the growing season. Effect of cutting intervals on nutritive quality of herbage is estimated by analyzing the contents of ash, crude protein, crude fiber, organic matter and also for the content of phosphorus, calcium, sometimes also potassium and magnesium (Bogdan, 1977). As grasses reach maturity, the rate of growth slows down, and if the plant is not cut until late in life its power of recovery is impaired, therefore, regularly cutting produced better quality and quantity of pasture grass (Moore, 1950).

Although few report on the cultivation, cropping and cutting management on pasture have been observed in Myanmar, appropriate cutting management and crop combination for high productivity of pasture remains as the main constraints in Myanmar. Therefore, this study was carried out with the following objectives:

- to find out the high productive pasture grass and legume cultivars in the study area,
- to evaluate the appropriate planting pattern for optimum herbage yield and quality of the tested pasture grass and pasture legume,
- to determine the appropriate cutting intervals for optimum herbage yield and quality of the tested pasture grass and pasture legume, and
- to examine the suitable combination of planting pattern and cutting interval for optimum herbage yield and quality of the tested pasture grass and pasture legume.

CHAPTER II
LITERATURE REVIEW

2.1 Important Role of Pasture for Livestock Production

Forage grasslands are used to feed livestock and globally it has been estimated that they represent 26% of the land area, and 70% of agricultural area (FAO, 2010). The majority of grasslands are located in tropical developing countries where they are particularly important to the livelihoods of poor peoples. Grasslands clearly provide the feed base for grazing livestock and thus numerous high-quality foods and such livestock also provide products such as fertilizer, transport, traction, fibre and leather. In addition, grasslands provide important services and roles including as water catchments, biodiversity reserves, for cultural and recreational needs, and potentially a carbon sink to alleviate greenhouse gas emissions (Boval & Dixon, 2012).

The consumption of livestock products can be regarded as important to a healthy diet due to their high nutrient density regardless of the numerous efficiency and environment concerns, particularly true in developing countries where undernourishment incidences are estimated as ∼4–22% of the populations (Alexandratos et al., 2006). Livestock production can convert non-edible crops such as the forages into human food, with sustainable intensification possible when inputs and outputs of the system are balanced (Derner et al., 2017).

Grassland agriculture is a distinct system in which major emphasis is placed on the production of grasses and legumes as forage crop for livestock. Grassland agriculture is a long-time program directed towards increased production from improved grasslands and more efficient use of high quality forage rich in proteins, minerals, and protective vitamins. Forage crops are usually grasses (*Poaceae*) or herbaceous legumes (*Fabaceae*). In the tropics, popular grasses include Napier grass (*Pennisetum purpureum*), *Brachiaria* and *Panicum* species. In the poorest parts of the world, livestock production is critically important for smallholders' livelihoods (Njuki & Sanginga, 2013).

2.2 Forage Biomass Production

Probably, the most important trait of any forage crop is rapid biomass production, as crops are either cut or grazed directly, and nutritional quality depends on the rate of biomass production. Intensive production with faster growth often decreases nutritional quality, but this depends on the species grown and some cultivars have better recovery from defoliation. Plant height correlates well with biomass for most crops (e.g., maize) and this factor together with ground area cover are the criteria underpinning methods to assess yields (Freeman et al., 2007).

Many plant species can be grown for forage production, but the ability of the shoot meristem to respond with increased growth after cutting is essential. In some forage species, aboveground grazing or cutting has been correlated with increased root exudation (Paterson & Sim, 1999). This flush of carbon release by roots can stimulate rhizosphere microbes that in turn help to mobilize soil nutrients to sustain aboveground regrowth. Maintaining an optimal nutrient and water supply is very important for forage biomass production. For example, the importance of N supply for re-growth after cutting grass has been demonstrated (Dawson et al., 2004).

2.3 Forage Nutritional Contents

The nutritional status of forage crop depends upon the concentration of carbohydrates, proteins and lipids. The composition of these organic nutrients determines the digestibility of each crop which along with mineral and vitamins provides the amount of energy which can be derived by the animal (Osbourn, 1980).

2.3.1 Protein

Nitrogen (N) availability to animals is predominantly from forage proteins and estimated using crude total protein measurements. Protein is usually abundant in the major form of Ribulose-1,5-bisphosphate carboxylase/oxygenase (RuBisCO), although relative amounts vary between species (Wallace et al., 1997). This is especially true when comparing content in grasses with herbaceous legumes such as red clover (*Trifolium pratense*), white clover (*Trifolium repens*) and lucerne (*Medicago sativa*) which are grown widely due to their high protein value (Ruckle et al., 2017). Crude protein (CP) content usually ranges from 3 to 20 % or even more in very young plants. Its content decreases as the growth of grass increased. Crude protein content of tropical grasses decreased faster than that of temperate species under water stress. It again decreased faster than under the more humid environments (Bogdan, 1977).

2.3.2 Fibre

The fibre fraction in forages varies in degree of development, chemical composition and structural complexity. The nature of fibre will depend on the type of deposition on primary cell walls. Substances such as cellulose, hemicellulose, lignin, suberin, cutin, waxes and salts are normally incorporated during the formation of secondary cell walls. Cellulose and hemicellulose are the major components of the cell wall and account for a large proportion of energy obtained from forages. They are both closely associated in plants and digested in the same way in ruminants and are often described under a common term “holocellulose” (Ely & Moore, 1955).

The neutral detergents insoluble are usually referred to as neutral detergent fibre (NDF). They embrace for the most part of the plant cell wall and are sometimes referred to as cell wall components or cell wall constituents. They consist primarily of cellulose, lignin, silica, hemicellulose, and some protein. Acid detergent fibre (ADF) consists primarily of cellulose, lignin and variable amount of silica. Acid detergent fibre differs from NDF in that NDF contains most of the feed hemicellulose and a limited amount of protein not present in ADF (Cullison, 1979).

2.3.3 Lipids

Lipids in forage crops are mostly found as polyunsaturated fatty acids (PUFAs) in the range of 10 – 30 g kg^{-1} (Hatfield et al., 2007) of which the most abundant is α-linolenic acid with linolenic and palmitic acid also being present. These dietary lipids are important in final animal product quality. Moreover, fresh forage has been shown through numerous studies to produce milk with lowered PUFAs content and increased *trans*-fatty acids (Chilliard et al., 2007). Striking differences in PUFAs content can be seen within species through profiling cultivars and moreover the harvest period and its environment (Elgersma et al., 2003; Clapham et al., 2005).

2.4 General Description of Tested Forage Crops

Panicum maximum cv. (Mombasa) is originally from Tanzania. It is a tall, tufted perennial with some short rhizomes. It is suitable for grazing, silage and fresh in feeding trough. Not suitable for haying due to its difficult drying characteristics. The forage quality is excellent (CIAT, 2018a).

Mulato I and Mulato II were the first hybrid *brachiaria* cultivars released from the international center for tropical agriculture (CIAT) breeding program in 2001 and 2004, respectively. Cayman grass is suitable for grazing, hay, fresh in feeding troughs and its quality and production also make it adequate for use as silage (CIAT, 2018b).

Desmanthus cultivar has been released specifically for western Queensland where in fact, no suitable sown legumes are available and where an adapted legume would contribute to the productivity and sustainability of the grasslands (Cook et al., 2005).

Stylosanthes (*Stylosanthes guinensis*) cultivar is widely adapted and very drought tolerant. It is well suited to soils low in phosphorus and tolerant of heavy grazing. Although it is well suited to extensive grazing systems, it is low palatable and not adapted to heavy clay soils (Cook, 2007).

Butterfly pea (*Clitoria ternatea*) may have originated from Latin America or Asia but is now naturalized in all the semi-arid and sub-humid tropics of Asia, Africa and Australia. It is fast summer-growing legume, can cover the soil within no more than 30-40 days after sowing and yield mature pods within 110 to 150 days. It is naturally found in grassland, open woodland, bush, riverine vegetation, and disturbed places (Staples, 1992).

2.5 Morphological Characters of Tested Forage Crops

Mombasa has large tussocks to 2 m, stems tinged with purple. Leaves are large, measuring about 3 cm wide and 97 cm long with short hairs on the upper surface; leaf sheaths are glabrous. It has a typical open seed head with drooping panicles. Stems do not have hair or wax and similar to hybrid Napier grass in habit, but more leafy. Mombasa has a deep root system which enables it to withstand long dry periods but it performs best under hot, humid tropical conditions (CIAT, 2018a).

Cayman is a leafy, vigorous, semi-decumbent perennial grass of medium height, growing to 80–110 cm without inflorescence. With a tillered growth habit, the Cayman grass produces abundant stolons. In addition in high moisture conditions, this grass modifies its growth habit and develops, early during its growth cycle, a large number of decumbent stems, which produce tillers and roots at the nodes. These superficial roots give the plant support, absorb nutrients and supply oxygen to the plant in these adverse conditions of poor drainage (CIAT, 2018b).

Mulato II is a perennial, tetrapliod hybrid, with a semi-erect growth habit, reaching heights up to 1 m. It stem are strong, cylindrical, and pubescent: some present semi-decumbent growth habit and are capable of rooting when they come into close contact with the soil. The dark green leaves of Mulato II are linear- triangular (lanceolate) in shape and approximately 3.8 cm wide. Both sides of the leaf blade and leaf sheath present abundant pubescence. The ligule is short and membranous (CIAT, 2018b).

Desmanthus is an erect perennial herb or small shrub, growing to 60 cm tall with green and hairless, angular with corky ridges. Bipinnate usually with 2-4 pairs of pinnae, leaflets small (2.4-7.0mm long and 0.7-1.6mm wide) with 13 to 19 pairs of leaflets/pinnae, a yellow/green gland on petiole below first pair of pinnae with small white/cream in bundles (Clem, 2009).

Stylo is perennial shrubby legume, usually to less than 1m tall, but capable of taller growth. It has large tap root up to 4 m deep. Young stems vary from green to reddish in colour, usually with dense hairs and sticky bristles, becoming woodier with age. Older stems are often more than 1 cm thick. Their leaves are dark green, hairy, elliptical to oblong leaflets, to about 2.5cm long and 1cm wide (Cook, 2007).

Burgundy plant is erect or trailing, summer growing and perennial legume. Stems have hairy, mostly fairly fine (1- 2 mm diameter). There are 3 leaflets; hairy on upper and lower surfaces with purple-red flower and are borne on stems about 15cm long with a ring of small leaf-like structures at the base. Pods are 4 - 9 cm long, straight and cylindrical; with 9 to 17 seeds per pod and their seed are mottled, brown, black and tan; 170,000 seeds/kg (Stuart & Pengelly, 2007).

The butterfly pea (*Clitoria ternatea* L.) is a vigorous, trailing, scrambling or climbing tropical legume. Its sparsely pubescent stems are sub-erect and woody at the base and may be up to 5 m long. They root only at the tips .The leaves are pinnate, bearing 5-7 elliptical, 3-5 cm long leaflets. The flowers are solitary or paired, deep blue or pure white, about 4 cm broad. The fruits are flat, linear, sparsely pubescent pods that dehisce violently at maturity and throw 8-10 dark and shiny seeds (Staples, 1992: Cook et al., 2005).

2.6 Environment and Establishment of Tested Forage Crops

Mombasa grass grows on wide varieties of soil, preferring higher fertility with good drainage as it will not tolerate water logged conditions as well as Signal Grass (*Brachiaria decumbens*). It is well eaten by all classes of grazing livestock, with particularly high intakes of young leafy growth. Recommended planting rates for Mombasa grass are 6-8 kg $ha^{-1}$and marginal dryland: 6 kg $ha^{-1}$and good dryland: 8 kg ha^{-1}. Seed should be sown into a well prepared seed bed using high quality seed. Care should be taken not to cover the seed too deeply or preferably surface sown onto a freshly cultivated seed bed. It can be either planted in rows, 50 cm apart, or broadcast sown at 6 kg ha^{-1}. The seed can be sown on to the soil surface and brushed with soil by using tree branches or large brooms. The seed should not bury more than 1-2 cm under the soil. It is easy to plant from rooted tillers (CIAT, 2018a).

In high moisture conditions, the growth habit of *Brachiaria* hybrid develop early during its growth cycle, a large number of decumbent stems, which produce tillers and roots at the nodes. These adventitious roots give the plant support, absorb nutrients, and supply oxygen to the plant in these adverse conditions of poor drainage. Cayman is broadcast sown at 6-8 kg ha^{-1} dryland or 8-10 kg ha^{-1} with irrigation into a freshly prepared seedbed. The seed should be sown on to the soil surface and buried the seed no more than 1-2 cm under the soil (CIAT, 2018b).

Clitoria ternatea grows within 20˚N and 24˚S, from sea level up to an altitude of 1600-1800 m, and in equatorial Africa up to 2000 m. Butterfly pea does better where average temperature is about 19-28˚C and where annual rainfall ranges from 700 to 1500 mm. However, it tolerates temperatures as low as 15˚C and even some frost as it may regrow from the stems or from the plant base, provided it is already woody when the frosting occurs. It does well under irrigation but has only a low tolerance of flooding or waterlogging. It has also some drought tolerance and can grow in places where rainfall is as low as 400-500 mm. It can survive a 5-6 month drought in the drier tropics. *Clitoria ternatea* can grow on a wide range of soils but is particularly adapted to shallow, heavy clay and sodic soils (pH 5.5-8.9). It thrives in full sunlight but can also grow under light shade in rubber and coconut plantations (Staples, 1992; Cook et al., 2005).

2.7 Herbage Yield and Quality of Tested Forage Crops

*Panicum maximum (*Mombasa) grass is a very productive leafy grass, producing between 20 and 40 t ha^{-1} dry matter per year. In Thailand, Mombasa have 8-12% crude protein on poor soils and 12-14 % crude protein on better soils (CIAT, 2018 a).

Mulato II produced 0.97 t ha^{-1} in the dry season and 1.9 t ha^{-1} in the rainy season. Cayman produces similar dry matter yields to Mulato II. Cayman showed high nutritive value, including high percentage of leaf (70 - 80%), and crude protein (19 - 21% in leaves, 10 - 12% in stems). The protein potential up to 17% and palatability of Cayman is high, as is digestibility (CIAT, 2018 b).

