An evaluation of *Tithonia diversifolia* and *Sapium ellipticum* as supplement fodder for Ruminants.

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.

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This thesis has been submitted for examination with approval as university supervisors.

1. Date 1/7/2009

PROF. M.S. Badamana.

2. Date 1/7/2009

DR. R.G. Wahome.

DEDICATION

This thesis is dedicated to my beloved wife

Salome Mwari Nyaga

and

my children

- **Caleb Muchiri Nyaga**
- **Joram Mutwiri Nyaga**
- **Eunice Murugi Nyaga**

for their patience and encouragement

Thanks for the many prayers and endurance. May God reward your sacrifice and encouragement and every other role you prayed during the course of my studies. I will always remain indebted to you. May the gracious God bless you. Finally to the one, who was and there before and after creation. He saw the end before the beginning and He worked with me side and side. He comforted me gave me advice and encouraged me during the course of this work. He is none other than the Lord God almighty.

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ABBREVIATIONS

ADF	Acid Detergent Fiber
ADL	Acid Detergent Lignin
ARC	Agricultural Research Centre
Ca	Calcium
CF	Crude Fiber
CP	Crude protein
DF	Degrees of Freedom
DM	Dry Matter
DMD	Dry Matter Digestibility
DMI	Dry matter Intake
DMY	Dry matter Yield
ICRAF	International Centre for Research on Agroforestry
K.A.R.I	Kenya Agricultural Research Institute
MOLD	Ministry of Livestock Development
N	Nitrogen
NDF	Neutral Detergent Fiber
P	Phosphorus
SEM	Standard error of Mean
USDA	United State Development Agency

ABSTRACT

An evaluation of *Tithonia diversifolia* and *Sapium ellipticum* as supplement fodder for Ruminants

Studies were carried out to investigate the potential of *Tithonia diversifolia* (*Tithonia*) and *Sapium ellipticum* (*Sapium*), local livestock fodder species, grown in Eastern, Central, Coastal and Western provinces of Kenya. Fodder from the two species was harvested, dried into hay under shade and their nutritional potential assessed at the KARI Regional Centre, Embu, Kenya. The effects of shade and sun on stem height, leaf to stem ratio and dry matter yields (Biomass production) of the two fodder species was determined. Dry matter yields for *Tithonia* at different cutting intervals ranged from 5.9 to 58.9 tonnes/ha for plots under the shade and from 3.3 to 88.4 tonnes/ha for plots under the sun. *Tithonia* stem height ranged from 13.40 to 80.63 centimeters at cutting intervals of 4 to 10 weeks. The dry matter yields for *Sapium* was from 0.5, 0.5, and 0.6 to 0.7 tonnes/Ha at the cutting of 7 9, 11 and 13 weeks, while the twigs strippings lengths ranged from 42.8 to 86.5 centimeters at the same cutting intervals. *Tithonia* had higher dry matter yields than *Sapium* ($p<0.05$) over time. The Dry matter intake of *Sapium* by sheep was higher ($p<0.05$) than of *Tithonia*. *Tithonia* had higher Crude protein, ADF and Ash levels than *Sapium* but lower NDF ($p<0.05$). Results indicated that sheep preferred wilted napier grass, *Sapium* and *Tithonia* in a decreasing order. Intake decreased with substitution of napier grass fodder with either *Tithonia* and *Sapium* hays. Digestibility decreased with increased level of inclusion of *Sapium* and *Tithonia* fodder while increased *Tithonia* forage in the diet significantly improved Nitrogen balance in sheep. Diets

containing 25% *Tithonia* had the highest intake with 0.6kg/Dm while diets 75% *Sapium* had the least intake with 0.4kg/Dm per sheep per day. This led to the conclusion that *Tithonia* and *Sapium* are useful supplements for napier in ruminant feeding during the dry season.

CHAPTER 1

INTRODUCTION

Ruminant animals are usually fed on napier grass as a basal diet. Napier grass is the most popular fodder plant for the small- scale farmers in Kenya and is the most widely grown because of its high yields, ease of harvesting and ability to grow in virtually all types of well drained soils and agro-ecological zones from the sea level to well over 2000m altitude (Kariuki, 1989).

In the intensive systems in Kenya, ruminants are usually fed on napier grass as the main basal diet. However, this over-reliance on napier grass has occasionally proved inappropriate. The amount and quality of fodder crops, such as napier grass drastically declines during dry season while excessive frequency of cutting reduces its overall yield. Reliance on napier grass has prevented optimal ruminant production (Kaitho *et al.*, 1996).

Over-reliance on napier grass reduces feed availability and hence severe effects on livestock performance, in terms of growth, milk and meat production. The amount and quality of fodder crops, such as napier grass drastically declines during the dry season. This reduces feed availability and hence severe effects on livestock performance in terms of growth, milk and meat production. There is need to diversify the feeding base through exploration of indigenous fodder trees and shrubs with feeding potential and it has been suggested that the use of tropical trees and shrubs could lead towards the development of sustainable systems of animal production in the tropics (Topps, 1992).

In many parts of the tropics, fodder trees and shrubs are actively harvested by farmers and fed to cattle, buffaloes, goats and sheep. When used as supplements to low quality diets, tree fodder increases live weight gain, milk and wool production (Devendra, 1990; Roothaert *et al.*, 1998). Even so, exotic fodder tree species have been introduced, sometimes with undesirable consequences. For instance, when the fodder tree psyllid (*Heteropsylla cubana*) appeared in the parts of the world where *Leucaena leucocephala* was introduced, it caused major damage up to the extent that farmers had to give up livestock production (Djogo, 1995). There is need, therefore, to explore the potential of indigenous fodder species as an alternative to introduction of exotic ones. In the Eastern Province districts of Meru and Embu, a shrub known as *Tithonia(Tithonia diversifolia)* and a tree referred to as Sapium(*Sapium ellipticum*) are reportedly used to supplement fodder during the dry season. However, as with many indigenous fodder trees and shrubs, data on their biomass production is lacking.

Tithonia diversifolia, a native of Mexico and Central America, where it is known as the Mexican Sunflower, is a succulent shrub used as fodder for ruminant animals. *Tithonia* belongs to the family compositae or *aster* family. In Kenya it is widespread in Central, Western province and the wetter areas of the coastal and Rift Valley regions and adapts well to varied conditions of acidity and soil fertility. It's a robust shrub with fast growth that grows to a height of three meters, can withstand intense pruning (Roothaert and Paterson 1997). *Tithonia* is a warm season annual shrub growing to 1.5-1.8 meters tall and 0.9-1.2 meters wide and having coarse three-lobed leaves. It produces large quantities of biomass (Zemmelink *et al.*, 1999), though the amount of the leaf production is influenced negatively by the numerous brilliant red-orange flower heads. *Tithonia* has a high concentration of nutrient nitrogen in the dry matter (Zemmelink *et al.*, 1999), which prompts it use as a protein supplement. Its high yield of biomass may render it useful as an alternative for napier grass (Wambui, 2005).

Sapium ellipticum is a drought tolerant evergreen tree growing to 15 meters tall with drooping branches. Widely distributed in East and Central Africa, it is often found near rivers and its forage is reported to be highly palatable to ruminant animals. It is also common in fallow lands and farm boundaries (Sekatuba *et al.*, 2004). However, there is very little information regarding the use of *Sapium ellipticum* as fodder to ruminant animals.

1.1 The objective of the Study

The overall objective of the study was to assess the potential of two indigenous fodder species as suitable fodder supplements for ruminants. The specific objectives were:

1. To assess the potential biomass production of *Tithonia* and *Sapium* forages for use as possible supplement to napier grass.
2. To assess comparative acceptability of napier grass, *Tithonia diversifolia* and *Sapium ellipticum* to sheep.
3. To assess the suitability of *Tithonia* and *Sapium* forages as potential protein supplement at the critical periods when napier grass is both energy and protein Deficient.

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CHAPTER TWO

LITERATURE REVIEW

2.1 Fodder scarcity

Among the constraints to ruminant production in Kenya, as in most tropical countries, is inadequate fodder. The high rainfall areas are characterized by small farm sizes normally carrying more stock than they can grow fodder for. Poor nutrition or unreliable feed resource is therefore a major constraint to animal production (Devendra, 1993). During the dry season, the bulk of ruminant's diet is composed of low quality natural pastures or crop residues. Cereal crop residues have become more abundant because more land has been put into production of cereals than that has been put on fodder production. This is necessitated by need to meet the food demand for the growing human population. Crop residues such as maize Stover are hence an important feed for dry season feeding in Kenya. The crops residues are characterized by high fiber contents, low nitrogen and low digestible nutrients (Leng, 1990). The result is low intakes, reduced live weight gains and milk production (Abdulrazak *et al.*, 1997). Even so all small holder farms keeping ruminant animals in the areas of high rainfall do grow some fodder.

2.2 Basal feedstuffs for Ruminants Animals in Kenya.

Forages form the highest component and sometimes the only feed for ruminants in the tropics. Generally, tropical forages are characterized by rapid growth during the wet season and slow growth during the dry season, and in particular, the grasses which are shallow rooted (Njarui *et al.*, 2003). Forage in small holder farms is obtained from fodder grasses, crop residues or from fodder/ shrubs trees.

2.3 Fodder grasses

Napier grass (*Pennisetum purpureum*) is the most popular fodder plant for small scale farmers in Kenya due to its high yields and ease of harvesting. It is a native of Tropical Africa (Kariuki, 1989). It is a perennial and robust forage growing to a height of 2 - 6 m with up to 20 nodes. The leaves range from 30 - 120cm in height, 1-5cm in width and are glabrous or hairy. Cultivars differ in thickness of stems, size of leaves; hairiness of stems and leaf sheaths, general vigor, the size of hefts, the number of tillers and height of plant. There are over thirty types of napier that have been tested in Kenya, but only a few varieties, namely; Bana grass (Gold Coast), French Cameroon, Kakamega 1, Clone 13 and Pakistan hybrid, have received wide acceptance (Kariuki,1989). It is recommended that the grass be fed to dairy cows at a height of 60 - 100cm or at intervals of 6 - 10 weeks of growth (MLD, 1991).

Sorghum is also grown for either its forage or its forage. The Sweet sorghum variety is grown for forage rather than grain. Its stems are juicy and sweet while those of grain sorghum are pithy. All sorghums contain trace amounts of cynogenic glycosides which might pose some poisoning effect. This anti-nutritive factor in sorghum is well documented. Occasional fatal results of cyanogenesis by forage sorghums have been reported in all classes of animals. The presence of cynogenic glycosides in sorghum may adversely affect animal production through direct poisoning, fear of stock poisoning on the owners part, reduced intake or reduced production.

2.4 Natural grasses

Natural grasses are another important feed resource for ruminant animals, as they form the bulk of the animal feed. Majority of the natural herbage varies in their quantity and quality. Grazing animals generally face serious nutritional stress whenever the quantity of the herbage is inadequate or when the quality is low especially during the dry spell (Chileshe and Kitalyi, 2002).

Natural grasses can either be annuals or perennials. Both annual and perennial grasses are important resource as animal feed. Perennial grasses have a life cycle of more than two years compared to one growing season of the annual grasses. Perennial grasses may be established through cuttings, splits and the use of seeds. They produce few seeds as compared with the annual grasses. Natural grasses are a major animal feed since they are readily available. They require minimal management as compared with improved grasses (Chileshe and Kitalyi, 2002).

2.5 The role of crop residues in crop/livestock farming systems.

The greatest constraint farmer's face in increasing output of livestock products is their inability to feed animals adequately throughout the year. However, significant opportunities exist to increase ruminant livestock feed supplies by using crop residues and other feed resources such as trees and shrubs. Cattle obtain between 16 and 40% of their DM intake from crop residues. The proportion rises from 50 to 80% during the dry seasons when few alternative feeds are available. The most commonly used crop residues are maize stover, rice/wheat/barley straws and bean/pea haulms.

2.5.1 Maize Stover.

Crop residues play an important role as feed resources, particularly during the dry seasons when hardly any napier grass is available. Maize, a major food crop, is grown by virtually every smallholder farmer, and maize stover is therefore the most abundant arable crop by-product on smallholdings (Wambui, 2005). High levels of lignifications and low crude protein characterizes most of the maize stover feedstuffs. These two factors limit digestibility and voluntary intake and therefore utilization of the material by ruminant animals is decreased. To improve intake, digestibility and utilization, stover is often chopped. Chopping of maize stover is, however, laborious and many farmers do not chop their stovers prior to feeding. It has been observed that chopping of maize stover appear to improve intake in cattle and sheep. However, its efficacy in improving digestibility is more obvious in sheep than in cattle (Ngwa *et al.*, 2003).