Demanthuus leaf is high in crude protein (18-24%) and has high digestibility (Acid detergent fibre of < 20%). Well eaten through the growing season (Clem, 2009).

The nutritive value of shrubby stylo declines with age, even in the leaf where crude protein ranges from 20 in young leaves to 10% in older leaves, phosphorus from 0.3 to 0.1% and in-vitro dry matter digestibility from 70 to 50%. Acid detergent fibre values may be about 30 % in the leaf, and over 40% in the stem. Palatability of shrubby stylos is fairly low, and in the early part of the growing season, the grass is grazed preferentially. In mature grass/legume pastures, shrubby stylo can contribute 2 - 7 t ha^{-1} DM yr^{-1}, and result in annual live weight gains of 140 - 160 kg/hd (Cook, 2007).

Burgundy produces high quality feed with crude protein levels around 20%, compared with those of lucerne of 22% and butterfly pea of 24.5% and it is extremely palatable. Burgundy bean can produce 5 - 8 t/ha of dry matter each year, with a first year production advantage over butterfly pea (Brown & Pengelly, 2007).

Clitoria ternatea is good protein-rich forage that is used either alone or as a protein supplement for grazing animals. Productive behavior of animals fed with *Clitoria ternatea* is quite acceptable and compares favourably to that obtained with other high quality supplements and forages, and it often contributes significantly to lower production costs (Villanueva Avalos et al., 2004). *Clitoria ternatea* forage is palatable to sheep, goats and cattle and no toxicity has been observed (Hall, 1985). There are few digestibility measurements available in the literature: in OM and DM digestibility values for the hay range from 50-60% (Ratan et al., 1982) to 72-74% (Medrano, 2001; Bustamante Guerrero et al., 2002), which reflects probably the high fibre content of the forage.

2.8 Effect of Cropping Pattern for Pasture Production

Agricultural production is intimately related to the harnessing of favorable weather conditions during every cropping season. It is an established fact that crop yield is the integral result of a number of mutually interacting physical and physiological processes that take place during the crop growth period (Kavi et al., 1990). The prevailing crop pattern in any region should reflect the best possible use of physical environment in the shape of land. Agricultural diversification is considered to be the most appropriate strategy that augments growth, stabilizes farm income especially of the small and marginal farmers, generates full employment, protects natural resources and attains the goals of food security, forestry, livestock and fishery activities (Seeema, 2008).

The study of economics of the cropping pattern is assuming great significance in the view of the greater emphasis on the balanced development of agriculture to meet the food, fodder, fibre, oilseeds and other requirements of the population. Crop planning will also have to take into account the fodder and foodstuff needs of the dairy cattle and the poultry farms. It is hardly necessary to make out a case for augmenting the supply of protective foods (milk, meat and eggs) both for rural as well as urban population. It is in the interest of the farming community as well to develop them because they bring ready cash and make possible the use of crop residues which would go waste. The cattle and the poultry are also a source of organic manure. Adequate attention has to be paid to all these factors in laying down the crop pattern (Oommen, 1963). Moreover, Sayar et al. (2014) reported that substantial changes in the established crop patterns would be required for successful forage production when switching from dry farming to the irrigated agriculture. Therefore, the determination of the most convenient new perennial forage species and mixtures of the crops is important for improving forage production.

Pasture cropping is a farmer-initiated land management system that seamlessly integrates cropping with pasture production, and allows grain growing to function as part of truly perennial agriculture. Pasture cropping as a land management system has attracted a lot of interest over last decade, with offering consultancy both locally and in diverse agricultural area (Seis, 2006), Commonwealth Scientific International Research Organization (CSIRO) studying environmental effects of pasture cropping (Bruce & Seis, 2005). Moreover, Filmer and Seis (2008) said that the goals of pasture cropping provide not only of lower input costs and better profitability but also more importantly of regenerating the nature capital base, including soil conservation and health, water cycle health and biodiversity.

2.9 Effect of Cutting Management on Pasture Production

One of the objectives of management is to provide the huge intake of nutrients by the animals from pasture on a sustained basis. This is achieved by optimizing the balance between growth, losses due to tissue senescence and the yield of pasture removed by cutting. The effect of cutting is determined by quantity and type of removed tissue, remaining leaf area, frequency of cutting, and physiological stage of the plants (Bahmani et al., 2000). A common goal of pasture management is to maximize the yield of forage produced and harvested without pasture deterioration and forage quality. Forage production is strongly affected by cutting regimes (Warner & Sharrow, 1984). Harvest regime may affect the comparative productivity rankings of grass species (Heinrichs & Clark, 1961). Therefore, knowledge of the effect of cutting frequency and its quality is crucial for successful pasture management and for sustainable animal agriculture (Sarwar et al., 2006).

Increases dry matter yields with extended cutting intervals are consequences of additional tiller and leaf formation and stem development (Robertson et al., 1976). Cutting too frequently reduces total forage yields, depletes carbohydrate reveres, causes a decline in root development, favours weed invasion and adversely affects regrowth potential (Perez & Lucas, 1974).

The cutting interval between harvests of grasses profoundly affects herbage production, nutritive value, regrowth potential, botanical composition and species survival. In general, an extended period between cuttings has the following effects:

(1) an increase in the percentage content of dry matter, crude fiber, lignin and cell wall

(2) an increase, then decrease, or fluctuation, in total dry matter production and nitrogen- free extract

(3) a decrease in leaf, stem ratio, percentage of crude protein (CP), mineral constituents and soluble carbohydrates

(4) an increase, and then a decrease in the amount of nitrogen (N) uptake by the plant and N recovery and

(5) a rapid decline in animal intake and digestibility.

The nutritive value of grasses may be kept at a relatively high level by cutting at frequent intervals. Schofield (1995) said that the effect of cutting at one, two and three month intervals on the yield and chemical composition of 19 grasses, the highest protein content and dry matter yields were obtained with the three-monthly frequency.

2.10 Reason for Intercropping

A number of reasons have been advanced for the use of intercropping in place of sole cropping. Lamberts (1980) cited that the reasons for intercropping are increased productivity (yield advantages), better use of available resources (land, labor, time, water and nutrients), reduction in damage caused by pests (diseases, insects and weeds), socio-economic and other advantages (greater stability, economics, nutrition, the biological aspect).

2.10.1 Increase productivity and yield stability

The major reason for intercropping rather than sole cropping of the same species is increase return (usually yield) ha^{-1}. Petersen (1994) stated that intercropping provides a measure of yield stability that is not present in sole cropping. The studies of Singh (1983) indicated that sorghum-legume intercropping systems were more stable than the sole cropping of either of the component crops on the basis of coefficients of variations and the regression of yield on the environmental index. It was possibly due to a compensation mechanism i.e. if one crop fails due to the vagaries of nature, the other crop of the system gave some yield and to some extent compensated for the loss.

The persistence of legumes in mixtures is determined by the growth habits of both the legume and the grass as well as the management of the sward. Olsen and Tiharuhondi (1972) showed that *Medicago sativa* (Alfalfa) performed better than *Desmodium intortum* (Desmodium) when grown together with the grasses *Setaria anceps* (Setaria), *Chloris gayana* (Rhodes) and *Panicum maximum* (Mombasa).

2.10.2 Better use of available resources

2.10.2.1 Nitrogen

In cereal-legume intercropping system N_2-fixing legumes are often used to increase dry matter production and protein content of the harvested crop while minimizing N fertilizer inputs. Ideally, the legume will fix most of its required N and also supply a significant portion of that required by the non-legume; however, there is considerable uncertainty on how effective N is transferred from various legumes to non-legumes. For example, Mallarino et al. (1990) found that grasses in association with clovers obtained up to 60% of N from the legume, whereas Izaurralde et al. (1992) found little evidence of N transfer from field pea (*Pisum sativam* L.) to barley (*Hordeum vulgare* L.) and Van Kessal and Roskoski, (1988) found little evidence of N transfer from cowpea (*Vigna unguiculata*) to maize (*Zea mays* L.). The inconsistencies in N transfer may be due to differences in how N is transferred from legumes to non-legumes (Cochran & Schlentner, 1995).

Lory et al. (1992) listed six pathways for loss of symbiotically fixed nitrogen from legumes to the soil (i) excretion from roots, (ii) sloughing of root cells, (iii) root and nodule decay, (iv) passage through endomycorrhizal fungi that infect the roots, (v) leaching of N from living herbage by rain water, and (vi) decomposition of dead herbage on the soil surface. The extent that any one of these processes contributes to N transfer is dependent on physiological characteristics of the legume, duration of legume association with non-legume and to some extent, the environmental conditions during the growing period. Thus, fertilizer management strategies need to be developed for intercrop systems that will maximize the fixation of N_2 and also maintain high production of dry matter.

A napier grass-forage legume mixture can improve the nutritional plane of stock as forage legumes generally have a higher nutritive value than tropical grasses and also have the ability to fix atmospheric nitrogen through their symbiotic association with rhizobia (Giller, 2001). The mixture also has the potential to produce higher total dry matter yields, suppress weeds and improve soil fertility. Therefore, the integration of forage legumes into a Napier grass fodder system may provide an effective means of increasing forage and dairy productivity for smallholders in central Kenya and other highland areas in Africa (Goldson, 1977).

2.10.2.2 Water

An intercrop of two species often uses soil water more efficiently than a monocrop of either species (Willey, 1979). Hulugalle and Lal (1986) have reported higher water use efficiency (WUE) by intercrops than monocrops of component species. In their studies, total seasonal water use did not increase under the intercrops but WUE by the intercrops was greater.

Snaydon and Harris (1981) indicated that intercrops of species competition for water at partially different times (i.e. growth and development not fully concurrent) or from partially different zones (i.e. different soil water extraction patterns) use water more efficiently than do mono-crops of the component species.

2.10.2.3 Light

In agricultural systems, competition can be considered to be mainly for light resources, given that irrigation and fertilizer application are adequate. The two species; sun species and shade species growing together form a canopy that intercepts light qualitatively and quantitatively differently than either of the monocultures. Trenbath (1981) has developed this idea and analyzes the light use efficiency (LUE) of an intercropping system. The light use efficiency is the light-conversion efficiency (the quantity of intercepted light actually used for photosynthesis) multiplied by the proportion of light intercepted. Fisher (1975) reported the situation in which a taller crop species does not completely utilize the incoming solar radiation, even when planted at its optimal density. Thus the light environment at the ground contains 'wasted' light, which obviously could be used by another crop.

Engles and Krieger (1997) stated that the light environment within the canopy of the mixtures of annual crops changed as the crop system matures, with LAI and light intensity at different levels undergoing considerable variation over time. Farmers have learned to take advantage of these changing conditions.

2.10.3 Socio - economic and other advantages

Itulya and Aguyoh (1998) stated that intercropping practice has continued to be popular in the developing world because several advantages are associated with this ancient practice: (1) increase soil erosion control, (2) insurance against crop failure, (3) spreading labour requirement and harvesting more evenly throughout the season, (4) facilitating production of many commodities in a limited area, (5) efficient utilization of resources by plants with different growth periods, heights, rooting systems, and nutrient requirements, (6) transfer of nitrogen fixed by legumes to non-legume species, and (7) controlling the spread of diseases and pests.

Nutritive quality of forage crops were increased by intercropping. Ram (2015) reported that crude protein yield also increased significantly when Guinea grass intercropped with Stylo (*S. seabrana)* than intercropping with Butterfly pea (*C. ternatea*) and Burgundy (*M. atropurpureum*). This was due to higher dry matter yield obtained by intercropping of *S. seabrana* with Guinea grass than *M. atropurpureum* and *C. ternatea*. While available phosphorus (9.75 kg ha^{-1}) and potash (194.8 kg ha^{-1}) was highest in plots where *C. ternatea* was intercropped with Guinea grass.

2.11 Land Equivalent Ratio (LER)

The measurement most frequently used to judge the effectiveness of an intercrop is the land equivalent ratio (LER) (Mead & Willey, 1980). It is the ratio of the area needed under monoculture to a unit area of intercropping at the same management level to give an equal amount of yield. It is calculated to study inter-crop competition and yield advantages in intercropping compared with sole cropping. The land equivalent ratio is simply the sum of the relative yields. Thus LER can be computed using the following formula:

$$\text{LER} = \sum_{i=0}^{n} \left(Y_i^I / Y_i^M \right)$$

Where, Y_i^I = Yield of crop i in intercropping

Y_i^M = Yield of crop i in sole cropping

n = total number of crops in the cropping system

(Mason et al., 1986)

The land equivalent ratio (or relative yield total) is thus easy to compute and easy to interpret. If it is greater than 1.0, the intercrop is more efficient. If it is less than 1.0, monocultural production is more efficient. The value 1.0 is the critical value, above which the intercrop is favored, and below which the monocultures are favored (Vandermeer, 1989).

CHAPTER III
MATERIALS AND METHODS

The study was carried out in the upland field of Department of Agronomy, Yezin Agricultural University in Yezin, which is situated at 19˚ 38' N latitude, 96˚ 50' E longitude and 102 m altitude. The study was started from October, 2016 to September, 2018. The weather conditions during the experimental periods are shown in Appendix – 2 and 3.

3.1 Experiment I. Preliminary Study on the Performance of Pasture Grasses

3.1.1 Experimental layout

The experiment was conducted in randomized complete block design with four replications. The individual plot size was 4m x 6m. In each plot, 8 rows of stem cuttings were sown with the spacing of 50cm x 50cm.

3.1.2 Land preparation and crop establishment

Ploughing was carried out on 18th October 2016. Harrowing and leveling were done on 21th, October 2016. The tested pasture grass cultivars were Mombasa, Cayman and Mulato II. Planting materials, which were introduced from Thailand, were obtained from the upland field of Department of Agronomy. Cuttings were cut at the point of six inches from plant base including root to use as planting material. One stem cutting was planted in one hole on 22nd, October 2016. The plants that failed to survive after 14 days of planting were replaced to have a complete final stand. In this experiment, 100 kg ha^{-1} of compound fertilizer (15:15:15) was applied as basal. Hand weeding was carried out before plant establishment and after every cutting.

3.1.3 Data collection

Cutting was done by hand. Six months and twelve months after planting, the plants were cut with sickle at the height of 15cm above ground level.

3.1.3.1 Agronomic characters

Before cutting, three hills from sampling area of each plot were measured for plant height and number of tillers per hill. Four hills from harvested area of each plot were cut and the fresh weight were recorded and then dried at 60˚C for 72 hours to obtain dry matter yield.

3.1.3.2 Chemical composition

The dried samples of the whole plants were analyzed for OM content (%), total nitrogen (N) to calculate CP content (%) by using official methods of analysis (AOAC, 1990) and for neutral detergent fiber (NDF) content (%) and (ADF) content (%) by using forage fibre analysis (Goering & Van Soest, 1970). All chemical analyses were carried out at the laboratory of Department of Physiology and Biochemistry, University of Veterinary Science, Yezin.

3.1.4 Data analysis

The data were analyzed with the analysis of variance (ANOVA) by using Statistix (Version 8.0) and means were separated with least significant difference at 5% level of significance (Gomez & Gomez, 1984).

3.2 Experiment II. Preliminary Study on the Performance of Pasture Legumes

3.2.1 Experimental layout

The experimental plots were laid out in randomized complete block design with four replications. The individual plot size was 4m x 6m and then seeding holes were made with the spacing of 50cm x 50cm on the each plot. In each plot, seeds were sown in 8 rows.

3.2.2 Land preparation and crop establishment

Ploughing was carried out on 25th May 2017. Harrowing and leveling were done on 28th May 2017. The tested varieties were Stylo, Butterfly pea, Desmanthus and Burgundy. The seeds of the tested legume varieties that were introduced from Thailand were collected from the field of Meikhtilar Dairy farm and University of Veterinary Science. Seed were sown in 8 rows with the spacing of 50cm x 50cm in each hole on 3rd, June 2017. In this experiment, 100 kg ha^{-1} of compound fertilizer (15:15:15) was applied as basal application.

3.2.3 Data collection

Cutting was done similar procedure as in experiment I.

3.2.3.1 Agronomic characters

The data were collected from harvest area (5 m^2) of each plot and fresh weight were recorded and then dried at 60˚C for 72 hours to obtain dry matter yield.

3.2.3.2 Chemical composition

The dried samples of the whole plants were analyzed for OM content (%), total nitrogen (N) to calculate CP content (%) by using official methods of analysis (AOAC, 1990) and for NDF content (%) and ADF content (%) by using forage fibre analysis (Goering & Van Soest, 1970). All chemical analyses were carried out at the laboratory of Department of Physiology and Biochemistry, University of Veterinary Science, Yezin.

3.2.4 Data analysis

The data were analyzed with the analysis of variance (ANOVA) by using Statistix (Version 8.0) and means were separated with least significant difference at 5% level of significance (Gomez & Gomez, 1984).

3.3 Experiment III. Effect of Planting Patterns and Cutting Intervals on Herbage Yield and Quality of Pasture Grass and Legume

3.3.1 Experimental layout

Split plot design with 3 replications was used in this experiment. The experimental area was 588 m^2. The size of main plot was 4m x 12m and the size of subplot was 4m x 3m. The study investigated two factors, main plot factor was planting patterns and sub plot factor was cutting intervals, planting patterns included pasture grass sole cropping, pasture legume sole cropping and pasture grass - legume intercropping (1:1) and cutting intervals included 3-month cutting, 6-month cutting, 9-month cutting and 12-month cutting.

3.3.2 Land preparation and crop establishment

Ploughing was carried out on 25th May 2017. Harrowing and leveling were done on 28th May 2017. Mombasa stem cuttings and Butterfly pea seeds from experiment I and II were used as planting materials. Cuttings were cut at the point of six inches from the plant base including roots to use as planting materials. One stem cutting was planted in one hole with the spacing of 50 cm × 50 cm on 3rd, August 2017. The plants that failed to survive after 14 days of planting were replaced to have a complete final stand. And then, Butterfly pea seeds were placed as 3 seeds in one hole. After 2 weeks, one seedling was left by thinning. Three months later, the plants were cut according to the treatments. Cutting was done by hand. For 3-month cutting, there were 4 cuttings during the experimental period. For 6-month cutting, there were 2 cutting during the experimental period. For 9-month and 12-month cutting, there was 1 cutting during the experimental period. In the experiment, 100 kg ha^{-1} of compound fertilizer (15:15:15) was applied as a basal application. Hand weeding was carried out before plant establishment and after every cutting.

3.3.3 Sampling area

For destructive sampling, two sample hills were randomly taken from the rows of the sampling area ($5m^2$) leaving the outside rows as border rows (Appendix 1).

3.3.4 Data Collection

3.3.4.1 Agronomic characters

Plant height and number of tillers per plant were measured from sampling area of each plot before cutting. The two hills from the sampling area of each plot were cut and the fresh weight was recorded. Then, five tillers as sub-sample were randomly selected from those 2 hills and measure for leaf area to calculate leaf area index. The fresh material was dried at 60˚C for 72 hours to obtain dry matter yield.

RFV (%) $= [88.9 - (0.779 \times \text{ADF g g}^{-1}\text{ DM})] \times 120/\text{NDF g g}^{-1}\text{ DM} \times 0.775$

CP yield (kg ha^{-1}) = DM (kg ha^{-1}) ×CP (g g^{-1})

RFV yield (kg ha^{-1}) = DM (kg ha^{-1}) × RFV (g g^{-1})

ADF yield (kg ha^{-1}) = DM (kg ha^{-1}) × ADF (g g^{-1})

NDF yield (kg ha^{-1}) = DM (kg ha^{-1}) × NDF (g g^{-1})

OM yield (kg ha^{-1}) = DM (kg ha^{-1}) × OM (g g^{-1})

DM = Dry matter

(Horrocks & Valentine , 1999)

3.3.4.2 Chemical composition

The dried samples of the whole plants were analyzed for OM content (%), total nitrogen (N) to calculate CP content (%) by using official methods of analysis (AOAC, 1990) and for NDF content (%) and ADF content (%) by using forage fibre analysis (Goering & Van Soest, 1970). All chemical analyses were carried out at the laboratory of Department of Physiology and Biochemistry, University of Veterinary Science, Yezin.

3.3.5 Leaf area index

Leaf area index (LAI) was determined on two sample hills from each plot starting from 3-month cutting interval. Five tillers were randomly selected from 2 hills of sampling area and all the leaves from 5 tillers were detached and leaf area were measured by leaf area meter. After measurements of the leaf area from 5 tillers, leaves were dried and recorded. The remaining leaves of 2 hills leaves were dried and recorded and calculated for 2 hills leaves area by dried weight basic. Leaf area index (LAI) was calculated according to the following formula.

$$\text{LAI} = \frac{\text{Sum of the leaf area of all leaves (cm}^2\text{)}}{\text{Ground area of field where the leaves have been collected (cm}^2\text{)}}$$

(Waston, 1947)

3.3.6 Land equivalent ratio

In this experiment, land equivalent ratio (LER) for each treatment was calculated by using the following formula:

$$\text{LER} = \sum_{i=0}^{n} \left(Y_i^I / Y_i^M \right)$$

Where, Y_i^I = Yield of crop i in intercropping

Y_i^M = Yield of crop i in sole cropping

n = total number of crops in the cropping system

(Mason et al., 1986)

3.3.7 Data analysis

The data were analyzed with the analysis of variance (ANOVA) by using Statistix (Version 8.0) and means were separated with least significant difference at 5% level of significance (Gomez & Gomez, 1984).

CHAPTER IV
RESULTS AND DISCUSSION

4.1 Experiment I. Preliminary Study on the Performance of Pasture Grasses

This experiment was carried out in the upland field of Department of Agronomy, Yezin Agricultural University in Yezin, from October, 2016 to, September 2017.

4.1.1 Agronomic performance of three pasture grasses

Different plant heights were observed in different grass cultivars (Table 4.1). Mombasa was found as significantly highest plant height (122.51 cm) cultivar among tested cultivars. There was not significantly different in plant height between Cayman and Mulato II, however Cayman was taller (60.59 cm) than Mulato II (55.64 cm).

Tiller numbers were significantly different among tested cultivars and the lowest tiller number (26) was observed in Mombasa. Although Mulato II provided the highest number of tillers (79), it was not significantly different from that (64) of Cayman. Vegetative growth (height, spread and tiller number) can be attributed to the differences among the cultivars. Plant spread can be attributed to individual growth habits of the cultivars (Nguku, 2016).

Among three grass cultivars, the highest herbage fresh yield (73540 kg ha^{-1}) was observed in Mombasa with the tallest plant height though fewer tiller numbers. It was followed by the yield of Cayman (44530 kg ha^{-1}) and the lowest yield (28860 kg ha^{-1}) was resulted from Mulato II. Laidlaw (2005) stated that, tillers increase the chance of survival and the available forage resource of grasses and tiller numbers is an indicator of resource use efficiency by different grass species. Moreover, Nelson and Zarrough (1981) reported that the weight of a plant’s tillers will determine its productivity.

There were significantly different in dry matter yields among tested cultivars. Mombasa was recorded as the highest dry matter yield (18380 kg ha^{-1}) cultivar. The lowest yield (7220 kg ha^{-1}) was recorded from Mulato II though this value was not significantly different from that (11140 kg ha^{-1}) of Cayman. Average yields of dry matter in well fertile soil can be expected to fluctuate between 20000-40000 kg ha^{-1} for high yielding grasses, 10000-25000 kg ha^{-1} for medium-yielding grasses and 3000-10000 kg ha^{-1} for poor yielding grasses (Bogdan, 1977).

Table 4.1: Mean comparisons for agronomic performance of three pasture grasses, October 2016 –October 2017

Cultivars	**Plant height (cm)**	**Tiller number**	**Fresh weight (kg ha^{-1})**	**Dry weight (kg ha^{-1})**
Mombasa	122.51 a	26.00 b	73540.00 a	18380.00 a
Cayman	60.59 b	64.00 a	44530.00 b	11140.00 b
Mulato II	55.64 b	79.00 a	28860.00 b	7220.00 b
LSD $_{0.05}$	14.76	22.89	22590.00	5650.00
Pr>F	0.0001	0.003	0.008	0.008
CV%	10.72	23.38	26.67	22.67

Means followed by the same letter within the column are not significantly different at 5% level.

4.1.2 Nutritional composition of three pasture grasses

Different tested pasture grasses produced different nutritional composition. In this experiment, crude protein yield, acid detergent fibre yield, neutral detergent fiber yield, relative feed value yield and organic matter yield were analyzed for pasture quality.

4.1.2.1 Crude protein yield

Crude protein is the most important measure of nutritive values of forages. The crude protein in herbage is determined as nitrogen (N). Most nitrogenous compounds in plant contain on average 16%N. The total N content is multiplied by 6.25 to estimate crude protein. Normally, 70-90% of the total N in herbage is in the form of proteins, the remainder being non protein nitrogen (NPN) as peptides, amino acid, amines and inorganic nitrate (Holmes, 1980).

There were significantly different among three tested cultivars in crude protein yield (Figure 4.1). Maximum crude protein yield (1079 kg ha^{-1}) was resulted from Mombasa followed by Cayman (718 kg ha^{-1}) and the lowest was obtained from Mulato II (419 kg ha^{-1}) for the whole year. Generally, there have been instances of high CP concentration in hybrid *Brachiaria* (Cayman and Mulato II) which could provide average (about 7 -11 %) crude protein in leaf in Thailand (Hare et al., 2007). In this experiment, Cayman and Mulato II produced lower dry matter yield than Mombasa, therefore the highest crude protein was observed in Mombasa during the whole year due to the production of highest dry weight (Table 4.1).

Minson (1990) showed that crude protein concentrations of 560 tropical forages samples, grown and determined in different parts of the world, ranged from 2% to 27% of the dry matter according to growth stage and soil fertility. Gőhl (1975) stated that wide variation of CP was mainly related to different content of CP in the grass and fiber component.

4.1.2.2 Acid detergent fiber yield

The fiber fraction in forage varies in degree of development, chemical composition and structural complexity. The nature of the fiber depends on the deposition on primary cell walls. Acid detergent fiber consists of cellulose, lignin, bound protein, and acid insoluble ash protein of a feed (Dewhurst et al., 2009).

Figure 4.2 showed different acid detergent fiber yield on three tested grass cultivars with significantly highest value in Mombasa (8189 kg ha^{-1}). There were no significant difference between Cayman and Mulato II, however Cayman included more acid detergent fiber (3952 kg ha^{-1}) than that (2485 kg ha^{-1}) of Mulato II in numerically. Evitayani et al. (2004) reported that species and season had significant effect on chemical composition and mineral concentration.