2.6 Fodder trees and shrubs.

There are about 300 important species of trees and shrubs that may be used for fodder production globally. The potential for many of these has not been exploited (Devendra, 1993) because research has concentrated only on a few of them (Brewbaker, 1986). A lot of work has been done on *Leucaena* and *Glicidia* especially in Asia and Africa. Extensive research has been done on some Acacia species (Kaitho, 1997). However this narrow focus on particular species has tended to overlook many other valuable shrubs, which could act as suitable alternatives. Research on these other species would eliminate the dangers of over reliance on a few genera. In the recent past, research and dissemination initiative on fodder species and shrubs in the country have concentrated largely on exotic species. Much as these exotic species are appealing both in terms of growth rates and yields, complete reliance on them has proved unfortunate because none of them have been without profound limitations (Roothaert, 2000). Local trees and shrubs may be used for fodder production, but their utilization has been restricted because of inadequate information on how to grow and harvest them, and about their chemical composition /nutritive value and feeding value. Many of the species have nutritional values superior to those of grass and can produce high amounts of palatable biomass (Jama *et al.*, 2000). Trees and shrubs fodder contains high levels of crude protein and minerals and many show high levels of digestibility. They are readily accepted by livestock and presumably because of their deep-root systems, they continue to produce well into the dry season. Although they are the most visible plant forms in the arid lands, shrubs have been neglected in most scientific research (Brewbaker, 1986) and land management policies (Le Houerou, 1980).

Calliandra calothyrsus, Sesbania sesban and *Leucaena leucocephala* are the most researched fodder trees species (Brew baker, 1986). The high tannin levels in *Calliandra calothyrsus* reduces digestibility (Nherera *et al.*, 1998). Sesbania on the other hand is unable to withstand intensive cutting management (Roothaert *et al.*, 1997). The *psyllid* infestation on Leucaena and its poor performance in acidic soils does not make it amenable to over-rely on it for fodder.

Other trees and shrubs have high re-growth ability (Maundu and Tegnas, 2005). *Tithonia* (Wild sunflower) has been cited as one of the popular species used as fodder in Kenya (Roothaert *et al.*, 1997). Given the known characteristics of the tropical grasses, with low digestible protein levels and high rate of fiber, the foliage of *Tithonia* has been demonstrated as a possible nutritional strategy in the supplementation of ruminants in the tropics mainly during the periods of foliage shortage. *Tithonia* is an abundant multipurpose shrub that grows naturally in Central and Western Province (Wanjau *et al.*, 1998). The flower of *Tithonia* is about 3cm in diameter. Each mature stem may bear several flowers at the top of the branches. It is resistant to persistent cutting, robust in biomass production and is easily established from cuttings. It has high concentrations of soluble nitrogen 4.6 to 5% (DM) and therefore has potential for use as a protein supplement. In Sri-Lanka, Premarante *et al.* (1998) reported an increased total feed intake and digestibility of rice straw in growing sheep after supplementation with *Tithonia* at 15 to 30g/kg $^{0.75}$ DM.

Sapium ellipticum is an evergreen tree growing to fifteen meters tall with drooping branches growing commonly on the outskirts of evergreen forests and wooden ravines. It is widely distributed and often found near rivers. It is a native of thirty one countries including Kenya, Uganda, Tanzania, Angola, Benin and South Africa. It is drought tolerant and reportedly very palatable. In Kenya, little has been done on the nutritive value and utilization of this shrub as a livestock feed though it is mentioned to be browsed on by goats (Sekatuba *et al.*, 2004).

2.7 Comparative fodder production practices.

Napier grass grows well on fertile loam soils and warm to hot environment. It prefers plenty of rain (over 1000mm) although it has roots that go deep which enable it tolerate mild drought. This explains its natural habitat of forest edges and river beds. It is grown as a pure stand or along contour terraces for soil erosion control. It can tolerate mild drought and some varieties tolerate frost. However, its productivity and nutritive value varies a lot with variation in the soil, climatic conditions and cropping practices (Kariuki, 1989). Sorghum plants have nine specific developmental stages similar to those of maize. Environmental factors such as soil fertility, moisture stress, plant population, weed competition and insect damages determines the maturity period of sorghum forages. The crude protein content of sorghum forages decreases from 5.4% to 3.8% with advancing maturity and thereby causes a decline in the quality of the forage sorghum. Digestion coefficients for crude protein and crude fiber significantly declined with advancing maturity in sorghum forages (Hove *et al.*, 2003).

2.8 Fodder trees: *Sapium* and *Tithonia* production.

Fodder trees and shrubs are now receiving increased research attention although systematic information from farmers about the species they use is scanty. The conventional way of screening fodder trees species in the tropics involves on station agronomical trials comparing biomass production of selected species under different management regimes. These trials usually emphasize exotic species, such as Leucaena and *Glicidia sepium*, because planting materials and information are readily available from international sources. In recent years, some researches have examined local tree species and involved farmers in their search for promising fodder species (Roothaert and Franzel, 2001). Local fodder trees and shrubs have the advantage in that they are well adapted to the local environment, farmers know them and locally available planting materials are abundant.

2.9 Production of *Tithonia* and *Sapium*.

2.9.1 *Tithonia*.

Tithonia is a common roadside weed where it grows up to a height of 1-3 meters. It is available in farmer's fields especially in high potential areas where it is planted along roadside reserves and planted as a hedge and could thus act as an alternative source of protein (Wambui, 2005). There is evidence that species of non-leguminous plants such as *Tithonia* accumulate as much nitrogen in their leaves as the leguminoses. They have an ample range of adaptation, tolerate conditions of acidity and low fertility in the ground and are vigorous growing (Wanjau *et al.*, 1998). The flowering and seeding of *Tithonia* may take place throughout the year. The seeds of *Tithonia* are very light and can easily be dispersed by wind, water and animals, where it easily establishes itself. Therefore, *Tithonia* can easily be propagated by direct seeding using a furrow for the seeds and covering them lightly with sandy soil. Application of mulch is important in preventing the seeds from being washed away and for retention of the soil moisture.

Tithonia plants can also be established through the use of cuttings. For successful establishment, cuttings between 20-30 centimeters long with at least 3 internodes should be cut from clean *Tithonia* plants. During planting, push the cutting into the soil slanting at an angle of 45 to 60 degrees with at least one internode buried into the soil to facilitate root development. It may be necessary to water the cuttings if the soil is not moist enough. The use of cuttings is the easiest and cheapest method of propagation for *Tithonia* (ICRAF, 1997)

2.9.2 Harvesting of *Tithonia* fodder

Tithonia is best cut for incorporation into the soil or feeding to animals every three to four months from the previous cutting. If *Tithonia* is left to grow beyond five months, for example, from March (beginning of the rainy season) to September, and October (end of the growing season), it will have flowered, seeded and dried up. It is therefore, recommended, that *Tithonia* be cut before flowering. The cutting is quite pleasant because *Tithonia* branches are succulent and soft (ICRAF, 1997).

2.9.3 Production of *Sapium*

Sapium trees grow in their natural habitat along the bank of rivers and forested areas. By wilding, young *Sapium* plants can be found in the habitat and may be collected and readily planted in farms. In addition, mature seeds can be harvested from naturally growing and mature trees that are growing in clusters. *Sapium* seeds are generally rare because *Sapium* trees are not allowed to grow to the point where the tree produces seeds. However mature trees produce mature seeds that fall down and germinate after heavy rains. Hence seeds are not easy to find. The seeds are then sown in well prepared nursery beds and watered throughout until the seed sprout which usually takes several months. The nursery bed can be established during the dry period and seed sowing done at the start of the rain to have ready seedlings for transplanting at the start of the next rains. Manure or inorganic fertilizer is used to enhance root establishment and growth. When the seeds sprout on the ground they are allowed to grow to the height of about 10 inches and then uprooted and sown again into the farm. For successful establishment the germinated seedlings will require sufficient rainfall, manure and fertilization. The seedlings are planted with a spacing of three meters per plant. Incase of insufficient rainfall, watering of the seedlings is necessary to promote establishment of roots. The trees may also be established through direct sowing of seeds after extraction from their capsules. The slow growth rate, poor survival rate and high labour input for protecting seedlings do not foster enthusiasm for adapting *Sapium* tree planting on a medium or large scale. *Sapium* tree comes into economic production after 6 to 7 years (Maundu and Tegnas, 2005).

2.9.4 Harvesting of *Sapium* fodder.

Sapium trees have a productive life span of about 30 years. Thereafter, the productivity declines rapidly, many branches dry up and the stem bark starts peeling off. The trees used in this study were about twelve years old and therefore at the prime of their life. *Sapium* branches are harvested using a well sharpened panga. The stripping of leaves and twigs is done on the branches and not on the main trunk. The cutting of twigs is done, about 30cm from the lateral branches. This promotes further sprouting of new growth. *Sapium* trees are harvested once a year. The fodder from *Sapium* is cut mostly between August and September when the other fodder, such as napier grass is scarce. This enables the *Sapium* trees to actively play its role as a drought recovery plant (Maundu and Tegnas, 2005).

2.9.5 Fodder crops yields.

As napier grass is grown widely by smallholder dairy farmers in Kenya, it often serves, often unconsciously, as a yield reference point for alternative fodder crops. This is surprising given its production variability; although recorded yields surpass any other fodder grass species (Muia, 2000). The dry matter yields vary from 10 to 40 tonnes per hectare per annum depending on soil fertility, climate and production practices. Higher yields can be obtained with fertilization. In Kenya the highest dry matter yields of 28.5tonnes/ha/year has been recorded in Kakamega with a rainfall of 1910mm and cutting intervals of 7 weeks. Napier grass DM yields depends on factors such as; varieties, climate, prevailing weather conditions, water supply, soil fertility, cultural practices and cutting interval (Kariuki, 1989). In Kilifi a dry matter yield of 5.5ton/ha/yr was recorded with a low rainfall of 612mm at a cutting interval of 18 weeks. For feeding purposes, the dry matter yield that is acceptable to the animal is more important as it reflects on intake. Napier grass left to grow forms largely unacceptable tough and pithy canes thus limiting intake. Frequency of cutting therefore influences amounts of dry matter yields as well as dry matter intake of napier fodder (Kariuki, 1989). During the dry season, the cell wall constituents increase while the proportion of the easily digestible cell contents decreases (Van Soest *et al.*, 1991). Natural pastures, especially napier, are often of low nitrogen content (<3% CP) and total soluble sugars during the dry season and as a result they rarely meet the nutrient requirement of ruminants thus require both protein and energy supplementation (Muinga *et al.*, 1998).

In comparison, sorghums have an estimated yield of 21.2 $\pm$ 2.5 tonnes/ha/year and fodder maize of 6.6 tonnes of dry matter per hectare per year (Chileshe and Kitalyi, 2002). Maize stover yields from a grain maize crop were reported to range between dry matter yields f 2.2-3.8 tonnes per ha per year in Muguga, Kiambu District (Abate, 1992).

2.9.6 Yields of *Tithonia* and *Sapium*

One advantage of *Sapium* is that it produces large amount of biomass. It is also drought resistance due to the deep root characteristics.

2.9.7 Acceptability, chemical composition, and digestibility of fodder types.

Generally, napier grass is one of the most accepted fodder grasses by ruminants animals such as cattle and sheep. This general recommendation is based on the optimal CP concentration (100 -120g kg^{-1} DM) for moderate milk production by dairy cows (Muia, 2000). However, napier grass tends to loose its high nutritive value with age. Concurrently, its acceptability decreases, it has been reported that the CP levels after 10 weeks of growth decreases below the critical levels for optimal microbial activity of 6-8% (Milford and Minson, 1966). The low CP values most likely affects its digestibility and may consequently reduce dry matter intake. At this critical point the need for protein supplementation is crucial if napier grass is the only source of basal feed (Kariuki, 1989).