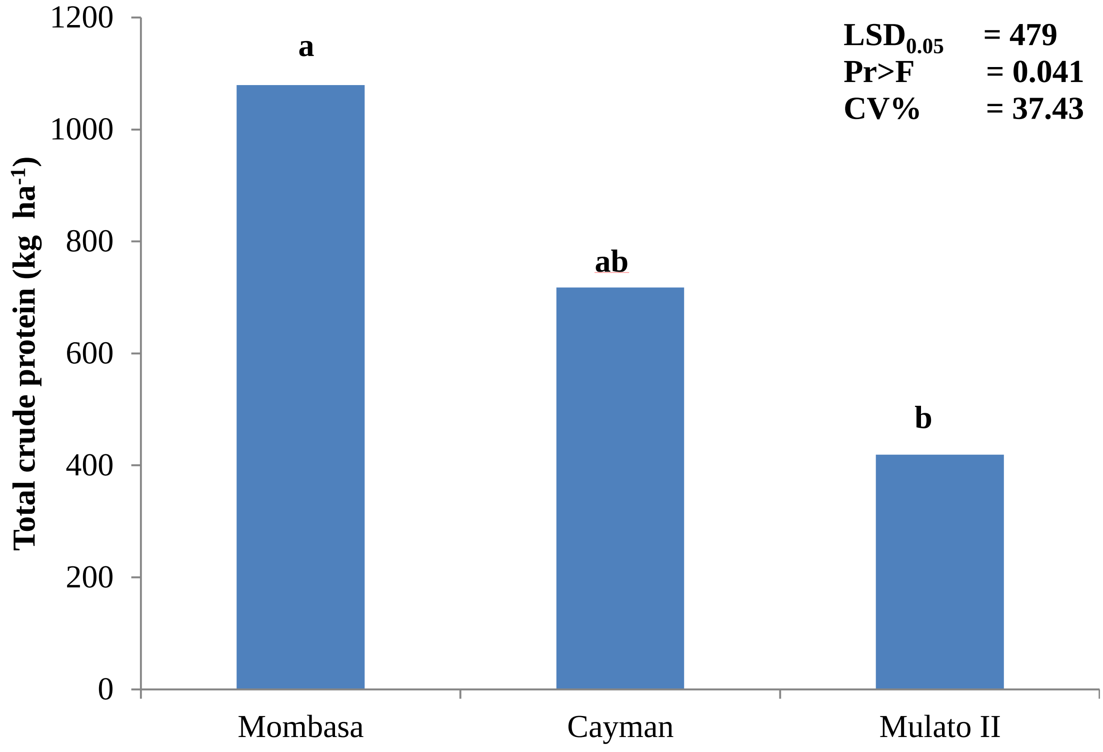

Figure 4.1: Crude protein yield of three pasture grasses, 2016-2017

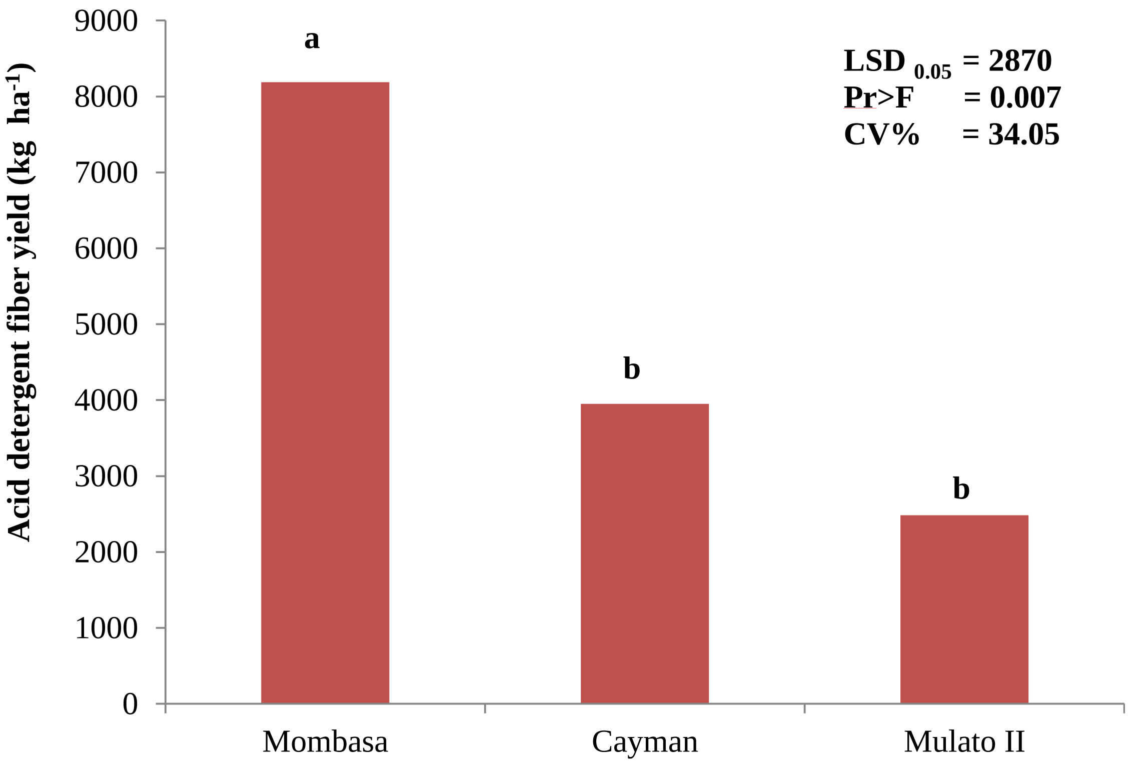

Figure 4.2: Acid detergent fiber yield of three pasture grasses, 2016-2017

4.1.2.3 Neutral detergent fiber yield

Neutral detergent fiber refers to the total cell wall, which is comprised of the ADF fraction plus hemicellulose (Albayrak et al., 2011). The NDF content is important in ration formulation because it reflects the amount of forage that can be consumed by animals (Bingol et al., 2007). It is better than ADF and the more common measurement for fibre composition (Dewhurst et al., 2001).

The different NDF values were resulted from different grass cultivars (Figure 4.3). The maximum NDF (12113 kg ha^{-1}) was obtained from Mombasa followed by that (7014 kg ha^{-1}) of Cayman while the minimum NDF (4392 kg ha^{-1}) was resulted from Mulato II.

According to the report of Bula et al. (1977), dry matter digestibility of forage during the grazing stage can vary considerably, and is related to changes in the chemical composition particularly in fiber, lignin, silica contents.

4.1.2.4 Relative feed value yield

Relative feed value is an index combining the important nutritional components of intake and digestibility of forages. Although the index has no units, comparisons forage quality of grasses, legumes, and intercropping mixtures can be made by using the index. As ADF and NDF percent decrease, the RFV value increases (Schroeder, 1994). Relative feed value (RFV) yield adjusts biomass yield according to the relative value of the forages for livestock (Zhang et al., 2018). There were significantly different in RFV among three forage grass cultivars (Figure 4.4). Maximum RFV yield (7340 kg ha^{-1}) was resulted from Mombasa with the highest CP yield while minimum RFV (3460 kg ha^{-1}) was recorded from Mulato II. Relative feed value (5360 kg ha^{-1}) of Cayman was not significantly different from Mombasa. From the result, Mombasa may be considered for improved pasture production with highest RFV.

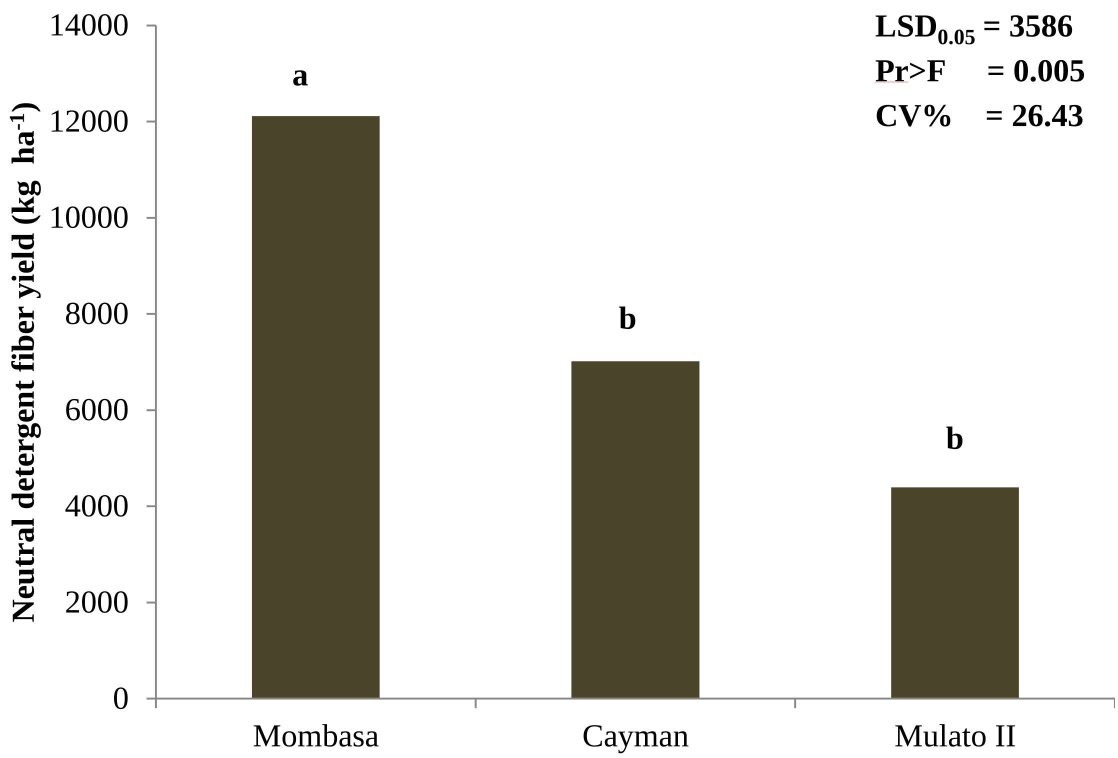

Figure 4.3: Neutral detergent fibers yield of three pasture grasses, 2016-2017

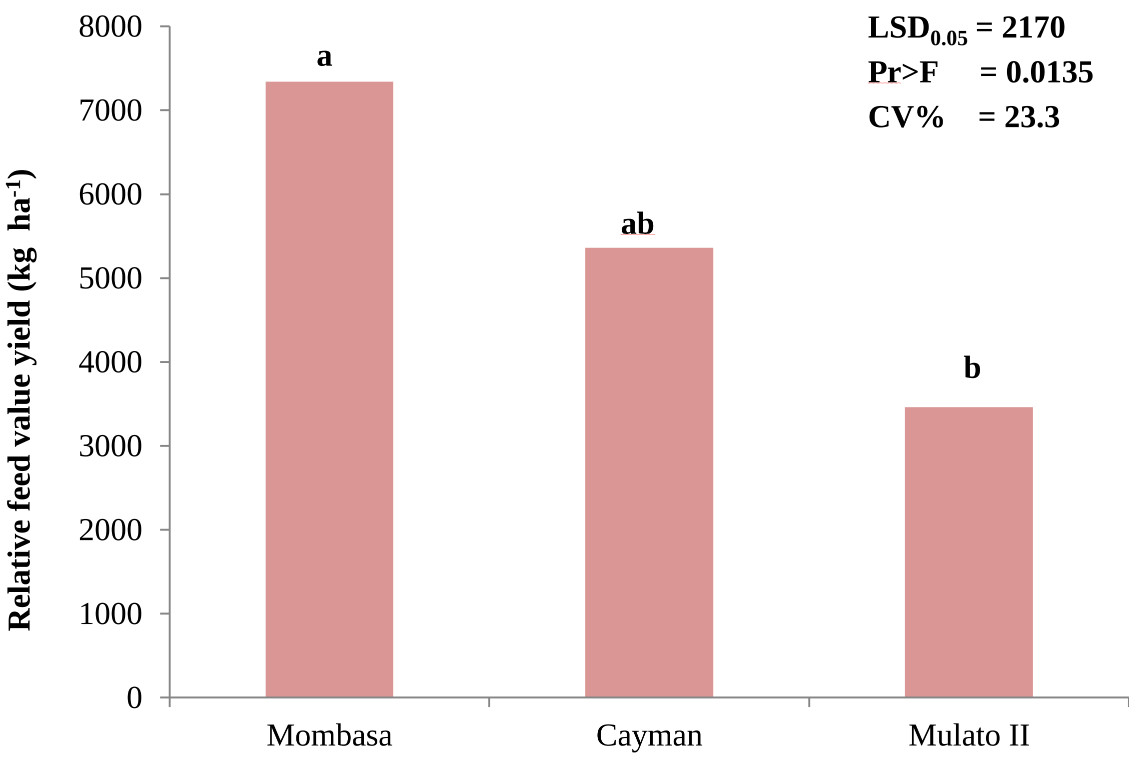

Figure 4.4: Relative feed value yield of three pasture grasses, 2016-2017

4.1.2.5 Organic matter yield

Organic matter was also play an important role in forage quality. Different organic matter yields were observed in different forage grass cultivars (Figure 4.5). Mombasa could produce maximum organic matter yield (15758 kg ha^{-1}) which was significantly different from that (9713 kg ha^{-1}) of Cayman and that (6209 kg ha^{-1}) of Mulato II with highest CP. Pieterse et al. (1997) reported that the highest dry matter producer had the best water use efficiency; a well balance nutrient concentration and a high IVDOM (in vitro digestibility organic matter).

4.1.3 Conclusion

From experiment I, it could be concluded that Mombasa provided the highest yield due to highest plant height though fewer tiller number than Cayman and Mulato II. Moreover, the highest nutritional composition was recorded from Mombasa among tested cultivars. Therefore, Mombasa was considered as the most suitable cultivar in the study area and decided to be used as tested grass cultivar in experiment III.