Despite this draw back of CP levels with age in napier grass, it is still the most preferred pasture grass for the small-scale farmers in Kenya, more so in Central and Eastern Kenya. The reasons for this popularity are its high yields, ease of harvesting and its ability to retain good quality much longer than most of other fodder grasses (Kariuki, 1989). Acceptability of napier grass is also influenced by the amount of leaves in the diet. The leaves have a higher digestibility than the stems in mature herbage. Leaf to stem ratio is known to affect digestibility and chemical composition of forages (Van Soest *et al.*, 1991). As the Napier grass matures, the percentage of leaves decline due to stem elongation and death of older leaves. This percentage decline in leaves could cause a decrease in feed intake for un-chopped napier; but this phenomena can be masked through chopping.

2.9.8 Chemical composition of grasses fodder and crop residues

The dry matter content of fresh napier grass fodder is among the lowest in all the important grasses of East Africa. The thick fleshy stems of napier grass are responsible for the high water content (Wilson *et al.*, 1991). The dry matter content for Bana grass and French Cameroon grasses varies between 15.8% to 17.67% and 14.52% to 17.7% at 4 weeks to 14 weeks of cutting. Therefore, dry matter intake in animals particularly in the early stages of growth could be limited due to its high moisture content. Napier grass at different stages of growth may have completely different crude protein content. Crude protein values for napier grass decreases with age. The CP values for two napier grass cultivars, French Cameroon and Bana grass declines on average with age and maturity from 14.2% to 4.5% from 4 weeks to 10 weeks of growth respectively.

2.9.9 Chemical composition of sorghums.

On the other hand grass crop residues are poor sources of nutrients. Stover leaves at the time of harvest of the grain tend to be dry and brittle. The ash content is often high in the leaf fractions of cereal straws due to a high content of silica (Goering and Van Soest, 1970). This limits digestibility of the leaf component of cereal crop residue. Silica is taken up and deposited in the cell walls as silica. The leaves, large surface area also probably accumulate a large amount of dust particles resulting to high ash content. The leaves of maize stover have a CP content of over 70g/kg DM; a dietary level that is considered as critical for acceptable voluntary feed intake by ruminant animals and for rumen function (Van Soest *et al.*, 1991). The stems, sheath and husks all have a CP value below the critical value. In addition, maize stover leaves have the low levels of NDF indicating a high concentration of cell content that is generally assumed to be completely digestible in the rumen (Oluokun, 2005).

Because leaves and stems are fed concurrently, intake, digestibility and associated performance of ruminants on stover basal diets is low. Several methods have been used to improve intake and digestibility of maize stover. Supplementation with green materials and commercial concentrates or milling by-products targets increasing dietary CP content with intention of increasing intake and rumen function. This is done at risk of selection against the stover especially if the amount of green material added is large. Fine chopping and mixing minimizes selection considerably. A number of authors working with maize stover have recognized that supplementation particularly with protein sources, improved intake (Wambui, 2005). Soaking also reduces dustiness and dryness of the stovers. soaking of dry crop residue in water for 24 hours prior to feeding increase intake by more than two times that of protein supplementation and may be used to overcome constraints to intake of maize stover, particularly in situations where protein sources are scarce or expensive (Woyengo, 2001).

2.10 Chemical composition of tree and shrub fodder.

Compared to grasses, trees and shrubs generally have higher digestibility and their nutritive value tends to remain higher as plant matures. During the dry season leguminous and non leguminous trees provides green forage rich in protein. The protein content of forages and shrubs such as *Tithonia* and *Sapium* leaves and twigs is between (12-30%) which is much higher in comparison with that of mature grasses (3-10%). This is above the critical protein level mentioned above for optimum intake and microbial activity in the rumen (Norton, 1994a). As plant mature, CP and the more easily digestible carbohydrates decrease while CF, lignin and cellulose increase (Van Soest *et al.*, 1991) and these changes affect forage intake and therefore performance of the animals. Variation in the type of plant communities present, their distribution and factors such as canopy structure and biomass have important implication on animal behavior and performance (Ngwa *et al.*, 2003). Forage management by planting fodder banks for emergency goat feeding during the dry season when natural pastures cannot produce sufficient forage have been reported in Kenya and Nigeria in high potential areas (Chileshe and Kitalyi, 2002). Many of these species have nutritional values superior to those of grass and can produce high amounts of edible biomass (Kaitho *et al.*, 1996). Nevertheless there is evidence that species of non leguminous plants as *Tithonia diversifolia* accumulate as much nitrogen in their leaves as the leguminous. They also have high phosphorus levels. They have ability to recover the scarce nutrients from the ground, have ample rank of adaptation and tolerate conditions of acidity and low fertility in the ground (Wanjau *et al.*, 1998).

Despite the use of *Tithonia diversifolia* in the feeding of animals and the agronomical potential demonstrated by the culture, few investigations of its potential use as forage exist (Jama *et al.*, 2000). In evaluation of the nutrient content of *Tithonia diversifolia* (leaves, flowers and stems), Wambui (2005) found that the dry matter and CP varied from 13.5 -23.23% and 15-29%, respectively. These are by far higher than for most grasses such as napier. The high CP of *Tithonia* was also reported by Wanjau *et al.*, (1998) with a CP value of 28%; and Premarante *et al.*, (1998) with a value of 5-29% DM based on their vegetative state. The concentration of nutrients is highest in younger parts and then before flowering. *Tithonia* can thus be classified as shrub of high protein value that falls within the levels of 14-37% (Devendra, 1993)

Tithonia shrub contains higher concentrations of calcium and phosphorous than other minerals and tend to retain carotene for long periods though vitamins A,B and C are in varying concentrations in leaves, fruits and seeds of some trees and shrubs (Dicko and Sikena, 1992). The calcium levels of *Tithonia* of 1.65-2.25% provide a Ca: P of 2:1 closer to what is usually recommended for ruminants diets.

The nutritive value of browse trees and shrubs is however very variable depending on the soil type, location, plant parts (leaf, stem, flower and pods), ages of the leaf, season and concentrations of the anti-nutritive factors (secondary compounds) and the form of presentation (fresh or dried). These affect their nutritive value by influencing their chemical composition, palatability, intake, the extent, and rate of digestibility. Nutrient utilization by ruminants fed predominantly low quality roughages can also be influenced by the trees and shrubs forage (Norton, 1994a; Kaitho, 1997). Most browses contain anti-nutritive factors like tannins and saponins. These compounds adversely affect nutritive value especially when they are used as basal feed. The significance of the secondary plant compounds become more evident when browse herbage is the only feed consumed (Norton, 1994a; Kaitho, 1997). Levels of tannins in shrubs like *Tithonia* can be reduced by drying, diluting with other feed materials. Browse in most situations is used as a supplement to enhance the intake and utilization of other fibrous crop residues like cereal straws and hay to meet the maintenance and variable levels of production requirement (Kaitho and Kariuki, 1998). Supplementing poor quality forage with leaves and twigs of *Tithonia* or *Sapium* resulted in faster rumen outflows rates, thereby increasing DMI and providing more digestible organic matter (Orden *et al.*, 2000). Devendra (1998) recommended that when browse foliage are used as supplements the optimum dietary levels of browses and shrubs should be about 30-50% of the ration on DM basis or 0.9 to 1.5kg/100kg body weight. A few farmers in Central Kenya have adopted as protein supplement the use of *Tithonia* and *Sapium* in the cut and carry system of Kenya (Kaitho and Kariuki, 1998). *Tithonia* can produce up to 275 tons of green material which is about 55tons of dry material per hectare per year (Wanjau *et al.*, 1998). The medicinal value of *Tithonia* is probably the most acknowledged in Western Province part of Kenya. Crushed *Tithonia* leaves and buds mixed with water are used as medicine for stomach pains, indigestion, constipation, sore throat and liver pains for humans (Wanjau *et al.*, 1998). *Tithonia* is also used to control internal worms amidst its use as a fodder. *Tithonia* has a capacity to increase rate and efficiency of microbial biomass production. This results to increased voluntary, DMI and subsequently increased average daily gains. This was demonstrated when *Tithonia* emerged overall best compared to *Leucaena* and *Glicidia* at two levels of supplementation (15 and 30g/kg $^{0.75}$ (Premarante *et al.*, 1998). The low utilization of fodder trees and shrubs in Kenya is partly attributed to inadequate information on their nutritive value and utilization (Roothaert, 2000). In practice farmers feed the fodder trees and shrubs at various stages of regrowth depending on the animal needs and availability of other feed resources such as grasses or hay with little consideration being paid to nutritive quality. Although maturity stage is known to widely affect both the DM yield and chemical composition for fodder trees and shrubs, there is insufficient information available regarding the best stage to harvest for optimum nutritive value and yield.

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CHAPTER 3

ASSESSMENT OF BIOMASS PRODUCTION FOR *TITHONIA DIVERSIFOLIA* AND *SAPIUM ELLIPTICUM*

3.0. Biomass production for Tithonia Diversifolia and Sapium Ellipticum

3.1 Introduction.

The amount and quality of fodder crops, such as napier grass drastically declines during dry season. This reduces feed availability and hence severe effects on livestock performance, in terms of growth, milk and meat production.

Fodder trees and shrubs have been proportionately overlooked in terms of the research effort devoted to agricultural cropland, pasture grasses and fruit trees crops. Although they are the most visible plant forms in arid lands, shrubs have been neglected in most of scientific research (Brewbaker, 1986) and land management policies (Le Houerou, 1980). There is need, therefore, to explore the potential of indigenous fodder species as an alternative to introduction of exotic ones. In the eastern province districts of Meru and Embu, a shrub known as *Tithonia (Tithonia diversifolia)* and a tree referred to as *Sapium* (*Sapium ellipticum*) are reportedly used to supplement fodder during the dry season. However, as with many indigenous fodder trees and shrubs, data on their biomass production is lacking. The objective of this study was, therefore, to assess the potential biomass production of *Tithonia* and *Sapium* forages for use as possible substitute to napier grass so as to widen the choice of forages and thus reduce risk of single species dependence, such as napier grass, and or *Leucaena leucocephala.*

3.2 Methods and Materials.

3.2.1 Experimental Site.

The data was collected at the Kenya Agricultural Research Institute (K.A.R.I) Regional Research Centre, Embu, and the neighboring areas. The centre is located in the Central highlands of Kenya, on the south eastern slopes of Mt. Kenya at an altitude of 1480m above sea level. The soils are mainly humic Nitosols derived from basic volcanic rocks and classified by USDA under humic palehumult. Rainfall is moderate at an average of 1200 - 1500mm (Jaeltzold and Schmidt, 1983) and bimodal with the long rains (LR) coming between mid March and June amounting to an average of 750mm and the short rains (SR) from mid-October to December and averaging 350mm. Monthly temperature range between the averages of 18-21^{0}C.

3.2.2 The study fodder species.

The experimental test shrub and tree were *Tithonia diversifolia* and *Sapium ellipticum*. Because of their difference in stature and growth period, the biomass yield for the two species was assessed separately.

3.2.3 Assessment of biomass production by *Tithonia*.

Tithonia common name is Mexican sunflower and a native of Mexico or Central America. *Tithonia* belongs to the family compositae of *Asteraceae* of *Aster* family. It is a succulent shrub occasionally used as a fodder. It grows along roadside to a height of three meters and has a characteristic yellow flower. It produces large quantities of biomass and tolerates regular pruning.

3.2.3.1 Selection of site.

To assess its dry matter yield, four (4) plots measuring $8m^2$ each were randomly chosen from an area of bush land already entirely occupied by *Tithonia*. The piece of land, from which the four plots were chosen, at the Embu Research Centre, is in an area popularly known as, 'The Agroforestry Farm'. Two of the plots were on an open ground while the other two were under trees shade. The distance between the plots was twenty meters.

3.2.3.2 Identification of the plot.

The four main plots were marked alphabetically, A, B, C, and D. Plots B and D were under the trees while plots A and C were in the open ground. Each of the main plots was subdivided into four Subplots of $2m^2$. These 16 sub-plots were randomly marked with numbers from one (1) to sixteen (16). Using a table of random numbers the 16 subplots were grouped for the purpose of consecutive cutting.

3.2.3.3 Demarcation of plots.

A measuring tape, a panga and a meter and two-meter measuring sticks were used to demarcate the four plots and the sixteen subplots. The panga was used to clear vegetation from around the sites to pave way for erecting plot boundary sticks. Four border sticks were erected to mark the external perimeter of the plots and five other sticks were erected to mark the length of the subplots within the main plot.

3.2.3.4 Harvesting procedure and yield determination.

The existing herbage of *Tithonia* in the four plots was cut down at the ground level (harvested) on day zero (0) of the experiment and then left to re-grow. The height of the stems was taken in centimeters using a measuring tape and recorded before each cut. The three shortest and the three longest stems were cut from every sub-plot, the length between the bottom and the apex of the stem measured and the average height calculated for each subplot. Both the stems and the leaves were harvested together by cutting all the stems from the ground level and collecting the herbage into gunny bags. The amount of herbage harvested from every plot was weighed using a spring balance and recorded.

The first cutting of the first four subplots was done four weeks after clearing of the plots. Subsequent harvesting of the *Tithonia* herbage for the remaining subplots was done at fortnightly intervals, i.e. after six, eight and ten weeks of growth. Four subplots, one from each main plot were harvested at each time period.

The herbage from each subplot was dried separately under shade and weighed in order to determine the dry matter yield. The dried stems and leaves were weighed together and then the leaves and the twigs were stripped from the dried herbage, weighed separately and the weights recorded. These values were later used to compute the leaf to stem ratio of the harvest.

3.2.3.5 Dry Matter Determination.

Samples from the four subplots were collected into four marked paper bags. The fresh samples were taken to the analytical laboratory and dried in ovens set at 105^0c for dry matter determination.

3.2.4 Assessment of biomass production by *Sapium ellipticum*.

3.2.4.1 Selection of site and identification of *Sapium* trees.

KARI Embu has an orchard located at the Agro-forestry Farm, with fifty-four *Sapium* trees planted by Roothaert (2000) who researched on intensive use of indigenous and naturalized fodder trees and shrubs in Central Kenya. The trees were planted at a spacing of three meters. Sixteen trees having similar characteristics in terms of height and the crown cover were selected randomly from the 54 in the orchard. The selected trees were in a uniform stand. The trees were randomly marked with numbers (1-16) on the stem and grouped into groups of four for the purpose of herbage production estimation. The ground cover for each tree was estimated by marking the shade cover on the ground at twelve noon and estimating the irregular shade shape area through best lines approximately retaining similar space as that covered by shade.

3.2.4.2 Harvesting procedure and yield determination.

At day zero (0) all the sixteen trees were harvested by stripping the leaves and twigs from the trees. This was done in order to allow sprouting of new herbage for uniform estimation of fodder dry matter yield. The second harvesting after the initial harvesting was done after seven weeks of re-growth. Subsequent, stripping was done after weeks nine, eleven and thirteen re-growth. A gunny bag sheet carpet was spread on the ground to catch strippings from the tree during the herbage harvesting. The herbage was then put in marked gunny bags; the weight was determined and recorded. The shortest and the longest twigs were selected, and their length determined and recorded. A sample of the harvest was taken for dry matter determination. The harvested herbage was then dried under shade. After the drying the dry matter weight was determined. The leaves and the twigs were then separated, their weights determined and recorded.

3.2.4.3 Dry matter determination.

Samples of *Sapium* for each harvesting were analyzed for dry matter as stated on section 3.2.4.2.

3.3 Data management and analysis.

The data recorded for *Sapium* and *Tithonia* was entered into the Microsoft Excel® spreadsheet for management, and calculation of descriptive statistics. *Tithonia* dry matter data yields was subjected to the main plot and sub-plot analysis of variance with the week of growth as a covariate (Steel and Torrie, 1980). Only the effect of growth period time on dry matter yields and twig length was assessed statistically for *Sapium.*

3.4 Results and Discussion.

3.4.1 Stem height and dry matter yield of *Tithonia*.

Stem height determination is important because it demonstrates how herbage responds to differences in growth period and environment (Thornley, 1999). Stem heights for cuts 1-4, representing 4, 6, 8 and 10 weeks of growth were 13.4, 47.6, and 63.1 and 80.6 meters respectively (table 1). Plant growth is influenced by growth period and environmental factors such as light, soils, water and temperature or quality. In this study, growth of *Tithonia* took place under similar environmental conditions with exception that half the plots were under tree shade while the other two were in open ground fully exposed to the sunrays. The soils under all the plots were well-drained and similar, therefore unlikely to influence growth of *Tithonia* which is known to do well in areas with such soils (Zotz *et al.*, 2001). The subplots were close together and therefore any variation in growth originating from soil, water and atmospheric conditions were not expected to be large. The stems of the herbage under the shade were taller and slender compared to the stem of the herbage growing under the sun (Table 2a). Light availability has a profound effect on plant growth and development, a phenomenon called phototropism (Begna *et al.*, 2002). Depending on the plant species there are two types of morphological adaptation. In some plants, changes in light quality lead to shade tolerance responses characterized by an increase in leaf area ratio and specific leaf area (Peace and Grubb 1989, Heraut *et al.*, 1999); and in others there is an increased stem internode elongation and reduced leaf to stem dry weight ratio (Ballare *et al.*, 1991). Culturaly *Tithonia* prefers full exposure to sunlight but it also tolerates filtered sun or partial shade (Aphalo and Letho, 1997). The stem mean heights for both plots under the shade and sun increased with the growth period in weeks. During the fourth week the stem mean heights for the plots under the shade and the sun was 12.5cm and 14.3cm respectively, while at the sixth week the stem mean heights was 53.5cm and 42.3cm respectively. Throughout the growth period the stem mean heights increased with increase in *Tithonia* plants maturity. The biggest mean stem-heights for the plots under the shade and under the sun were 83 cm and 78.3 cm at the tenth week of growth. The growth of the *Tithonia* herbage did not level off as growth period was cut shorter than would normally be the case. Hence the herbage did not attain its potential full height of three meters in six months (Muoghalu *et al.*, 2005).

Table 1: Average stem height, amount of cut, dry matter of cut and dry matter yield of harvested *Tithonia* fodder with the length of Growth period.

Growth time (days/weeks)	Growth height (cm)	Dry Matter of cut (%)	Dry matter yield(Kg/m^2)	DMY Tonnes/ha	Leaf to stem ratio
4weeks	13.40	9.9	0.07	4.6	10
6weeks	47.63	10.3	0.48	31.1	3.41
8weeks	63.13	12.0	0.58	38.0	1.26
10weeks	80.63	16.5	1.13	73.7	0.27
L.S.D	12.56	1.899	0.1169		

Table 2a: **Effect of shade and sun on *Tithonia* fodder with changes in growth period (weeks) on the average of stem length, leaf to stem ratio, dry matter of cut, dry matter yield and extrapolated dry matter yields per ha per year.**

		Growth period length (weeks)			
Parameters	**Light effect**	**4**	**6**	**8**	**10**
Stem length (cm)	plots under shade	12.30	53.50	68.0	83.0
	plots under sun	14.50	41.80	58.2	78.3
Leaf to stem ratio	plots under shade	10.00	1.80	1.60	0.30
	plots under sun	10.00	5.00	0.90	0.30
Dry matter of cut (%)	plots under shade	9.80	10.20	11.70	13.90
	plots under sun	10.20	10.50	12.30	19.10
Dry matter yield ($kg/2m^2$)	plots under shade	0.09	0.66	0.66	0.91
	plots under sun	0.05	0.30	0.50	1.40
Extrapolated DM yield per ha per year(tonnes)	plots under shade	5.90	43.0	42.60	58.90
	plots under sun	3.30	19.3	33.50	88.40

Table2b: **Mean square values of analyses of variance for growth period and light effects on *Tithonia* forage production.**

Factor		Variable				
	DF	**Stem height, cm**	**Leaf to stem ratio**	**Dry Matter %**	**DMY/m^2**	**Extrapolated DMY (tonnes/ha)**
Light	1	145	1.6	10.7	0.002	8.8
Growth time	1	9433*	197*	91.2*	2.2*	9175*

*(P<0.05)

The dry matter percentage of the herbage both cut under the shade and the sun increased throughout the growth period. Overall dry matter of cut (%) was 9.9, 10.3, 12.0 and 16.5 for cuts 1-4 respectively. The dry matter of the harvested *Tithonia* increased from the 28^{th} day to the 70^{th} day. This increase is normal and is attributed to the fact that as the herbage matured the stems were becoming thicker, a reflection of increase in the stem dry biomass. Plants like *Tithonia, Sapium* and other indigenous fodder species such as *Gewia Similis* have a unique allocation of dry matter to different structures within its own system. Plants allocate the highest amounts of dry matter to the stem production and the lowest dry matter to the leaf production. Since the stem is made up of woody material the water content in this material is far much lower than in the leaves (Muoghalu *et al.*, 2005). Shade did not have a significant (P>0.05) effect on the dry matter proportion. However, cuts of herbage grown under shade had a consistent lower dry matter percentage, with average percentage differences of 0.4, 0.3, 0.6 and 5.2 for herbage harvested at the cutting intervals of 1-4 respectively. Plants growing under shade should have less dry matter content because of reduction in photosynthetic capacity. Shading causes a reduction of the total soluble carbohydrates and an increase in lignin in the tissues (Wilson *et al.*, 1991).

The amount of *Tithonia* herbage harvested increased from the fourth week through to the tenth (P<0.05). Longer growth period allowed for increase in stem thickness and height (Akinola *et al.*, 1971). The greatest amount of *Tithonia* harvest in kg/2m^2 was at the tenth week with 1.13kg per 2m^2 plot. The dry matter yield (kg/2m^2) for leaves and stems increased from the initial harvest of the *Tithonia* herbage (28^{th} day), through to the 70th day. The shade effect on dry matter yield was inconsistent. The amount of herbage produced under the sun was higher than that produced under the shade in the last harvest while the initial, second and the third harvest produced unexpected results. There was a sharp increase in the DM yield between the 4^{th} and the 6^{th} weeks for both plots under the shade and the sun. Thereafter, the increase was more gradual. The annual dry matter yields (tonnes/Ha) extra-polated for each of the growth periods, increased with the length growth period. This ranged from 5.9 to 58.9 and 3.3 to 88.4, for plots under the shade and the sun at the 4^{th} and 10^{th} weeks respectively. It can therefore be argued that the biomass produced from the plots under the shade was less (table 2a) as a result of reduced light availability for carbon assimilation in the leaves (Begna *et al.*, 2002).

Tithonia propagates through seeds and cuttings. The density of plants in an area that is colonized by *Tithonia* can increase rapidly over a short time through tillering, germination of seeds and stems/cuttings taking hold on the ground (Muoghalu *et al.*, 2005). Thus although density of plants can cause great variation in herbage yield, stands of *Tithonia* that have lasted a few years are fairly uniform in density. Such was the case in this study.

Frequency of cutting influences the total annual herbage yield of plants that are capable of re-growing. Using vernal alfalfa grass, it was shown that fodder harvested three or four times per season produced more total fodder (Kust *et al.*, 1961; Smith *et al.*, 1967). Cutting frequency determines stem height at cutting with higher frequencies resulting in shorter stem heights. Dry matter yields and nutrients yields are higher for shorter cuttings heights as compared to leaving taller stubble (Sheaffer *et al.*, 1988). The cutting frequencies in this study were 13, 8.7, 6.5 and 5.2 weeks per year. An extreme cutting frequency may result, as in this study, with low annual herbage yields than expected. This study has not been, therefore, able to determine the optimal cutting frequency for *Tithonia* in Embu district.

3.4.2 Leaf to stem ratios.

Leaf to stem ratio is an important factor affecting diet selection, quality and fodder intake in ruminants' nutrition. In trees, shrubs and grass fodders, leaf to stem ratio declines logarithmically over time. The leaf to stem ratios variation for plots under the shade and under the sun was 10.0, 1.8, 1.6, 0.3 and 10.0, 5.0, 0.9 and 0.3 at the 4^{th}, 6^{th}, 8^{th}, and 10^{th} weeks respectively. The ratio declined ($P<0.05$) from 10.0 kg/kg to 0.3 for both plots under the shade and the sun from the 4^{th} and 10^{th} weeks of growth respectively. For some fodders, the leaf to stem ratios remains relatively constant under moist conditions, but declines rapidly after the onset of the dry season (Starks *et al.*, 2006). Digestibility of the stem sections decreases with increasing maturity while that of the leaves remains constant. The lower stem portions decreases in quality and digestibility at a faster pace than the upper portion of the stem. This occurs because the lower sections have been growing for the longest period of time and tend to be more fibrous and woody compared to the less mature upper stem sections (Buxton *et al.*, 1985). With advancing maturity, plants develop xylem tissue for water transport, accumulates cellulose and other complex carbohydrates and other tissues become bound together by a process known as lignification. The fiber component of leaves differs from that of stems. Leaves have much less lignin and that is entirely located in the rachis. Therefore, the leaves are more palatable and digestible. They have a higher CP digestibility than the stems and twigs (Kariuki, 1989). Hence the higher the leaf to stem ratio, the better the quality of fodder; except for sugarcane where the stem plays a role as a reserve organ, hence has higher quality than the leaves (Duarte *et al.*, 1982). As the forage matures, leaf to stem ratio declines (more stems, fewer leaves) and as result (NDF) digestibility declines (Lugo *et al.*, 1988). This could consequently lead to a reduction in the voluntary feed intake. The separation of leaves from the twigs and stems increases the palatability and digestibility of a feed material. This will consequently increase the extent and rate of digestion of the fibrous material. This will result in a higher dry matter intake reflected in the extent of live weight change and increased milk and meat production (Paterson *et al.*, 1999).