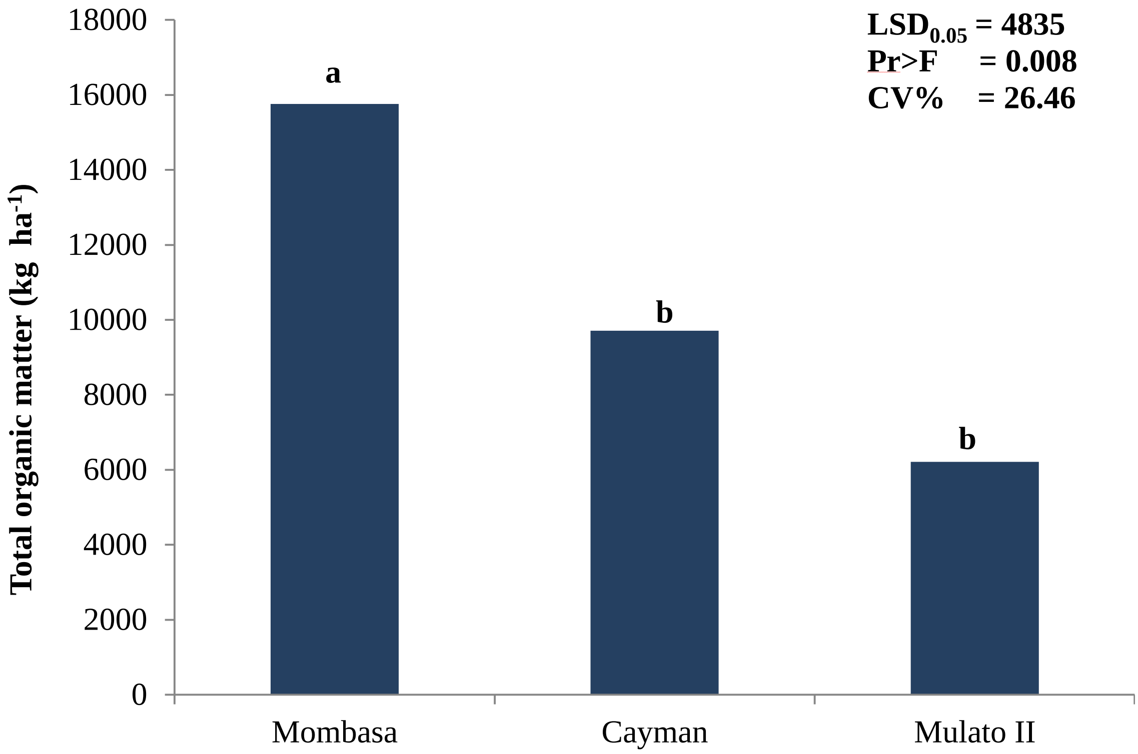

Figure 4.5: Organic matter yield of three pasture grasses, 2016-2017

4.2 Experiment II. Preliminary Study on the Performance of Four Pasture Legumes

This experiment was carried out in the upland field of Department of Agronomy, Yezin Agricultural University in Yezin, from June, 2017 to, June 2018.

4.2.1 Biomass yield of tested pasture legumes

Differences in biomass yield as affected by different legume cultivars were highly significant. The highest biomass yield (38542 kg ha^{-1}) was resulted from Desmanthus. It was followed by those (14310, 10710, 8842) kg ha^{-1} of Butterfly pea, Stylo and the lowest (8842 kg ha^{-1}) was resulted from Burgundy (Table 4.2). Radhakrishnan et al. (2007) assessed that biomass yield of Desmanthus was 15338 kg ha^{-1} and first cut began at 60^{th} day and sequent cuts after 45^{th} day intervals. However, Desmanthus slowly developed at early growth stage and had woody stem with increased age among tested legume cultivars. Therefore, this cultivar could not help meet the early forage demand and provide plenty of leafy portions for livestock production.

4.2.2 Nutritional composition yield of tested pasture legumes

Different nutritional yield were resulted from different legume in numerically (Table 4.3). Maximum CP yield (1691 kg ha^{-1}) was observed from Desmanthus followed by Butterfly pea (734 kg ha^{-1}) and Burgundy (462 kg ha^{-1}) while minimum (166 kg ha^{-1}) was resulted from Stylo. Cook et al. (1993) stated that Desmanthus leaf is high in crude protein (18-24%) and has high digestibility (ADF of < 20%).

Desmanthus produced the highest CP yield, ADF yield, NDF yield, RFV yield and OM yield because the highest biomass yield was observed from Desmanthus. It was followed by Butterfly pea, Burgundy and Stylo.

4.2.3 Conclusion

As the result of experiment II, Desmanthus provided the highest herbage yield and nutrient compositional yield. Desmanthus would have better tolerance of cutting and good performance under field condition and had a greater ability than other tested legume cultivars (Clem, 2009). However, proportions of Desmanthus stem increases with age, from about 20% of herbage yield early in the growing season to 75% at the end of the season (and higher in grazed pastures). Therefore, edible dry matter yields are often only 20 to 25% of the total yield (Clem, 2009). Butterfly pea quickly covers the soil and can be directly harvested by grazing or as cut-and-carry forage. Forage dry matter yield may range from 200 to 16000 kg ha^{-1} yr^{-1} depend on growing conditions. Under irrigation, yields up to 30000 kg ha^{-1} could be achieved (Cook et al., 2005). Therefore, Butterfly was considered as the appropriate cultivar in the study area and investigated as tested legume cultivar in experiment III.

Table 4.2: Mean comparisons of forage yield of four different legumes, 2017-2018

Cultivars	Fresh yield (kg ha^{-1})	Dry matter yield (kg ha^{-1})
Desmanthus	38542.00 a	11542.00 a
Butterfly pea	14310.00 b	5611.00 b
Burgundy	8842.00 b	2630.00 b
Stylo	10710.00 b	3240.00 b
LSD $_{0.05}$	9820.00	3110.00
Pr>F	0.001	0.002
CV%	27.5	27.1

Means followed by the same letter within the column are not significantly different at 5% level.

Table 4.3: Nutritional composition yield of four different legumes, 2017-2018

Cultivars	Crude protein yield (kg ha^{-1})	Acid detergent fibre yield (kg ha^{-1})	Neutral detergent fibre yield (kg ha^{-1})	Relative feed value yield (kg ha^{-1})	Organic matter yield (kg ha^{-1})
Desmanthus	1691	5096	5630	9716	10978
Butterfly pea	734	2433	3362	4517	4919
Burgundy	462	1234	1456	1986	2193
Stylo	166	1357	1604	1987	2173

4.3 Experiment III. Effect of Planting Patterns and Cutting Intervals on Herbage Yield and Quality of Pasture Grass and Legume

This experiment was carried out in the upland field of Department of Agronomy, Yezin Agricultural University in Yezin, from August, 2018 to August, 2018.

4.3.1 Plant height of grass and legume under different planting patterns and cutting intervals

Mean values of grass and legume plant height were collected every month during experimental period (Figure 4.6). Plant height of pasture grass sharply increased during initial months due to flowering time which produce the highest plant high and gradually decreased at middle and then increased again in later month under both grass sole and intercropping. Among cutting intervals, plant heights of grass under 6, 9 and 12-month cuttings intervals were significantly higher than that of 3-month cutting interval.

The result showed that plant heights of 6, 9 and 12-months cuttings slightly increased in grass-legume intercropping as compared to grass sole cropping. It may be due to the result of wider spacing of plant growth factors by grass crop in grass-legume intercropping.

Pant height of pasture legume was nearly stable along the growing period in both legumes sole and intercropping. Among cutting intervals, plant height of 3-months cutting slightly fluctuated in legume sole cropping. Plant height of legume in intercropping was lower than that in legume sole cropping. It may be due to the suppression of aggressive grass crop in grass legume intercropping.

4.3.2 Tiller numbers of grass under grass sole cropping and grass-legume intercropping

Mean values of grass from sole cropping and intercropping tiller were collected every month during experimental period (Figure 4.7). Tiller numbers of pasture grass were fluctuated in each cutting interval in both grasses sole and intercropping. Among cutting intervals, tiller numbers of 3-month, 9-month and 12-month cuttings intervals were slightly lower than that of 6-month cutting interval.

The result showed that tiller numbers of all cutting intervals significantly increased in grass legume intercropping as compared to grass sole cropping. It may be due to the effect of better utilization of growth factors by grass crop in grass-legume intercropping.

Among cutting intervals, tiller number of 3 and 6-months cutting intervals significantly fluctuated under both grass sole and intercropping. It may be due to the effect of shorter cutting interval that caused regrowth the new tiller compared with the other cutting intervals.

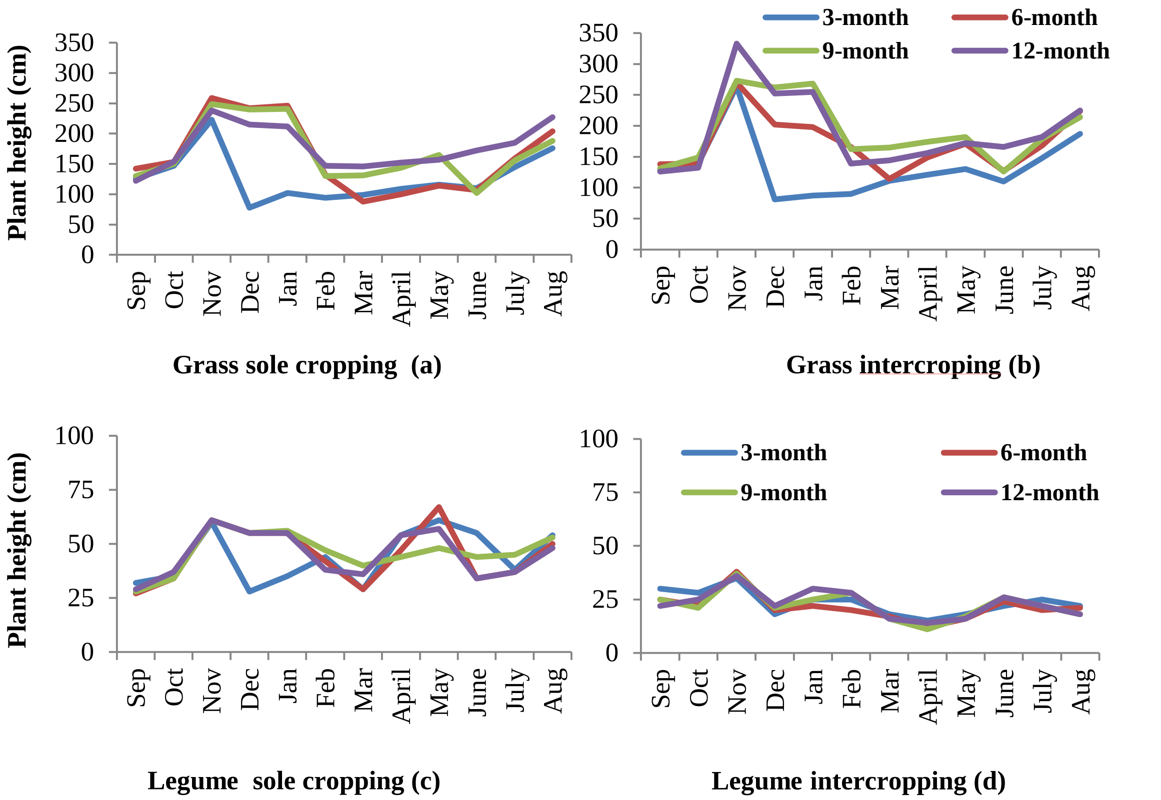

Figure 4.6: Plant height of pasture grass and legume under different planting patterns and cutting intervals

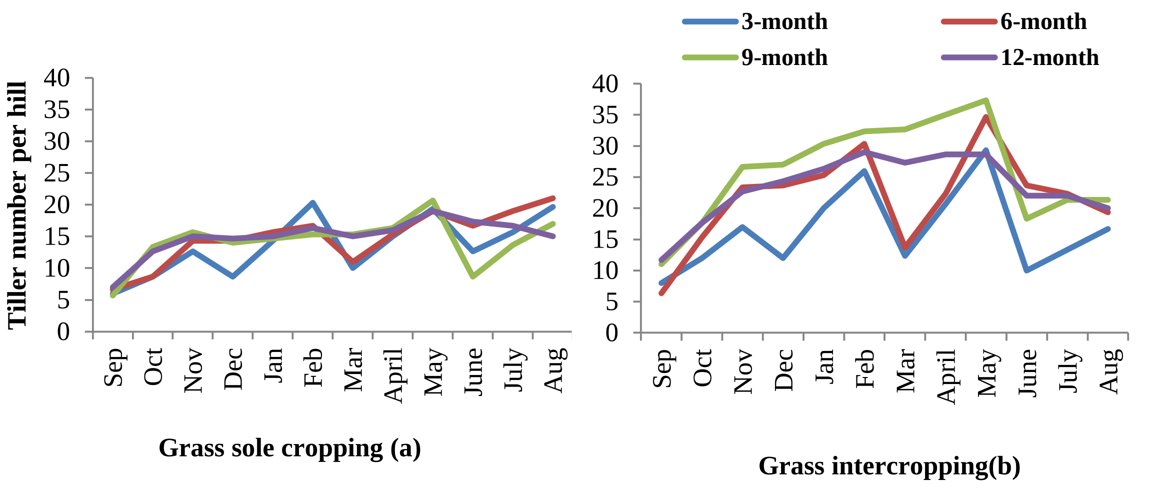

Figure 4.7: Tiller numbers of pasture grass under grass sole cropping and grass- legume intercropping

4.3.3 Leaf area index of grass and legume under different planting patterns and cutting intervals

Leaf area index (LAI) was significantly different among planting patterns (Table 4.4). Grass-legume intercropping gave the highest (7.7) LAI among planting patterns, however grass (2.8) and legume (2.2) sole cropping were not significantly different between grass and legume sole croppings. The value of LAI is correlated to the biological and economic yields and increase in LAI causes higher yield (Singh et al., 2009). The value of LAI was also significantly different among different cutting intervals. Maximum leaf area index (5.6) was resulted from 9-month cutting interval followed by 12-month (4.8) and 6-month (4.2) cutting intervals while minimum LAI (2.3) was observed from 3- month cutting interval. Intercropping has been reported to increase light interception in the intercrops, reduce water evaporation and improve conservation of the soil moisture, resulting in higher dry matter compared with monocropping (Ghanbari et al., 2010). There was no interaction between cutting intervals and planting patterns in leaf area index.