3.4.3 Stripping Twig Length and Dry Matter Yield

The determination of stripping twigs length demonstrated how the *Sapium* forage responded with the increase in the cutting period. The twig and leaf height of the *Sapium* fodder increased linearly with the consecutive increase in the length of the cutting period (7, 9, 11 and 13 weeks). This ranged from 42.8 to 86.5 cm at the 7^{th} and 13^{th} weeks respectively. The average twig length difference between the four cutting periods was 17.6cm, 6.1cm and 20cm. The increase in height of the twigs also corresponded with the increase in maturity of the *Sapium* fodder. The increase in dry matter yield with maturity suggested that leaves grew coarser while the twigs became thicker and elongated. Generally it is agreed that with delayed cutting, there is a corresponding increase in total dry matter yield and that height is a reflection of dry matter yield (Wilson *et al.*, 1991). The dry matter yield of *Sapium* may vary with different trees as well as with trees components (Sekatuba *et al.*, 2004). The DM yield of the *Sapium* fodder increased throughout the growth period. The yield ranged from 1.1, 1.7, 1.9, and 7.3 kg/m^2 from the 7th, 9th, 11th and the 13th week respectively. Canopy cover percentage reflected from the *Sapium* trees explain more about the variation in the difference of the dry matter yields than any other variable (Guan *et al.*, 2002). The dry matter yield obtained in this study are significantly higher than that reported by Development and on farm evaluation of agro forestry livestock feeding systems of 0.3tonnes/ha.

3.4.4 Leaf to stem ratio in *Sapium* fodder.

As forage mature, stems, with their low forage quality, constitute a larger proportion of the total forage. Leaves typically are of higher quality than stems with higher CP and soluble sugar concentrations and higher digestibility (Kariuki, 1989). Maturity is the most important factor affecting fodder quality by altering leaf/stem ratios. With maturity other morphological modifications and changes in chemical composition take place in the fodder parts. This limits the consumption (intake) and digestibility of forages. However crude protein concentration is usually greater in leaves and stem segments from the top of plant canopies than from the bottom. This has been attributed to shading within the plant canopy, which enhances senescence rates of bottom plant parts (Buxton *et al.*, 1994)

In the current study the leaf to stem ratio decreased from the seventh to the thirteenth week ranging from 1.6 to 0.8 from the seventh to the thirteenth week respectively (table 3). The decrease in ratio became gradual after the 11th week of growth as the *Sapium* forage matured (Guan *et al.*, 2002). The fact that the ratio decreased with maturity in this study is a proof that indigenous trees and shrubs growth trends resemble that of grasses. Leaf to stem ratio for grasses generally decreases with maturity (Kariuki, 1989).

3.4.5 Conclusion.

1 The amounts of yields of napier grass compared to both *Tithonia* and *Sapium* forages is much less because *Tithonia* is more aggressive in growth and *Sapium* has a more deeper rooting system than napier.

2 Proportion of yields of *Tithonia* and *Sapium* forages to napier grass increases with consecutive period of cutting.

3 To maximize the amount of annual dry matter yield (tonnes/ha) for both *Tithonia* and *Sapium* their cutting intervals should be 10 and 13 weeks respectively. This cutting interval will not only facilitate higher quantity of forage production but also greater and better ruminant nutrition and production.

Table 3: Effect of Time on Growth of *Sapium* on the Average of Stem Height, Leaf to Stem Ratio, Dry Matter of Cut, Dry Matter Yield per Ha and Dry Matter Annual Yield.

	Weeks of growth				
Parameters	**7**	**9**	**11**	**13**	**Std Dev**
Average tree ground cover, m^2	1.7	2.8	2.2	7.5	2.06
Stripping twig length, cm	42.8	60.4	66.5	86.5	6.75
Leaf to stem ratio, kg/kg	1.6	1.3	0.8	0.78	0.29
DM of strippings, %	22.3	30.2	33.8	40.1	3.02
Average tree DM YIELD, kg	1.1	1.7	1.9	7.3	1.83
Estimated annual DM yield, tonnes per ha	0.5	0.5	0.6	0.7	0.13

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CHAPTER FOUR

AN ASSESSMENT OF ACCEPTABILITY OF TITHONIA (TITHONIA DIVERSIFOLIA) AND SAPIUM (SAPIUM ELLIPTICUM) FORAGE TO SHEEP.

4.1 Introduction.

Ruminants such as goats and sheep may be fed with a wide array of plant material differing in nutrient content and quality. Free choice is used to determine palatability (acceptability). Acceptability is measured as the difference between the amount offered and the amount refused. It may be affected by (visual) appearance, taste, flavour and texture (Ngwa *et al.*, 2003). Grazing ruminants also select to make favourable combinations in order to maximize their biological performance and minimize toxicosis (Provenza, 1995).

An ideal alternative fodder crop for napier grass would be one that is approximately equally productive, acceptable and of high nutritive value. However, although a dry matter yield study on the two potential alternatives had been carried out, there was very little information regarding the acceptability of *Tithonia diversifolia and Sapium ellipticum* as fodder to ruminant animals. This study was set up to assess comparative acceptability of napier grass, *Tithonia diversifolia* and *Sapium ellipticum* fodder to sheep.

4.2 Materials and methods.

4.2.1 The Study site.

The study was carried out at KARI Embu in Eastern Province. The center is in a sub humid agro ecological zone and is located 1490 meters above sea level at $0^{0}30'S$ and $37^{0}27'E$. The soils in the area are humid Nitosol derived from basic volcanic rocks and classified by USDA (United State Department of Agriculture) under humid patehumult. The soils are deep, well weathered with friable clay texture and moderately high inherent fertility. Rainfall is moderate, with an average of 1200 - 1500 mm annually (Jaetzold and Schmidt, 1983). It follows a bimodal pattern with long rainy season from May to June amounting to an average of 750mm with the short rains from October to December with an average of 350 mm and Monthly temperature range from 18 to 21^0c.

4.2.2 Experimental animals and animal house.

Block B of the center had metabolic unit with 16 male Corriedale sheep housed in wooden slatted pens. Five one and half year old male sheep were selected on the basis of uniformity in live weight, averaging 23kg. The sheep were housed in individual pens, with approximate sizes of 1.5m by 1.5m by 2.0m mounted on the concrete floor of the wooden animal house.

4.2.3 Experimental diets.

Three different experimental fodders comprising of napier grass, *Tithonia diversifolia* and *Sapium ellipticum* fodders were fed to the sheep. The feed materials for both *Tithonia* and *Sapium* were initially cut as green fodder and then dried under shade. After drying, the leaves and twigs were separated from the stems, and then the materials were kept in gunny bags (100kgs) and put in a well ventilated store. Napier grass forage for feeding every day was cut a day before from a near by farm and then kept next to the metabolic crates. A sample of each fodder type was taken before feeding. The amount of *Tithonia* and *Sapium* to be fed every day, was weighed a day before using a weighing balance (Ohaus™).

Tithonia and *Sapium* were fed as hay while napier grass was fed as wilted green chop. Napier grass was chopped every morning into small pieces of 1 - 2 inches using a chaff-cutter. The three types of fodder were fed separately in three marked containers firmly fixed on the timber of the metabolic crates. However, in order to prevent the sheep from getting used to a particular feed the position of the containers was interchanged every morning. The plastic containers had a capacity of five kilogrammes. Each sheep was allowed to choose its preferred diet among the three test diets. All feeds were presented to all the sheep simultaneously at 8.00 am. The test diet was topped up whenever the level in the container was too low to be accessible to the sheep. The amount eaten by every sheep was recorded as the feeding progressed. The sheep were allowed to feed for a period of four hours in the morning (Kalio *et al.*, 2006). The feed refusals from the three diets were then removed and emptied into labeled khaki papers and weighed using a weighing balance (Ohaus™) and a sample taken for drying in an oven set at 60^0c.

The feeding study lasted a period of ten (10) days. The first five days were allowed to adapt the sheep to the crates and the feed and samples and feeding data was collected in the last five (5) days.

4.2.4 Laboratory analysis.
Feed on offer and refusal Samples submitted to the laboratory were analyzed for Dry matter, Crude Protein, and ash using standard proximate analytical methods (AOAC, 1990). Neutral Detergent fiber, Acid Detergent fiber, Acid Detergent Lignin, were done as described by (Van Soest et *al.*, 1991).

4.2.5 Data management and analysis.

The amount of each fodder type on offer to all the five Corriedale sheep and refusals was recorded over five days. The feed intake by the five sheep was determined by subtraction. The average daily feed intake for each test diet and each sheep was calculated over the five days. The intake of the three types of fodder was assessed using one way analysis of variance.

4.3 Results and Discussion.

4.3.1 Chemical composition of the fodder under test.

The dry matter of a feed indicates the form in which the feed was offered. The wilted napier grass fodder was offered as green chop with a DM content of 13.6%. *Sapium* and *Tithonia* forages were fed as hay with a dry matter content of 85.2% and 89% respectively (Table 4). The Crude protein for the three fodders (wilted napier grass, *Tithonia* and *Sapium*) was 4.29%, 20.7% and 11.8% respectively. The ash content for the three fodder species, wilted napier grass, *Tithonia* and *Sapium* was 10.2%, 16.24% and 7.06% respectively (table 4). The ash component describes the inorganic elements in feedstuffs required to facilitate body metabolism such as nutrient assimilation and could consequently improve on the intake of the forage materials.

Table 4: Nutrient composition of napier grass, *Tithonia* and *Sapium* fodder fed to sheep during the preference study.

Diets	Napier grass	*Tithonia* fodder	*Sapium* fodder
Dry matter, %	13.60	89.00	85.20
Crude Protein, %	4.29	20.70	11.80
Neutral Detergent fiber, %	80.10	33.57	39.52
Acid Detergent fiber, %	43.58	27.98	22.35
Acid Detergent Lignin, %	6.12	11.30	8.87
Ash , %	10.20	16.24	7.06

KEY: NDF -; ADF -; ADL -; ASH

Napier grass is low in protein and as such should be supplemented (Muia, 2000). The Crude protein of napier was quite low compared to the Crude protein of *Tithonia* and *Sapium* and this likely contributed to less preference than was expected despite the fact that it was fed as green chop.

Grasses like napier grass need to be supplemented with protein rich forages because the pasture Crude protein levels are usually inadequate. Crude protein contributes generally to the acceptability of a feed.

Indigenous fodder are known to contain high level of Crude protein due to their deep rooted characteristics that stabilize Crude protein levels across seasons and age unlike that of grasses (Roothaert *et al.*, 2001). The mineral content of ash in forages is a direct reflection of the mineral content of the soil they are grown on. Macro-elements of practical significance to ruminants such as sheep are Calcium, Phosphorus, Sodium, Chlorine and Magnesium. However supplementation of these minerals is generally required because most fodders have inadequate amounts (Wambui, 2005). Forage intake is modified by its quality in addition to energy demands.

Intake of ruminants foraging on low quality forages (below 50% digestibility) appears to be limited by bulk fill. When Neutral detergent fiber levels of the forage are above 60%, digestibility decreases, slows down the rate of passage and subsequently reduces forage intake. On the contrary lower NDF content is correlated to higher forage digestibility and rate of passage allowing greater intake (Van Soest *et al.*, 1991). In this study the NDF levels for the three fodder species, wilted napier grass, *Tithonia* and *Sapium* fodder were 80.1%, 33.57% and 39.52% respectively (table 4). The high NDF levels of wilted napier grass influenced a decrease to the rate of passage which limited its preference. Feeds that are least preferred in times of abundance and variety, such as *Tithonia* forage, could be relished during periods of scarcity and severe feeds shortages, based on animal survival instinct (Ngwa *et al.*, 2003). The intake of all the three diets fluctuated during the five days of the sample collection probably because the sheep aimed at balancing their protein requirements which were different each day.

The Acid detergent fiber levels for the three diets, wilted grass, *Tithonia* and *Sapium* hay were 43.58%, 27.98% and 22.4% respectively (table 4). ADF reflects the fibrous portions of the feed resistant to acid hydrolysis. It represents the cell wall materials that also account for the lignin and silica and imply a limitation to nutrient availability to the animal. The difference between the NDF and ADF of a feed may show the proportion of the cell wall material that is degradable by the ruminants. The digestibility of forage is negatively related to both increases in ADF and lignifications levels. Forages at advanced maturity are characterized by high content of acid detergent fibers and lignin and low total nitrogen content. High proportion of the previous fractions are bound within the indigestible vascular bundles resulting to low digestibility, low nutrient intake and consequently low animal performance (Van Soest *et al.,* 1991). The ADL levels for the diets 1, 2 and 3 were 6.12%, 11.3% and 8.87%, respectively. Though the DM intake of roughages is inversely proportional to the filling capacity and NDF concentration, this does not seem to be the case when ruminants are offered more than two feeds that vary in chemical composition as was the case in this study (Ngwa *et al.*, 2003).

4.3.2 Dry matter intake.

Dry matter is an important factor since it is an indication of the feed nutrient ingested. Intake and comparisons of the experimental diets are shown in table 5a and b.

Ruminant's dry matter intake level depends on parameters which are related to the animal or to the diet. Independent of the quality of the forages, ruminants prefers vegetable fractions with a high leaf to stem ratio, with a low fiber and high nitrogen content. It has been observed that they are sensitive to substances such as tannins. The most important factor influencing performance of ruminant animals consuming forages diets is dry matter intake (Wilson *et al.*, 1991). The average daily intake for wilted napier grass fodder, *Tithonia* and *Sapium* hay in kg/DM was 0.26, 0.11 and 0.18 respectively. Each sheep was taking an average of 0.56kgs DM per day which was about 2.4% of their body weight (Wilson *et al.*, 1991). The sheep took two times more napier than *Sapium* and three times more than *Tithonia*. The difference of napier taken was not significant (table 6a and b). All the three forages were accepted by the sheep although at different acceptance levels. The factors discussed below could have contributed to a higher preference of napier.

The effect of past experience did not contribute much to the preference since the sheep had been allowed to adapt to the other two fodder species for five days. The daily intake tended to increase from the first day of recording upto the third day. Thereafter the daily feed intake decreased possibly due to the satiety process of ruminants (Smith *et al.*, 2001).

Table 5a: Mean Napier grass, *Tithonia* and *Sapium* fodder intake (kg/DM) over the five day preference feeding trial.

Day of intake recording	Wilted Napier grass fodder (13.6%DM)	*Tithonia* hay (89%DM)	*Sapium* hay (85.2% DM)
1	0.27	0.10	0.16
2	0.27	0.13	0.17
3	0.28	0.13	0.19
4	0.22	0.11	0.18
5	0.26	0.10	0.20
Average daily intake	0.26	0.11	0.18

Table 5b Analysis of variance of fodder and day of recording effects on fodder intake in Corriedale sheep fed three fodder alternatives.

Source	Df	Mean Square	F	Sig.
DAY	4	.002	.339	.850
FODDER	2	.113	23.150	.000
DAY * FODDER	8	.001	.267	.974
Error	56	.005		

R Squared = .472 (Adjusted R Squared = .340)

The preference for the three fodder species by the sheep in a decreasing order was wilted napier grass, *Sapium* and *Tithonia* (Kalio *et al.*, 2006). The fact that *Tithonia* was the least preferred in this study agrees with the findings of KARI, Embu research results of 1996 but contrast with Premaratne, *et al* (1998) when comparing the use of *Tithonia diversifolia* and *Leucaena leucocephala* and *Glicidia sepium* on ewes. Premaratne found out that *Tithonia* was the best preferred. The physical form in which a fodder is offered to the ruminants is important. Ruminants will generally discriminate dry and brittle fodder materials when they are given a chance to do so. Napier grass in the experiment was offered as a succulent green chop compared to the other two fodders which were offered as hay. The experimental animals probably found it easier to consume the former as compared to the later two. Ruminants will discriminate dustiness in the feed. *Tithonia* and *Sapium* forages had some levels of dustiness which probably denied the sheep quick acceptance as compared to napier grass which was relatively soft.

Ruminant's animals select some pasture plants and leave others. Some forage has been described as being more palatable than others. However, if variety and availability of forages is limited even the relatively unpalatable forages may be eaten. The sheep apparently selected more napier grass than *Tithonia* and *Sapium* since the former one was more succulent than the later two fodder species. The apparent ability of the ruminants to select the more digestible components of a diet is well known. The NDF and ADF levels of the three diets highly influenced the preference with wilted napier grass being affected most although its succulence status caused a bias in the choice.

4.4 Conclusion.

Napier grass, *Sapium* and *Tithonia* forages were preferred by the sheep in that order with an average daily intake in kg/DM of 0.26, 0.11 and 0.18 respectively. However the sheep consumed constant proportions of both *Sapium* and *Tithonia* probably to balance their protein requirements. This indicated that the two indigenous fodder species could be suitable supplements for napier grass particularly during the dry season.

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CHAPTER FIVE

DIGESTIBILITY OF DIETS BASED ON NAPIER, TITHONIA AND SAPIUM.

5.1 Introduction.

Tithonia or Mexican sunflower is a herbaceous plant, with characteristic yellow flowers, of the Asteracea (compositae) family originally from Central America (Wanjau *et al.*, 1998). In Kenya it is widespread in Central, Western Province and the wetter areas of the coastal and Rift Valley regions and adapts well to varied conditions of acidity and soil fertility. It is a robust shrub with fast growth to a height of three meters, can withstand intense pruning (Roothaert and Paterson, 1997) and has a high concentration of dry matter that prompts its use as a protein supplement.

Sapium ellipticum is an evergreen indigenous tree growing to fifteen meters tall with dropping branches, is widely distributed in lake shore regions like Lake Victoria in the Southern part of Uganda and is often found near rivers. *Sapium ellipticum* trees are also common in crop gardens and in forested areas. It is also common in fallow lands and farm boundaries (Sekatuba *et al.*, 2004). It is drought tolerant and reportedly very palatable to ruminants.

The two fodder species could be used to supplement napier grass fodder. However, there is little documentation on digestibility of diets that include varying proportions of either *Tithonia* or *Sapium*. Therefore, this study was carried out to compare the digestibility of diets consisting of varying proportions of *Tithonia* and *Sapium* forages with napier grass fodder.

5.2 Materials and methods.

5.2.1 Study Site.

The study was carried out at the KARI Embu Research Centre, Embu district, Eastern Province. The center is in a sub humid agro ecological zone and is located 1490 meters above sea level at $0^{\circ}30'$S and $37^{\circ}27'$E. The deep, well weathered with friable clay texture soils in the area are humid Nitosol derived from basic volcanic rocks and classified by USDA under humid patehumult. The rainfall is moderate, an average of 1200-1500 mm (Jaetzold and Schmidt, 1983). It follows a bimodal pattern with long rainy season from March to June amounting to an average of 750mm. The short rain comes from October to December and average 350 mm and month temperature averages $18-21^{\circ}$c.

5.2.2. Animal house.

Block B of the center had a metabolic unit with 16 male Corriedale sheep housed in individual wooden slatted pens. The metabolic init were wooden with raised and slatted floor subdivided into individual pens measuring approximately 1.5m by 1.5m by 2m mounted above a cemented floor.

5.2.3. Animals.

Fourteen (14) Corriedale rams aged 18 months selected for uniformity of live weight at 20±3kg were used in the experiment. The weight of the sheep was determined at the start and at the end of each feeding period.

5.2.4. Diets.

Seven different experimental diets comprising of varied proportions of napier grass, *Tithonia diversifolia* (*Tithonia*) and *Sapium ellipticum* (Muthatha) were fed. The composition of the diets was as shown in table 6.

Table 6: The ingredients Composition of the seven test diets (dry matter basis) containing napier, *Tithonia* and *Sapium*.

	Diet composition		
Diet Number	Napier, %	*Tithonia diversifolia*, %	*Sapium ellipticum*, %
1 (control)	100	-	-
2	75	25	-
3	50	50	-
4	25	75	-
5	75	-	25
6	50	-	50
7	25	-	75

5.2.5 Experimental design.

Feeding was done over four, fifteen (15) day periods. The sheep were adapted to the diets in question during the first ten (10) days of each feeding period for the adaptation, and samples were collected in the last five (5) days. The seven diets were randomly allocated to two sheep at the beginning of each period resulting in a completely randomized design (CRD) as shown in Table 7. Each diet was assessed with eight (8) animals during the feeding trail. During the five day collection period, daily feeds intakes and leftovers were measured and samples of feed on offer and refusals for each sheep were taken. The samples taken were dried at 60°c for 48 hours and milled to pass a 1mm screen and stored in clean grass containers for future analysis.

Total daily faecal output was measured for each sheep, pooled, mixed thoroughly and a 10% sample taken and stored as separate samples in a freezer (-20°C) for each experimental period. Similarly the 24 hours urine output from each sheep was measured, recorded, mixed and a 10% sample taken and stored as separate samples in a freezer for each experimental period. The five days samples for each sheep were pooled at the end of the experiment and a composite sample taken for each experimental period. Sub-samples of the faeces were taken, oven dried at 60°c to constant weight and ground (1mm mesh) for later chemical analysis. The DM for feed offered, refusals and faeces were obtained by oven dying at 105°C to constant weight. Ash of the feed offered was determined by igniting samples in the muffle furnace at 600°C for 5 hours (AOAC, 1990). The feed, faecal and urine nitrogen contents were determined by the standard micro Kjeldal method (AOAC, 1990). Neutral detergent fiber (NDF) and Acid detergent fiber (ADF) were determined by the procedures described by Goering and Van Soest (1970).

Table 7: Diets randomization within the four, feeding periods.

	PERIOD			
SHEEP NUMBER	1	2	3	4
1.	5	6	3	2
2.	6	3	7	1
3.	7	2	1	6
4.	1	4	2	7
5.	4	7	5	3
6.	3	5	6	4
7.	2	1	4	5
8.	6	4	5	1
9.	2	6	4	5
10.	7	1	6	2
11.	3	2	1	4
12.	5	3	7	3
13.	1	5	2	7
14.	4	7	3	6

5.2.6. Feeding.

The fodder types in diets 2-7 were thoroughly mixed together before feeding then placed in labeled 50 kilogram's gunny bags to minimize selection. Napier grass fodder was offered as fresh chop of about two to three inches while the two substitute forages *Tithonia* and *Sapium* were offered as hay from Leaves and twigs.

Two-thirds of the daily ration was fed in the morning at 9.00 AM and one- third in the afternoon at 3.00 PM to minimize wastage. A mineral block was availed ad-libitum to each sheep. Water was offered every morning at 10.00AM using a plastic container fixed in the metabolic crates. The animals were on these experimental diets for 60 days.