4.3.4 Biomass yield of grass and legume under different planting patterns and cutting intervals

Different fresh weights were observed in different planting patterns (Table 4.4). There were highly significant different among planting patterns, grass sole cropping showed the highest value (50917 kg ha^{-1}) of fresh weight followed by grass-legume intercropping (40658 kg ha^{-1}) while the lowest value (13637 kg ha^{-1}) was produced from legume sole cropping. The result of higher fresh weight in grass sole cropping and grass-legume intercropping may be due to the higher plant height of grass in those patterns. Therefore, it can be assumed that higher plant height is an important and desirable character for higher forage yield. The high dry matter yields of grass in mixtures, which was comparable to the sole plot, could be due to the vigorous nature of grass growth and its ability to rapidly utilize the nitrogen in the soil, which is released following cultivation (Tessema & Baar, 2006). The rapid establishment of the grass may have had a profound effect on the root system that enabled it to extract growth resources from the soil (Kechero, 2008). This result implies that Mombasa can associate well with Butterfly pea. There were highly significant different among cutting intervals, maximum fresh weight (52151 kg ha^{-1}) was resulted from 3-month cutting interval although it was not significantly different from that (43631kg ha^{-1}) of 6-month cutting interval followed by that (26779 kg ha^{-1}) of 9-month cutting interval. 12-month cutting intervals showed the minimum fresh weight (17721 kg ha^{-1}) and it was significantly lower than those of 3-month, 6-month and 9-month cutting intervals. There were interaction between planting patterns and cutting intervals in fresh weight. It indicated that the responses of fresh weight to different cutting intervals changed with different planting patterns. Tudsri et al. (2002) showed that yield of all grass species increased with increasing cutting intervals.

Different planting patterns produced different dry matter weights. There were highly significant different among planting patterns, grass sole cropping provided the highest value (11896 kg ha^{-1}) of dry matter yield, however it was not significantly different from that (10286 kg ha^{-1}) of grass-legume intercropping while lowest amount (2540 kg ha^{-1}) was produced from legume sole cropping. Almole et al., (2015) showed the same result that dry matter forage yields of the grass and legumes in the sole and mixed plots were significantly influenced by different planting patterns and age at harvest. There were highly significant different among cutting intervals, 3-month cutting interval resulted higher dry weight (12180 kg ha^{-1}) than 6-month (7381 kg ha^{-1}), 9-month (6934 kg ha^{-1}) and 12-month (6467 kg ha^{-1}) cutting intervals. However, the dry weight of 6-month, 9-month and 12-month cutting intervals were not significantly different. There were interaction between planting patterns and cutting intervals in dry weight with the responses of different cutting intervals changed with different planting patterns.

Table 4.4: Mean comparisons of LAI and biomass yield of grass and legume under different planting patterns and cutting intervals, 2017-18

Treatment	Leaf area index (LAI)	Fresh weight (kg ha^{-1})	Dry weight (kg ha^{-1})
Planting patterns			
Grass	2.8 b	50917 a	11896 a
Legume	2.2 b	13637 c	2540 b
Grass + Legume	7.7 a	40658 b	10286 a
LSD $_{0.05}$	1.4	9764	2244
Cutting intervals			
3-month	2.3 b	52151 a	12180 a
6-month	4.2 ab	43631 a	7381 b
9-month	5.6 a	26779 b	6934 b
12-month	4.8 a	17721 c	6467 b
LSD $_{0.05}$	2.2	8933	1991
Pr > F			
Planting patterns	0.008	0.0001	0.0006
Cutting intervals	0.042	<0.0001	<0.0001
Pattern × Intervals	0.078	0.0007	0.0014
CV% (a)	28.3	24.6	24.0
CV% (b)	53.6	25.7	24.4

Means followed by the same letter within the column are not significantly different at 5% level.

4.3.5 Nutritional composition yield of pasture grass and legume under different planting patterns and cutting intervals

Different planting patterns and cutting intervals produced different nutritional composition of pasture grass, legume and pasture grass-legume intercropping. In this experiment, crude protein yield, acid detergent fibre yield, neutral detergent fiber yield, relative feed value yield and organic matter yield were analyzed for pasture quality.

4.3.5.1 Crude protein yield

Crude protein (CP) yield was calculated from the product of shoot biomass and CP concentration to estimate the total CP provided by the forages harvested at various times through the growing seasons (Holmes, 1980). There was no significant difference in CP yield under different planting patterns. The highest CP yield was observed in grass-legume intercropping (392 kg ha^{-1}) followed legume (357 kg ha^{-1}) sole cropping because legume produced higher CP percent than grass while the lowest CP yield (319 kg ha^{-1}) was obtained from grass sole cropping (Table 4.5). As the result, grass-legume intercropping was the best planting pattern to obtain highest crude protein value. There were highly significant different among cutting intervals. The highest CP yield (512 kg ha^{-1}) was resulted from 3-month cutting interval followed by 6-month (406 kg ha^{-1}) and 9-month (384 kg ha^{-1}) cutting intervals while the lowest CP yield was observed from 12-month (121 kg ha^{-1}) cutting interval. It may be assumed that CP yield increased with frequent cutting, the same result of Okwori and Magani (2010) said that increasing CP contents at frequent cuttings. Moreover, pasture quality parameters decreased from the young to mature stages as a result of differences in plant composition between levels of maturity (Reiling et al., 2001). There was no interaction effect between different cutting intervals and different planting patterns.

The maximum CP yield was obtained from 3-month and 9-month cutting interval under grass-legume intercrop and 3-month cutting interval under legume sole cropping while the minimum value was observed from 12-month cutting interval under all planting patterns (Figure 4.8). As the result, grass- legume intercropping and legume sole cropping with 3-month cutting interval were provided as the best combination to obtain the highest CP value. Muhammad (2014) reported that guinea grass cut at short intervals and inclusion of centro into guinea grass pasture are very beneficial to increase pasture quality and meeting protein requirement of animals.

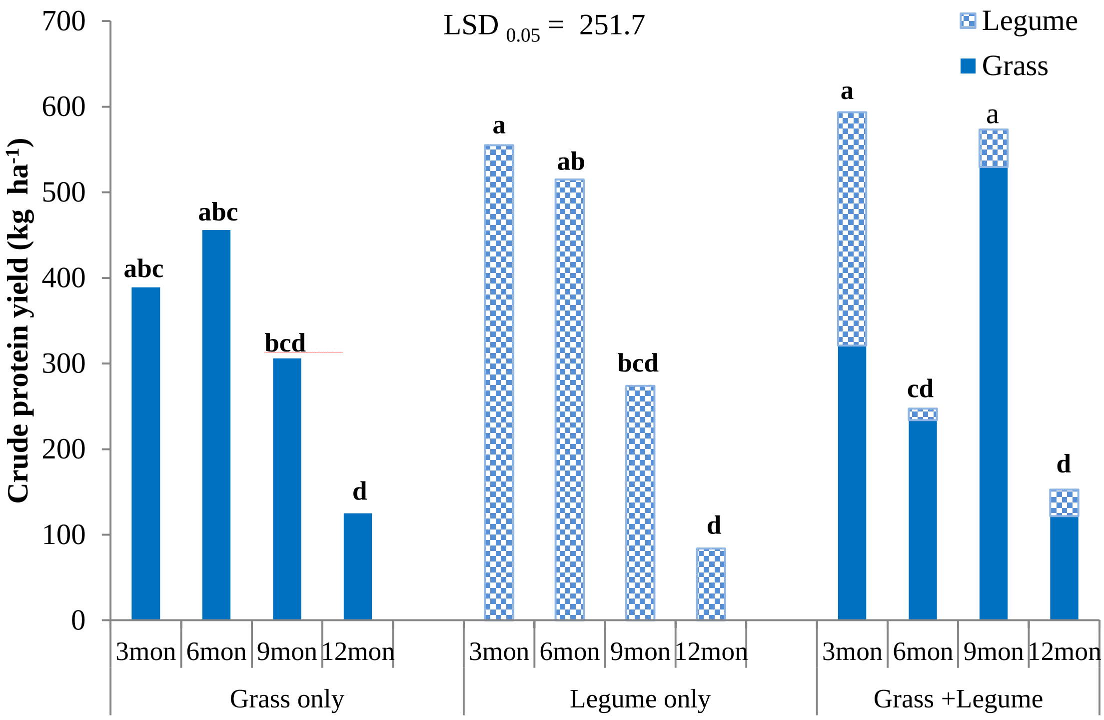

Figure 4.8: Crude protein yield of pasture grass and legume under different planting patterns and cutting intervals, 2017-2018

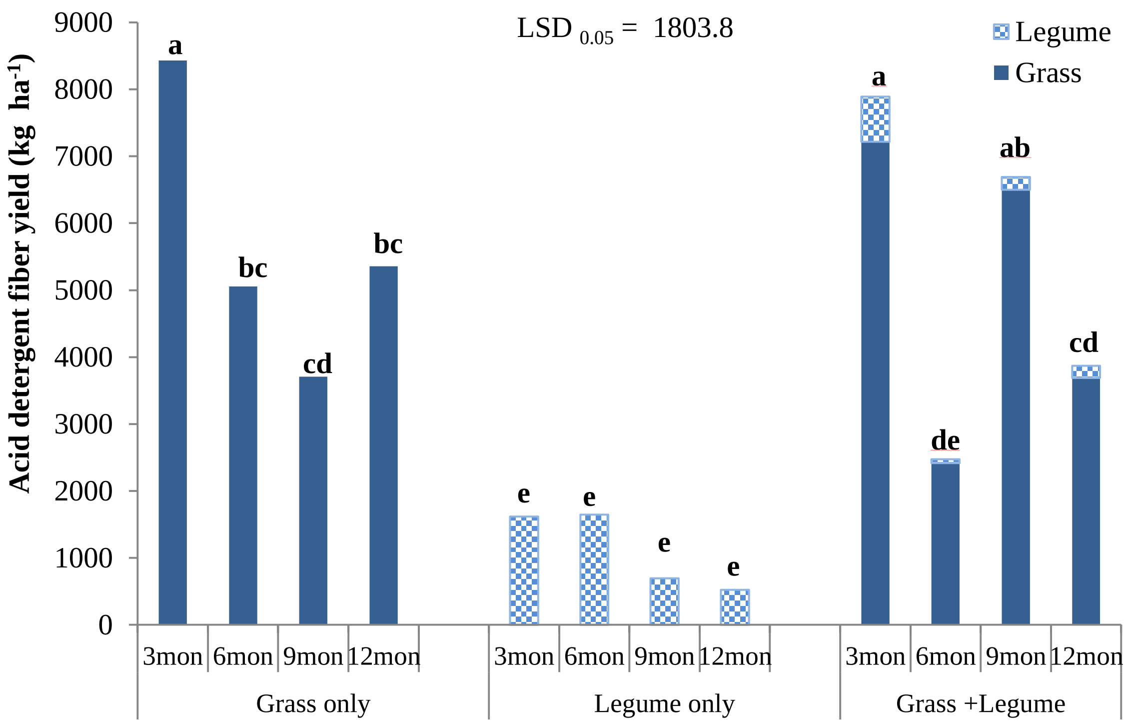

Figure 4.9: Acid detergent fiber yield of pasture grass and legume under different planting patterns and cutting intervals, 2017-2018

4.3.5.2 Acid detergent fiber yield

There were highly significant different among planting patterns of acid detergent fibre (ADF) yield (Table 4.5). The maximum ADF yield was resulted from grass sole cropping (5638 kg ha^{-1}) and grass-legume intercropping (5231 kg ha^{-1}). However, legume sole cropping which produced the minimum ADF yield (1123 kg ha^{-1}). Different ADF yields were observed from different cutting intervals, there were also highly significant different. The highest yield (5981kg ha^{-1}) of acid detergent fiber was produced from 3-month cutting interval though there were no significantly different in ADF yield among 6- month, 9-month and 12-month cutting intervals. Shorter cutting intervals may improve acid detergent fiber yield due to cumulated dry matter yield. The quality of available bites is depressed when green leaf material is scarce and largely dispersed among senescent material especially in the case of older pasture for which the NDF and ADF fractions increased with level of maturity (Aganga & Tshwenyane, 2004).There were interaction between different planting patterns and different cutting intervals in ADF. This indicated that the response of different cutting intervals altered with different planting patterns.

In Figure 4.9, the highest acid detergent fiber was obtained from grass sole cropping which was not significantly different with grass-legume intercropping under 3-month cutting interval. The lowest acid detergent fiber was resulted from legume sole cropping. Grass–legume mixtures generally have higher crude protein concentration and lower fiber concentration than pure grass stands.

4.3.5.3 Neutral detergent fiber yield

There were highly significant different in neutral detergent fiber (NDF) yield among different planting patterns (Table 4.5). The highest NDF value (8212.4 kg ha^{-1}) was observed from grass sole cropping followed by grass-legume intercropping (7394 kg ha^{-1}) while the lowest value (1370 kg ha^{-1}) was resulted from legume sole cropping.

Different NDF yields were resulted from different cutting intervals. NDF value was significantly higher in 3-month cutting interval (8644 kg ha^{-1}) as compared to the remaining cutting intervals. However, there were no significant differences in NDF yield among 6-month, 9-month and 12-month cutting intervals. Increased cutting interval may provide more NDF yield as the same result of ADF yield due to increase dry matter yield. Moreover, Mwangi et al., (2004) said that ADF and NDF concentrations in grass and legume tissue increased significantly as inter harvesting interval increased. There were interaction between different cutting intervals and different planting patterns in NDF.

This indicated that different NDF value under different cutting intervals was found due to the impact of different planting patterns.

Figure 4.10 showed the highest NDF value was obtained from grass sole cropping under 3-month cutting interval followed by grass-legume intercropping while the lowest was resulted from legume sole cropping. Murphy and Cocucci (1999) reported higher CP content, digestibility and lower crude fibre content of forage from forage-legume intercropping systems.

4.3.5.4 Relative feed value yield

There were highly significant different among planting patterns of relative feed value (RFV) yield (Table 4.5). Grass sole cropping produced highest RFV yield (7960 kg ha^{-1}) due to the highest dry matter yield was resulted from grass sole cropping. It was followed by grass-legume intercropping (7813 kg ha^{-1}). The minimum RFV (2422 kg ha^{-1}) was observed from legume sole cropping. There were highly significant differences in RFV among different cutting intervals. Maximum RFV (7859 kg ha^{-1}) was resulted from 3-month cutting interval followed by 6-month (5315 kg ha^{-1}) and 9-month cutting interval (5110 kg ha^{-1}) while minimum RFV (1369 kg ha^{-1}) was resulted from 12-month cutting interval. It indicated that 3-month cutting interval may provide the highest RFV yield, although increased in ADF and NDF yield, which provide the appropriate pasture production for livestock. There were interaction between different cutting intervals and different planting patterns in RFV. Therefore, RFV under different cutting intervals altered with different planting patterns.