5.3 Data management and analysis.

Intake, faecal and urine outputs were recorded daily during the five day sampling period. The DM and the CP contents of the seven diets were established using proximate analysis. The DM of the dried samples was calculated after further drying the samples in the oven at 60°C and 105°C. NDF, ADF and ADL levels of the seven diets was established using the Van Soest analysis. Ash content was calculated by drying sample in the oven set at 105°C and burning the samples in the muffle furnace at 600°C. Apparent digestibility were calculated using the equation formula below.

$$\text{Apparent digestibility\%} = 100 * \frac{\text{Nutrient intake} - \text{Nutrient in feaces}}{\text{Nutrient intake}}$$

5.4 Results and discussion.

5.4.1 Chemical composition of the diets.

The dry matter content of the seven diets varied; with diet one having the lowest percentages 136g/kg while diet four had the highest dry matter 639g/kg (table 8). The DM content depended largely on the proportion of napier grass fodder fed. The dry matter content of the substitute diets increased with the level of inclusion of other feedstuffs. *Tithonia diversifolia* forage produced diets that had greater dry matter content than *Sapium ellipticum*. Napier grass fodder (control diet) had the lowest CP percentages of (43g/kg) while 75% *Tithonia* mixture (diet 4) had the highest CP of 189g/kg (table 9). The CP levels for the diets increased with increase of either *Tithonia* or *Sapium* forages as the hay had higher levels of CP than napier grass. Leaves and twigs from trees and shrubs have crude protein content ranging from 12-30% which is usually higher than that of mature grasses 3-10% (Le Houerou, 1980). Crude protein value of 8% is considered absolute minimum needed to maintain rumen function. The nutritive value of browse trees and shrubs varies with soil type, location, plant part (leaf and stem), age of leaf and season. The latter factors influence the forage chemical composition, palatability, intake, the extent and the rate of degradation, digestibility and the nutrient utilization by ruminants (Kaitho, 1997). In this study the shrub/tree hay was collected from the same area, dried under similar conditions and mixed randomly while mixing the substitute diets thus largely minimizing variability in the fodder used.

Table 8: Nutrient composition for the seven diets containing 3 three levels of *Tithonia* and *Sapium* fodder g/kg DM (Dry matter basis).

Diet Mixture	DM, g/kg	CP, g/kg	NDF,gKg	ADF g/kg	ASH g/kg
All Napier grass fodder diet (D1)	136.0	42.90	800.01	436.0	111.1
25% Tithonia hay-75% napier grass fodder (D2)	417.7	124.10	641.2	365.50	141.1
50% Tithonia hay-50% napier grass fodder (D3)	512.3	143.40	591.7	311.50	145.8
75% Tithonia hay-25% napier grass fodder (D4)	639.0	189.20	499.4	269.90	146.6
25% Sapium hay-75% napier grass fodder (D5)	351.0	62.90	705.7	409.40	97.7
50% Sapium hay-50% napier grass fodder (D6)	460.0	99.80	628.5	370.20	94.4
75% Sapium hay-25% napier grass fodder (D7)	522.0	100.80	541.8	285.50	80.0

5.4.2 Fiber and ash proportions of the diets.

The insoluble cell wall fraction of forages consists of cellulose, hemi cellulose, lignin and silica and in the detergent analytical method forms the NDF (Van Soest *et al.*, 1991). NDF has been shown to be negatively correlated with dry matter intake in that as it increases, animals tend to reduce their dry matter intake. NDF levels increase with the advancing maturity of the forages (Van Soest *et al.*, 1991). Grasses with content of NDF above 60% DM for grasses are classified as poor in quality (Van Soest *et al.*, 1991). The *Tithonia* based diets had lower NDF-ADF proportion of 276g/kg, 282g/kg and 229.5g/kg than those of *Sapium* based diets with 296g/kg, 258g/kg and 256g/kg. The ADF levels decreased with increase in substitution of napier grass with either *Tithonia* or *Sapium*. The ADF component has been shown to be negatively correlated with the digestibility of forages (Van Soest *et al.*, 1991). It is then expected that either *Tithonia* or *Sapium* based diets had higher digestibility as the NDF and ADF values of the diets decreased with substitution. *Tithonia* based diets had higher Ash content than the other four diets, originating from the high ash content in *Tithonia* and were possibly an indication of high concentrations of minerals desired by animals (Kwabiah *et al.*, 2003).

5.4.3 Feed Intake.

During the time of the sample collection (five days), an assumption was made that all sheep were adapted to the three feedstuffs. Data on feed intake is presented in table 9. The amount of herbage a sheep can consume on daily basis is approximately three percent (3%) of its total body weight and feed offered was calculated slightly above this rate (Personius *et al.*, 1987). Feed intake in ruminants is determined by a combination of three factors, namely: nutritive value of the feed, voluntary intake and selectivity ability. Diet 2 had the highest intake with 0.6kg DM while diet 7 had the least intake with 0.4kg DM per sheep per day. Intake decreased with substitution of napier grass fodder with either *Tithonia* and *Sapium* hays. Intake of *Tithonia* based diets was higher than that of *Sapium* diets possibly because of the lower NDF-ADF proportions compared to those of *Sapium* fodder (table 9). Contrary to the expected results the substituted diets failed to meet the expected acceptance level though they had lower crude fibers and also higher CP than napier grass diet. This maybe due to the tender nature of the green chopped napier compared contrast to the other two fodder species which were fed as hay. Drying may have resulted in loss of structural carbohydrates and hence decreased palatability (Norton, 1994). Fresh napier grass could have been more easier to masticate and consequently to digest than the hay from *Tithonia* and *Sapium*. Therefore, feeding the fresh napier grass or the two fodder species as hay made significance differences in terms of dry matter intake. Roothaert (2000) has reported that approximately 19% of the total DMI is the maximum proportion that ruminant animals (heifer) will consume of *Tithonia*. This offers farmers flexibility in terms of feeding strategies, as they can feed the browse in the form that suits their situation.

5.4.4 Faecal material output and urine output.

The average faecal output per sheep per day decreased as the level of napier grass decreased in all the six diets (table 9). However proportionately, faecal output increased with substitution of napier grass with either *Tithonia* or *Sapium* to

the effect that diets with lower intake had proportionately higher faecal output. Concurrently the sheep urine output increased with substitution of napier grass. This was not surprising seeing that the sheep would have needed to take more water to facilitate degradation of the hay feed in the rumen. It is likely that the extra water intake increased the bulk of the digesta and consequently the rate of passage resulting in proportionately more faeces. If this was the case, there should have been a corresponding increase in intake. As this was not observed, it can only be assumed that the supplemented fodder had some unexplained and unappetizing constituent.
Sheep normally produce reasonable dry faeces. The resulting increase of water absorbed in the rectum during pellet formation directly related to the proportionate increase in urinary output.

As the level of inclusion of *Tithonia* and *Sapium* in feed mixtures increased, the faeces became drier and brittle causing a demand for more water by the sheep for the purposes of digestion. However, the dry material in the rumen absorbed water only proportionately to the intake. This explains why the average overall quantity of urine decreased with napier grass substitution while proportionately to intake more urine was shed.

The differences in N intake observed between animal species and level offered are largely due to fodder species differences in N content, since animals consumed most of the leaves on offer. However the large differences observed among the shrubs and trees species for faecal and urine excretion are more to do with the differences in rumen degradability of the N in these species. Drying at temperatures as low as 55^{0}c may cause irreversible locking of nutrients in leaves of the two fodder species (Hove *et al.*, 2003). It is important that sample preparation for digestibility studies are carried out to approximate the practical feeding situation to allow for more accurate prediction of the nutritive value of the shrub forages. The lack of significant effects of the status of browse (fresh or dry) on digestible dry matter intake and N retention is desirable because it offers farmers flexibility in terms of feeding strategies. Farmers may use the shrubs depending on their farm situation, in the dry or fresh state without compromising the value of the leaves as protein supplements. It is, however, important to note that similarity in value between fresh and dry leaves intake could be different at higher levels of browse inclusion.

5.4.5 Digestibility coefficients.

Average digestibility coefficients for the seven diets are presented in (table 10a) and the summary ANOVA of their comparison in (table 10b). The digestibility of the dry matter for all diets decreased with an increase in the level of inclusions of the substitution diets. Diet two had the highest digestibility coefficient for dry matter (72.3%) amongst the seven diets while diet seven had the lowest (56.5%). The digestibility coefficient of the CP was lowest in diet 1 (52.6 %) while the digestibility coefficient for CP was highest in diet 2 (81.6%). A general increase of CP digestibility coefficient for all the diets was observed with the napier grass fodder supplementation of *Tithonia* and *Sapium*. The increase was highest with the 25% replacement followed by a gradual decline to a low of 55% for 75% replacement for the *Tithonia* diets.

Table 9: Average Dry matter feeds intake (kgs), faecal output (kgs) and urine (Litres) for sheep offered.

	Feed Intake/ sheep/day	Faecal output/sheep / day	Faecal output/Intake %	Urine output/ sheep/ day	urine/intake %
All Napier grass fodder diet (D1)	0.588 a	0.18 a	32.9	0.111c	18.5
25% *Tithonia* hay-75% napier grass fodder (D2)	0.594 a	0.201	32.7	0.125 bc	25.7
50% *Tithonia* hay-50% napier grass fodder (D3)	0.545 b	0.183	32.6	0.158 ab	24.7
75% *Tithonia* hay-25% napier grass fodder (D4)	0.388 d	0.174	43.4	0.139 abc	30.9
25% *Sapium* hay-75% napier grass fodder (D5)	0.567 ab	0.196	33.9	0.171 a	29.5
50% *Sapium* hay-50% napier grass fodder (D6)	0.505 c	0.191	36.9	0.122 c	23.6
75% *Sapium* hay-25% napier grass fodder (D7)	0.383 d	0.187	47.3	0.119 c	30.1
SED	0.029	0.017		0.036	

Means with different superscript in the same column differ significantly (P<0.05)

The level of inclusion of *Tithonia* and *Sapium* supplied the required nitrogen for microbial action for the rumen for the breakdown of the digesta (Devendra, 1988). However the decline in DM and CP digestibility coefficient could be attributed to the formation of indigestible complexes with unidentified compounds within *Tithonia* and *Sapium* fodder thus rendering the nutrients unavailable (Smith *et al.*, 1995). The napier fed during the experiment was over grown. Crude protein digestibility for grasses is reported to range between 53-58% at 3 wks to 8 wks (Mpairwe *et al.*, 1998). Therefore the levels of CP digestibility observed in this study were within range.

A number of factors are known to influence digestibility. Among them are such feed factors as chemical composition, feed preparation and level of feeding. Among the animal factors are animal age, metabolic needs, water availability and feeding behavior (Dicko *et al.*, 1992). The arrangements in this study strategized to minimize selection. Napier grass fodder was chopped to the size of *Tithonia* and *Sapium* hays components. This was meant to ease the process of mixing and consequently reduce variability in intake and digestibility. Thus other than for the test parameters, the feed preparation was fairly uniform with thorough mixing of the various ingredients to reduce selection variability. The animals were of the same species, age, sex and weight. They were all given the same watering regime. The digestibility of the six diets were hence only influenced by the levels of inclusion of the three individual feedstuffs. Variability in intake and digestibility must then be associated with dietary factors. Selection skills in sheep are well documented (Personius *et al.*, 1987). It is still probable that the intake of some components of the diet on offer were preferred. It was not possible to demonstrate that this was the case in the experiment. Indeed the data showed clear pattern of intake and digestibility that could be attributed to the chemical nature of the diets on offer (table 8, 9,10a and b).

5.4.6 Nitrogen Balance.

Nitrogen balance simply refers to amount of dietary nitrogen retained in the animal's body. A positive nitrogen balance is a condition whereby the total daily amount of the ingested nitrogen is larger than the total amount of excreted nitrogen while a negative nitrogen balance indicates inadequate nitrogen intake. Nitrogen balance is influenced, in addition to dietary factors, by age, species, and the previous state of nutrition in ruminants. Faecal nitrogen as determined in digestibility trials is compounded by endogenous excretion of nitrogen that comes in from spent mucosal cells and enzymes. These are themselves not constant activities and are affected by the nature of the diet and health status of the animals fed.

Diets 1, 5 and 7 reflected a negative N balance (table 11). These were the napier grass control diet and the 25% and 75% supplementation of *Sapium* diets. *Tithonia* based diets yielded positive nitrogen balance. Loss of N through urine was low for all the treatment diets. Muia, (2000) suggested that protein supplementation improves growth and nitrogen balance in animals. Therefore the positive balance experienced in the diets of *Tithonia* was occasioned by the high protein content (20.7%) of *Tithonia diversifolia* foliage. The nutritional value or quality of a given protein depends upon its content of the essential amino acids and its digestibility.

Table 10a: Mean apparent digestibility coefficients (%) and nitrogen balance (g/day) for the different components analyzed for the seven diets.

Dig. Coefficients	Diets							
	1	2	3	4	5	6	7	SEM
DM	69.8	72.3	67.5	60.8	69.0	66.3	56.5	2.1
CP	52.6	81.6	77.4	74.9	80.9	78.0	55.2	3.6
NDF	69.8	70.2	65.0	58.3	67.7	62.8	49.1	2.5
ADF	67.9	68.6	58.9	52.0	66.9	62.4	38.2	2.6
ASH	60.5	69.8	64.2	50.4	54.5	58.6	28.9	3.5
Nitrogen balance	-4.64	4.26	4.77	8.61	-3.82	6.48	-3.24	1.45

Table 10b: Analysis of variance for Mean apparent digestibility coefficients for the different components analyzed for the seven diets.

	Df	Mean Square	F	Probability
DM	6	243.7	6.78	.000
CP	6	1157.8	10.05	.000
NDF	6	454.8	8.65	.000
ADF	6	966.0	15.92	.000
ASH	6	1397.7	11.37	.000

Diets constituted from *Tithonia* forages had significantly high CP digestibility coefficients (81.6%, 77.4% and 74.9%) as compared to those of *Sapium* (80.9%, 78% and 55.2%). Probably all the *Tithonia* constituted diets with high digestibility coefficients also provided all the essential amino acids in the right proportions and thus the amount of the ingested nitrogen was larger than the total amount of excreted nitrogen. For *Sapium* constituted diets only diet six yielded a positive nitrogen balance confirming the fact that the CP level was the major factor in determining the nitrogen balance. The negative nitrogen balance experienced in the diet one could have been caused by the low CP of 4.29% that was below the limiting level of 6-8% and consequently a low apparent digestibility coefficient of 52.6%. The negative nitrogen balance experienced in *Sapium* diets five and seven could be as result of low CP levels (6.29% and 9.98%) respectively. These two diets had CP levels considerably lower than those of *Tithonia*. The drying effect of *Sapium* fodder could have affected the *Sapium* diets probably more negatively than the *Tithonia* forages since *Sapium* is reported to have higher tannin levels than *Tithonia* fodder (Sekatuba *et al.*, 2004). However *Tithonia* masked the effect of drying because it is very low in tannins. The implication of negative nitrogen balance is that the experimental sheep would break down tissue protein to meet demand of amino acids required for normal metabolism.

5.4.7 Conclusion.

Tithonia fodder has a CP and ADF value of 20.7 % and 27.98%, while *Sapium* and napier grass have 11.8% and 4.29%, and 22.35% and 43.58% respectively. Inclusion of both *Tithonia* and *Sapium* fodders caused a decrease in feed intake, total faecal production and total urine output for all the diets although

Table 11: Nitrogen Balance (g/day) for sheep fed seven diets in four periods of a feeding trial.

	Diets							
Chemical component	**1**	**2**	**3**	**4**	**5**	**6**	**7**	SEM
Dietary crude protein	4.29	12.41	14.34	18.92	6.29	9.98	14.32	0.000
Dietary Nitrogen	0.69	1.99	2.29	3.03	1.01	1.6	2.29	0.000
Total nitrogen in faeces and urine	11.50	15.60	18.17	21.67	13.88	16.4	19.21	1.47
Nitrogen balance	-4.64^{d}	4.26^{c}	4.77^{c}	8.61^{a}	-3.82^{d}	6.48^{b}	-3.24^{d}	1.47

Nitrogen balance Means with different superscript differ significantly ($P<0.05$)

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CHAPTER SIX

6.0. General Discussion.

Basal feeds for ruminants in Eastern, Central and Western Province areas are mainly napier grass fodder and crop residues such as maize stover and bean haulms. Napier grass fodder production declines during the dry season. In addition, its nutritional value, especially crude protein, also declines drastically during the dry season. Maize stover and bean haulms are used to bridge the feed supply gap during this season. But these crop residues are characterized by high lignifications and low nitrogen levels and therefore insufficient nutrients for maintenance requirements for ruminants if fed a lone. They are hence only used to supply bulk and sustain the ruminants until the next rainy season (Chileshe and Kitalyi, 2002)

Tithonia and *Sapium* fodder species are abundant in Central and Eastern parts of Kenya. Fodder obtained from indigenous trees and shrubs have extensively been utilized for improvement in animal production in terms of milk, meat, income and wool. The importance of trees and shrubs cannot be underrated especially in the harsh periods of the year when napier grass and other grasses are scarce and of poor quality. The crude protein for most indigenous trees and shrubs varies between 12-30% and is usually higher than that of napier and other grasses which varies between 3-10% (Norton, 1994). The crude protein for *Tithonia* was 20.7% and was within the range of 12-30%. This high level of CP could boost the nitrogen in the low quality basal diet thus increasing feed intake and digestibility in the ruminants. These fodders also have low NDF contents within the range of 20-35%. Fodder trees and shrubs such as *Tithonia* and *Sapium* are large biomass producers, although little documentation of this ability is available in literature. There is little scientific research on them (Brewbaker, 1986). The biomass estimation for the two local fodder species justified their suitability as potential supplement for napier and other grasses during the dry season when most grasses quality and quantity declined (Chapter three). *Tithonia* and *Sapium* have unexploited potential as fodder species because in the past their nutritional and chemical composition was unknown (Roothaert, 2000) as compared to the well known exotic fodder species such as *Leucaena Leucochephala* and *Calliandra calothyrsus*.

The potential biomass yields for *Tithonia* fodder though influenced by shade was not fully estimated since the fodder plots were harvested before *Tithonia* achieved its full height and age. Even so cutting of *Tithonia* after 10 weeks of growth yielded up to 88.4 tonnes/ha per annum. In Kenya the highest dry matter yields of napier was 28.5tonnes/ha/year recorded in Kakamega within a cutting intervals of 7 weeks. Therefore the biomass yields harvested from *Tithonia* is significantly higher than that of napier grass. *Tithonia* unlike napier has a high tillering ability which requires high levels of management for it to produce any biomass. Likewise, stripping of *Sapium* after 13 weeks of growth yielded 0.7 tonnes of fodder per hectare per annum. Increased dry matter yields for *Tithonia* fodder resulted from additional tiller and leaf formation, leaf elongation and stem development (Akinola *et al.*, 1971). *Tithonia* produced higher amount of biomass than *Sapium* possibly because of its characteristic aggressive spread in its environment. *Tithonia* has also shorter coppice regrowth period than *Sapium*. *Tithonia* biomass produced in this study was lower than that reported by Roothaert, 2000 but lies within the range reported by (Wambui, 2005). It is generally agreed that with delayed cutting there is a corresponding increase in the total dry matter yields and increase in height is a reflection of dry matter yields (Wilson *et al.*, 1991). It was observed in this study that *Tithonia* stem height of 12.3cm (4 weeks) corresponded to dry matter yields of 4.6 tonnes/ha, while *Sapium* twig height of 42.8cm corresponded to a dry matter yields of 0.5 tonnes/ha.

Tithonia and *Sapium* fodders had similarities on the effect of leaf to stem ratios and stem height changes with the cutting period. The leaf to stem ratio at the fourth week of 10 corresponded to stem height of 12.3cm for *Tithonia* fodder while *Sapium* stripping height of 42.8cm corresponded to a leaf to stem ratio of 1.6. For both *Tithonia* and *Sapium* the leaf to stem ratio decreased with a corresponding increase in fodder maturity. The decrease in leaf to stem ratio could have been triggered by shading of the lower leaves resulting from greater senescence of lower leaves, as well as reduced photosynthetic efficiency above the cutting height. The decrease in leaf to stem ratio for *Tithonia* was more drastic for the fodder under the shade than under the sun a factor that could have been attributed to the faster stem elongation. However, the leaf to stem ratio for both plots under the shade and the sun were similar at the 10th week of cutting (chapter 3). The decrease in leaf to stem ratio as the fodder species matured was more drastic in *Tithonia* with the values falling from 10.0 to 0.3 while that of *Sapium* dropped form 1.6 to 0.8. The slow leaf to stem ratio drop in *Sapium* probably contributed to its higher digestibility. Leaves have a higher digestibility than stems in mature fodders. Equally leaf to stem ratio is known to affect digestibility and chemical composition of fodders. It should be noted that as the plant matures the percentage of leaf declines due to stem elongation and also due to the death of older leaves. High leaf to stem ratio is desirable since it may improve fodder intake (Kariuki, 1989).

Sapium though with a smaller biomass productivity potential than *Tithonia* was more preferred by the experimental sheep than *Tithonia*, and hence a more promising fodder to ruminants than *Tithonia* (Kabirizi and Francis, 2005).

The high CP level and low NDF level of *Tithonia* could be the factor that attributed to the high digestibility coefficient from the *Tithonia* constituted diets (chapter 5) (Wambui, 2005). This is consistent with other studies (Larbi *et al.*, 1997) and maybe attributed to variations in Nitrogen, Phosphorous and condensed tannins among fodder species.

Tithonia and *Sapium* fodders studied in this experiment has a CP of 20.7% and 11.8% respectively. *Tithonia* and *Sapium* fodder hay in this study had dry matter content of 89% and 85.2% respectively. Their low moisture content provides them with an advantage over grasses in that they can be preserved for a longer time as hay. The CP value for *Tithonia* of 20.7% and DM of 89% in this experiment was comparable to that obtained by Wambui, (2005) of 22.15% and 88.23% respectively. The *Tithonia* fodder with 33.57% NDF and ADF of 27.98% was higher than that obtained by Wambui (2005) of 26.63% for NDF and 23.63% for ADF. Similar values of 20.6% and 24.7% of CP were reported by Kwabiah (2003) for *Tithonia* leaves respectively. These values differ with the results of 28% CP reported by Premaratne (1997). Concentrations of nutrients in *Tithonia* could be influenced by plant parts, age, and position of the leaves within the plant canopy, soil fertility and provenance (Jama, 2000). The low NDF of 33.57% for *Tithonia* falls within the range of 20 to 35% that was found to promote high digestibility of browse species (Norton, 1994). However nutritive value parameters derived from fodder species should be treated with caution since height is a function of climate and cultural practices. For example higher fertilizer and water application will lead to a high CP and dry matter yields. It should be noted that both *Tithonia* and *Sapium* are capable of producing high yields of DM but half or more of this is composed of inedible stems which is particularly noted when the two fodder are cut and dried as it was in the case of this study. It is therefore important to ascertain the best cutting period that balances both the amount of leaves and stem since it is widely known that digestibility of any fodder material declines with its maturity.

Tithonia and *Sapium* fodder dried hay in this study were stored dry without rotting. It is known that spoilage in ensiled napier grass is attributed to its high moisture content and this rule out hay making from napier grass (Wilson *et al.*, 1991). Napier grass has a high moisture proportion during the early growth and the dry matter percent is between 12-18%. Aging and maturation of napier are two known factors that are inversely related to digestibility. Advancing fodder maturity is accompanied by an increase in dry matter contents. Increase in structural components of the plant cells partly explains the gradual decline in the herbage quality with napier grass maturity (Kariuki, 1989)

Both *Tithonia* and *Sapium* constituted diets (2, 3,4,5,6 and 7) provided a CP that was above the critical protein levels for optimum microbial activity of 7-8% (Milford and Minson, 1967). The CP values of diets 2,3,4,5,6 and 7 affected positively the digestibility of the diets and subsequently influenced the dry matter intake. This acceptable CP content for the diets tends to suggest that *Tithonia* and *Sapium* can be potential protein supplements for ruminants especially when napier grass or other grasses are offered. The feeding value of a fodder species defined as animal output per unit intake of digestible DM is a function of both the quantity and quality of fodder on offer production.

6.1 CONCLUSIONS.

1. To maximize annual dry matter yields from both *Sapium* and *Tithonia* forages the recommended cutting intervals should be between 10 and 13 weeks of growth, respectively.
2. *Sapium* and *Tithonia* were accepted by sheep in varying but sufficient quantities to balance the protein requirements of the animals, thus they are suitable forages to supplement grasses.
3. Increasing inclusion of *Tithonia* and *Sapium* forages in sheep rations, reduced feed intake, faecal, urine output and apparent digestibility.
4. Supplementation with *Tithonia* diets raised the nitrogen balance to a positive level against the negative nitrogen balance realized by napier grass fodder and rations supplemented with *Sapium.*

6.2 Recommendations.

Tithonia and *Sapium* should be harvested, dried and stored as hay for dry season feeding to supplement declining quantity and quality of conventional fodder.

6.3 Further research

A. Rumen degradability studies should be carried out on *Tithonia* and *Sapium* hay.
B. Preference and utilization studies on fresh green and succulent *Tithonia* and *Sapium* forage should be investigated.

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