The maximum RFV yield was resulted from grass sole cropping under 3-month cutting interval followed by grass- legume intercropping while the minimum value was obtained under legume sole cropping with 12-month cutting intervals (Figure 4.11). According to Zhang et al. (2018), the harvest timing that maximized RFV yield was similar to those that maximized CP yield, though the decline in RFV was less pronounced than the decline in CP content through the growing season and hence later harvest timings maximize RFV yield in some species and seasons. Therefore, 3-month cutting interval under grass-legume intercropping is suitable for pasture production.

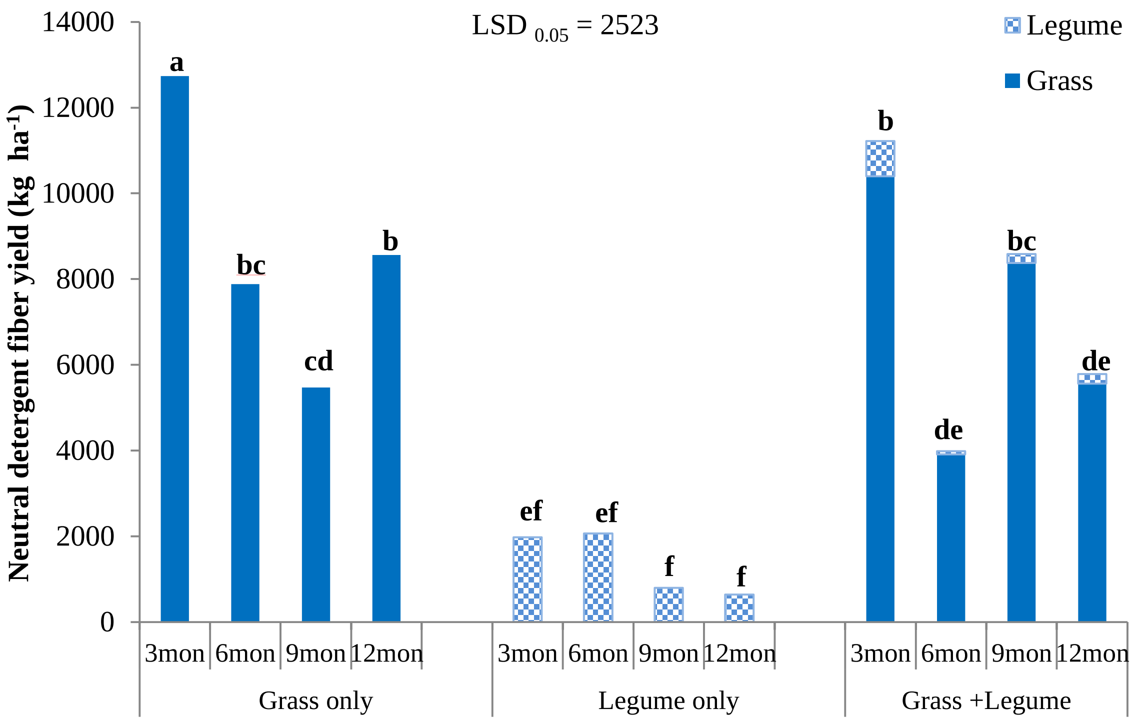

Figure 4.10: Neutral detergent fiber yield of pasture grass and legume under different planting patterns and cutting intervals, 2017-2018

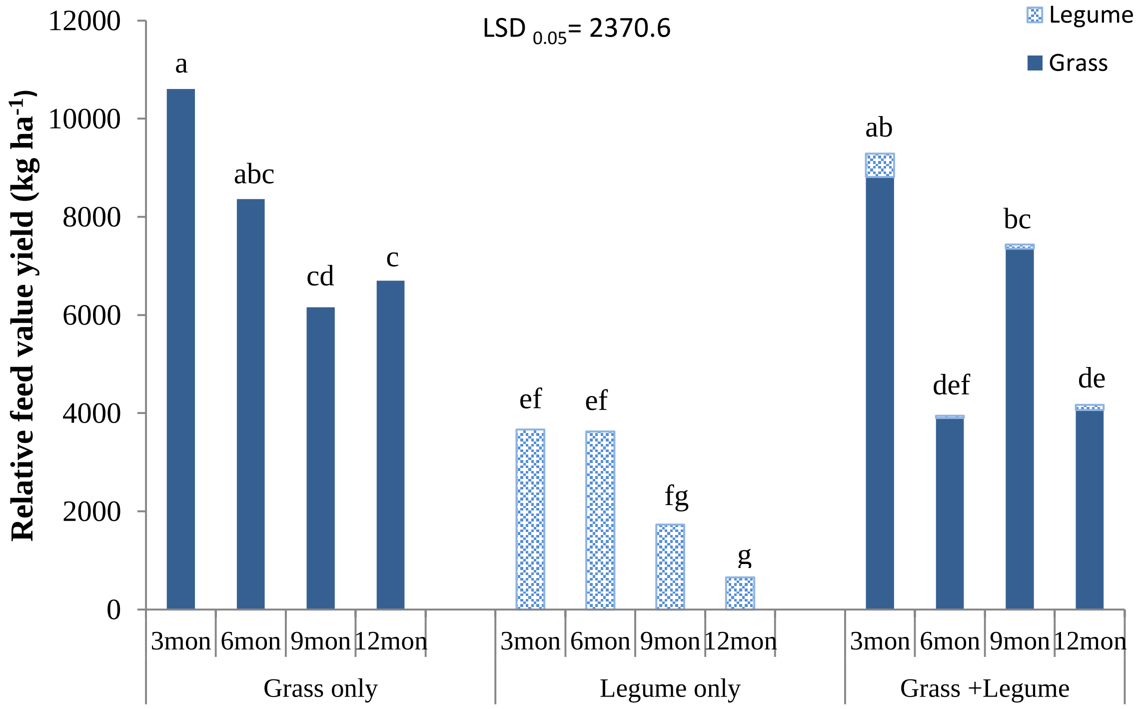

Figure 4.11: Relative feed value yield of pasture grass and legume under different planting patterns and cutting intervals, 2017-2018

4.3.5.5 Organic matter yield

There were significantly different among planting patterns of organic matter (OM). Although highest OM content (10505 kg ha^{-1}) was produced from grass sole cropping, it was not statistically different from that (9223 kg ha^{-1}) under grass-legume intercropping (Table 4.5). The lowest OM content (2359 kg ha^{-1}) was observed from legume sole cropping. Different organic matter values were observed among different cutting intervals. There were highly significant different among cutting intervals, 3-month cutting interval could produce highest organic matter value (10761 kg ha^{-1}) which was significantly different from those (6175 kg ha^{-1},6600 kg ha^{-1},5915 kg ha^{-1}) of 6, 9 and 12-month cutting intervals. However, those cutting intervals of OM yields were not statistically different. There were interactions between cutting intervals and planting patterns in OM yields. It indicated that the responses of that parameter to different cutting intervals altered with different planting patterns.

Figure (4.12) showed effect of different cutting intervals and planting patterns on organic matter yield. Maximum organic matter yield was found in 3-month cutting interval under sole grass followed by 3-month cutting interval under grass-legume intercropping while minimum organic matter yield was resulted from 12-month cutting interval under legume sole cropping.

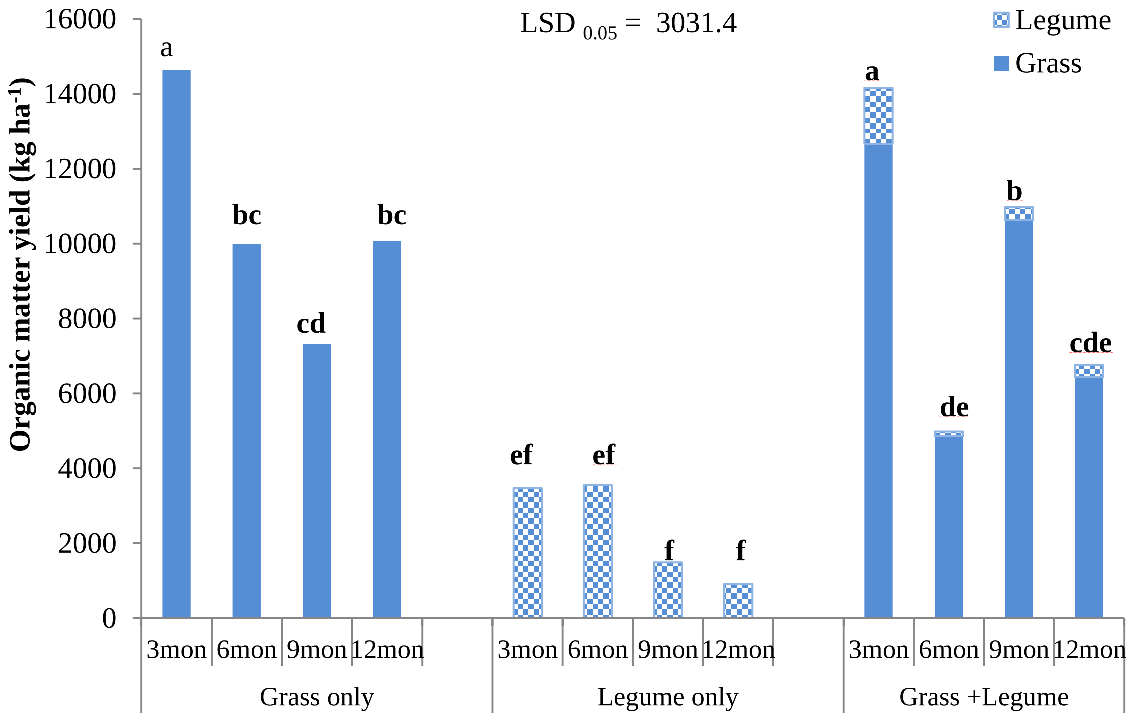

Figure 4.12: Organic matter yield of pasture grass and legume under different planting patterns and cutting intervals, 2017-2018

Table 4.5: Mean comparisons of nutritional composition yield of grass and legume under different planting patterns and cutting intervals,2017-18

Treatment	Crude protein (kg ha^{-1})	Acid detergent fibre (kg ha^{-1})	Neutral detergent fibre (kg ha^{-1})	Relative feed value (kg ha^{-1})	Organic matter (kg ha^{-1})
Planting patterns					
Grass	319.00 b	5638.0 a	8662.0 a	7960.0 a	10505.0 a
Legume	357.00 ab	1123.0 b	1370.0 c	2422.0 c	2359.0 b
Grass + Legume	392.00 a	5231.0 a	6355.0 b	6214.0 b	9223.0 a
LSD $_{0.05}$	72.49	1227.2	1861.9	1252	2110.3
Cutting intervals					
3-month	512.00 a	5981.0 a	8212.4 a	7859.0 a	10761.0 a
6-month	406.00 b	3060.0 b	4253.2 b	5315.0 b	6175 b
9-month	384.00 b	3697.0 b	4578.4 b	5110.0 bc	6600 b
12-month	121.00 c	3250.0 b	4805.8 b	3844.0 c	5915 b
LSD $_{0.05}$	145.33	1041.4	1456.8	1368.7	1750.2
Pr > F					
Planting patterns	0.1135	0.0009	0.0008	0.0006	0.0009
Cutting intervals	0.0002	<0.0001	<0.0001	0.0001	<0.0001
Pattern× interval	0.0590	0.0006	0.0011	0.0176	0.0013
CV% (a)	17.97	27.09	28.3	19.9	25.3
CV% (b)	41.24	26.31	25.32	25.0	24.0

Means followed by the same letter within the column are not significantly different at 5% level.

4.3.6 LER values for biomass yield and nutritional composition yield under different planting arrangements and cutting intervals

In this study, three planting patterns such as grass sole cropping, legume sole cropping and grass-legume intercropping gave the dry matter yield of 11896 kg ha^{-1}, 2540 kg ha^{-1} and 10286 kg ha^{-1} respectively (Table 4.4). Among these planting arrangements, the highest nutritional composition was observed in intercropping which also show high biomass yield with no significant different from grass sole cropping. It may be assumed that grass-legume intercropping was suitable planting pattern for pasture production. Therefore, the LER for biomass yield and nutritional composition was calculated to ensure the better performance of intercropping than sole cropping.

4.3.6.1 Herbage yield and dry matter yield

Herbage yield was no significantly different among different cutting intervals of pasture grass-legume intercropping (Table 4.6). Although 3-month cutting interval of LER value (1.04) was not significantly different from that (2.01) and (1.86) of 12-month cutting interval and 9-month cutting interval, these cutting intervals provided maximum LER value while minimum LER value (0.48) was obtained from 6-month cutting interval.

There were not significantly different of dry matter yield between different cutting intervals of pasture grass-legume intercropping. The LER value (1.7) was the highest in 9 month cutting interval it was followed by in 12-month cutting interval (1.57) and 3-month cutting interval (1.29) while the lowest LER value (0.52) was obtain from 6-month cutting interval. The results showed that yield benefit from grass-legume intercropping with range from 30 % to 70% than sole crops. Habineza et al. (2017) reported that, maize-soybean intercropping system gave LER higher than 1 which was advantageous for the component crops. As a result, 9-month cutting interval provided the best LER value among different cutting intervals. However, 6-month cutting interval was lower than 1 due to relatively high temperature with low rainfall compared to other cutting time (Appendix 3). Muoneke et al., (2007) obtained yield advantage from intercropping productivity of 2-63% as presented by LER of 1.02-1.63 showing effective utilization of land resource in intercropping system than in sole crop. Moreover, Ghanbari et al. (2010) determined that total LER for yield was higher in 100% cowpea + 100% mazie intercropping. Similarly, it was reported that straw yields of both sorghum and cowpea in sorgum-cowpea intecrrops with different planting patterns were higher in sole cropping than in the intercropping (Oseni & Aliyu, 2010). Intercropping affects vegetative growth of component crops depends on adaptation of planting pattern and selection of compatible crops, it can be suggested that intercropping with legumes is a desirable agronomic practice towards boosting crop production (Dantata, 2014).

4.3.6.2 Crude protein yield

The highest LER value of (1.86) CP was obtained from 12-month cutting interval, however it was no significantly different from that of 9-month and 3-month cutting intervals while the minimum LER value (0.59) was observed from 6-month cutting interval (Table 4.6). Legumes contain more than double of crude protein than forage sorghum, therefore, sorghum-legume intercropping has the potential to increase the biomass and quality of forage for per area compare to sole sorghum (Eskendari et al., 2009). The higher total protein yield produced by intercropping was attributed to higher forage production by intercrops and also protein content due to legumes supply nitrogen to grass-legume mixtures. Moreover, Basaran et al. (2016) reported that intercropping of sorghum-sudangrass hybrid with cowpea, and soybean improved the yield and quality of the hay compare to their monocrops.

4.3.6.3 Acid detergent fiber yield

Maximum LER value (2.08) of ADF was obtained from 9-month cutting interval, it was highly significant different from that of 3-month, 6-month and 12-month cutting intervals (Table 4.6). At the early growth stages, intercrop competition can drastically reduce the forage yield of component crops. Moreover, legumes intercropping with cereals improve forage quality by increasing protein and decreasing fiber content as fiber is considered to be an anti-nutritional factor (Iqbal et al., 2018). Adane (2003) also stated that P*ennisetum pedicellatum* grass sown alone have higher ADF and NDF than those sown in association with legumes. It may be due to grass include more fiber content than legume.

4.3.6.4 Neutral detergent fiber yield

The NDF content is important in ration formulation because it reflects the amount of forage that can be consumed by animals (Bingol et al., 2007). The LER values for NDF yield were significantly different among different cutting intervals. The highest LER value of (1.77) NDF was resulted from 9-month cutting interval, it was followed by 6-month, 12-month and 3-month cutting intervals of LER. Iqbal et al. (2016) said that sorghum-soybean intercropping in a row replacement series increased the agro-qualitative traits of forage sorghum probably due to nitrogen contributions from legume intercrops resulting in increased crude protein, ether extractable fat and total ash contents, while crude fiber was decreased considerably.

4.3.6.5 Relative feed value yield

Relative feed value (RFV) is not a direct measure of the nutritional content but it is important for estimating the value of the forage (Van Soest, 1996). There were significantly different from RFV yield of LER value (Table 4.6). Nine month cutting interval provided higher LER value (1.41) than among different cutting intervals. Sorghum-sudan grass when intercropped with legumes (cowpea and soybean) exhibited greater hay yield, protein yield, protein ratio and RFV than was in alone sowing, this increase in yield and quality was highly dependent with the legume species or varieties (Basaran et al., 2016).

4.3.6.6 Organic matter yield

Highest dry matter producer had the best water use efficiency with a well balance nutrient concentration and a high in vitro digestibility of organic matter (Pieterse et al., 1997). There was not significantly different from 9-month, 12-month and 3-month cutting intervals of LER value ranging from 1.7 to 1.32 while 6-month cutting interval of LER (0.53) was significantly lower than those of among cutting intervals. Legumes generally produce higher quality forage than grasses due to less fiber, favor higher crude protein and intake (Albayrak & Ekız, 2005). Therefore one of the benefits of legumes in mixtures is improvement of forage quality besides the higher yield.

Table 4.6: Mean comparisons of different (LER) values under different planting arrangements for biomass yield and nutritional composition of pasture grass - legume intercropping, 2017-2018

Treatments (Cutting intervals)	Herbage yield	Dry matter yield	Crude protein yield	Acid detergent fibre yield	Neutral detergent fibre yield	Relative feed value yield	Organic matter yield
Three month	1.04 ab	1.29	1.32 ab	0.98 b	0.90 b	0.93b	1.32
Six month	0.48 b	0.52	0.59 b	0.68 b	0.63 b	0.59 b	0.53
Nine month	1.86 a	1.70	1.82 a	2.08 a	1.77 a	1.41 a	1.70
Twelve month	2.01 a	1.57	1.86 a	0.9 b	0.78 b	0.78 b	1.57
LSD $_{0.05}$	1.197	1.140	0.915	0.516	0.450	0.400	1.169
Pr>F	0.059	0.153	0.045	0.002	0.003	0.011	0.163
CV%	44.35	45.02	32.74	22.27	22.08	21.65	45.71

Means followed by the same letter within the column are not significantly different at 5% level.

CHAPTER V
CONCLUSION

The present study was emphasized on the effect of cropping patterns and cutting intervals on herbage yield and quality of pasture grass and pasture legume.

The results from the experiment I showed that the forage yield and nutritive value of Mombasa was relatively higher than those of Cayman and Mulato II. Therefore, Mombasa was considered as the suitable grass species for pasture production in the study area. Mombasa was used as the tested grass cultivar in the next experiment III.

Experiment II result demonstrated that forage yield and nutritive value of Desmanthus was higher than those of other tested legumes. However, Desmanthus slowly developed at early stage and had woody stem with increased age while Butterfly pea provided quickly cover the soil and plenty leafy portion than among tested legumes. Therefore, Butterfly pea was used as the tested legume cultivar in the experiment III because that cultivar increased not only herbage yield but also nutritive quality after Desmanthus.

In experiment III, among different planting patterns, forage yield was higher in grass sole cropping as the result of higher plant height, fresh weight and dry weight. However, grass legume intercropping also produced higher plant height and dry matter yield which was not significantly different from those of grass sole cropping. Nutritional yield such as CP, RFV and OM of grass legume intercropping was higher than those of sole croppings. Moreover, except 6-month cutting interval, each cutting interval produced LER value greater than 1 for biomass yield and nutritional yield of grass-legume intercropping. Therefore, grass-legume intercropping could be considered as the most suitable pattern for pasture production in the study area. In the same experiment, among cutting intervals, forage yield and nutritive value such as CP, RFV and OM yield were highest under 3 month cutting interval of grass-legume intercropping. Therefore, grass-legume intercropping with 3-month cutting interval should be adopted to improve not only for forage yield also for nutritive value of pasture grass and legume farming in the study area.

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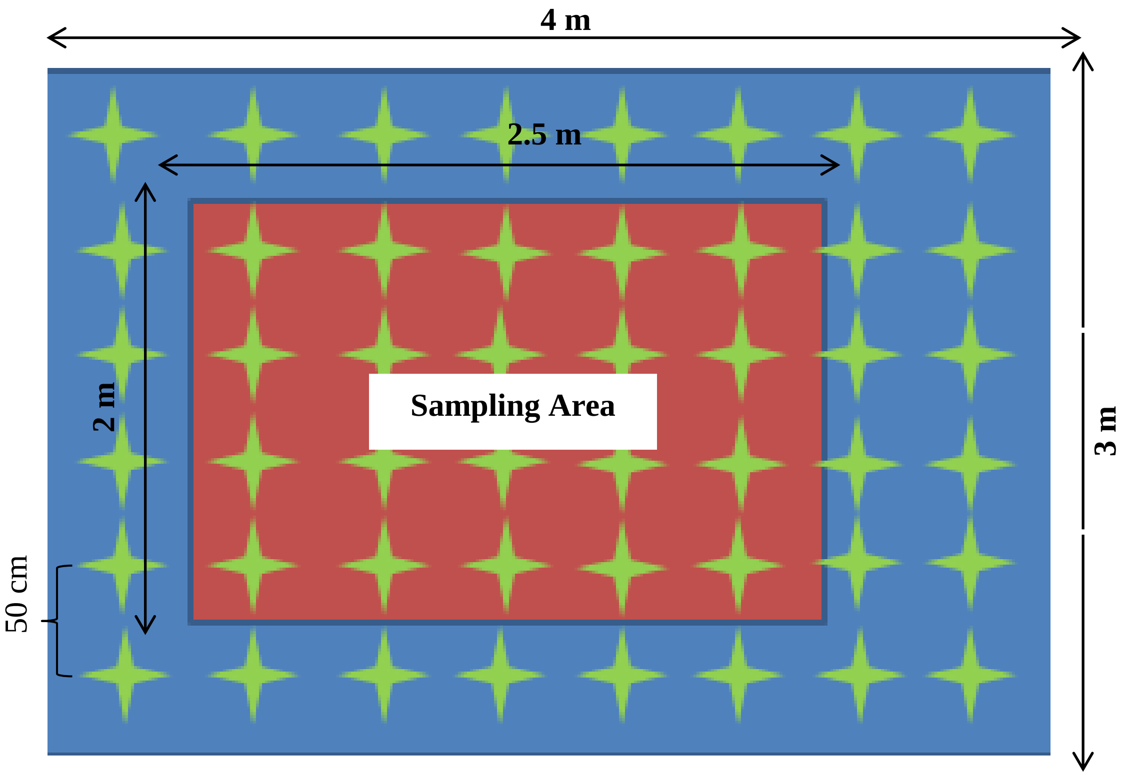
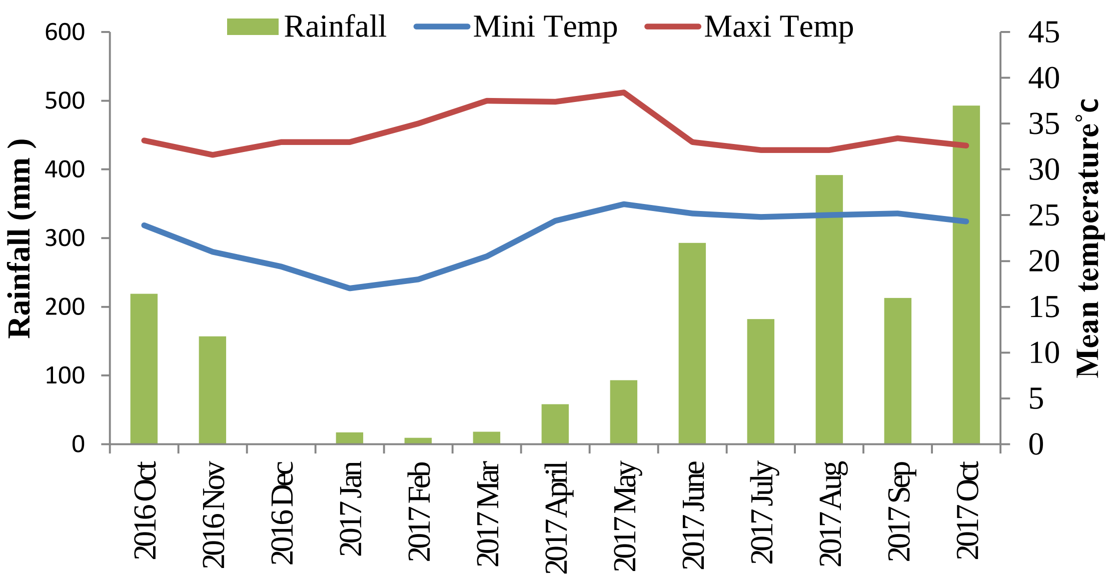
APPENDICES

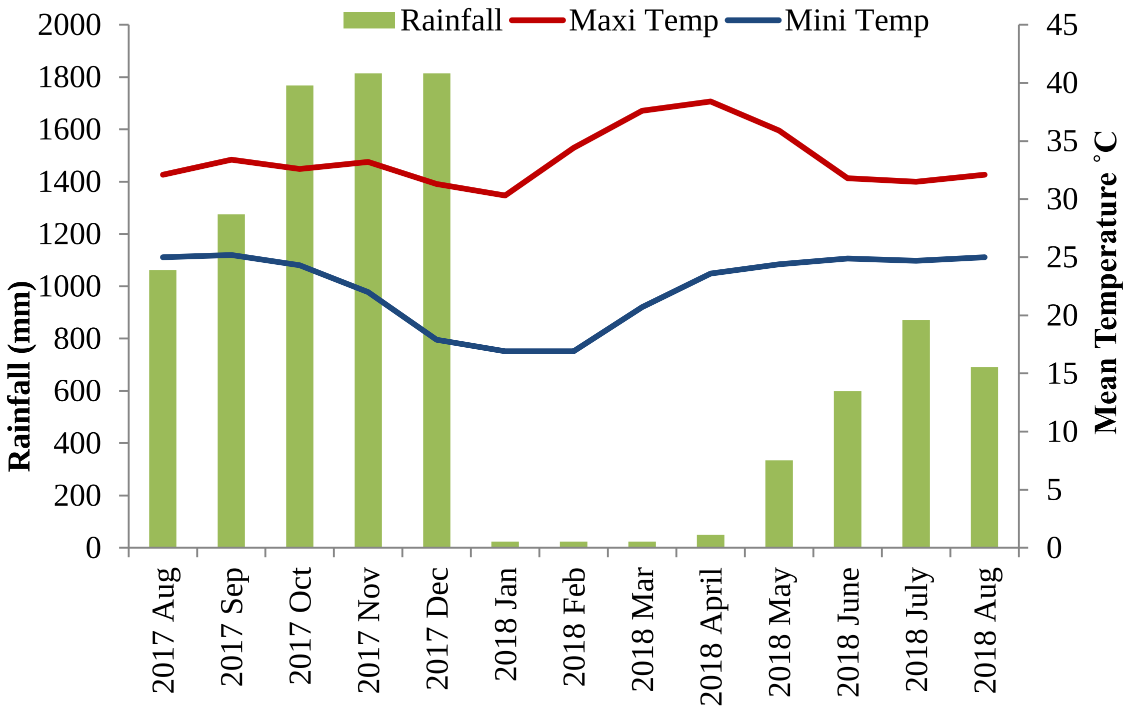
Appendix 1. Experimental plot



Appendix 2. Agrometerological data during experimental period of experiment I and II, October 2016 to October 2017, Yezin.



Appendix 3. Agrometerological data during experimental period of experiment III, 2017 August to 2018 August, Yezin.



Source. Weather Station, Department of Agriculture Research, 2018 August.