EVALUATION OF TWO NAPIER GRASS CULTIVARS (*PENNISETUM PURPUREUM*) UNDER IRRIGATION AT DIFFERENT STAGES OF GROWTH

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DECLARATION

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

JOHN NDIRITU KARIUKI

This thesis has been submitted for examination with our approval as University Supervisors.

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DR. AGGREY ABATE

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ABSTRACT

Two commonly used napier grass (*Pennisetum purpureum*) cultivars, Bana grass and French Cameroon were grown under irrigation to assess the changes in nutritive value at different stages of growth in Naivasha, Kenya. The experimental design was a split-plot with cutting stage (subplot) nested within variety (main plot). There were three replications per treatment. The response variables were evaluated at 4, 6, 8, 10, 12 and 14 weeks of age.

Dry matter yields and grass height at cutting ranged from 1.24 to 10.01 tons/ha and 22.11 to 189.99 cm respectively and significantly ($P<0.05$) increased with age. The differences between the cultivars for the two parameters were not significant ($P>0.05$). The leaf:stem ratio declined ($P<0.05$) with age but the differences between the cultivars were insignificant ($P>0.05$). The variations for leaf:stem ratio ranged from 5.03 at 4 weeks to 0.53 at 14 weeks of age.

Considerable changes ($P<0.05$) were observed in CP, ash and carbohydrate contents as the napiergrass matured. Crude protein decreased ($P<0.05$) from 14.84 to 3.98% while CF and NFE ranged from 23.39 to 39.01% and 33.74 to 39.86% respectively. Ash and EE contents decreased ($P<0.05$) from 26.41 to 15.75% and 3.42 to 1.49 at

4 and 14 weeks respectively. Ash, crude fibre and NFE increased ($P<0.05$) as the grass matured but the variation between the cultivars was insignificant ($P>0.05$). The dry matter percent varied from 15.81 to 17.70% and significantly ($P<0.05$) increased with age. Although French Cameroon had consistently lower DM values, varietal differences were insignificant ($P>0.05$). Calcium and phosphorus levels decreased from 0.39 to 0.30% and 0.31 to 0.21% at 4 and 14 weeks of age respectively. The effect of both age and variety for these two components were however statistically insignificant ($P>0.05$). Potassium levels were high and ranged from 11.70 to 4.21%. Although these levels decreased significantly ($P<0.05$) with age, varietal differences were insignificant ($P>0.05$).

The detergent fibres NDF and ADF increased ($P<0.05$) with age and rose from 54.44 to 72.68% and 25.97 to 42.00% respectively. Lignin (ADL) increased ($P<0.05$) with age and ranged from 2.26 to 5.77 from 4 to 14 weeks. Varietal differences in these constituents were not evident . Silica levels increased ($P<0.05$) with age from 4 to 14 weeks ranging from 4.07 to 6.67% respectively with Bana grass variety showing correspondingly higher ($P<0.05$) values.

Dry matter and organic matter digestibility *in vitro* decreased ($P<0.05$) with age from 72.04 to

58.30% and 75.72 to 62.22% respectively but the varietal differences were insignificant ($P>0.05$). The nylon bag dry matter loss *in sacco* increased ($P<0.05$) with increase in incubation time and was higher ($P<0.05$) the younger the napier grass. The ranges were from 71.09 to 27.57% at 72 and 12 hours of incubation respectively.

Significant ($P<0.05$) differences were observed in grass height, ash and percent dry matter with changes at cutting age. Silica content increased ($P<0.05$) with increased maturity and differences between the varieties were significant ($P<0.05$). However, it was concluded under the conditions of the experiment that dry matter yields, *in vitro* and *in sacco* DM digestibility, CP, CF, EE, NFE, detergent fibres, lignin and the minerals studied varied with the stage of cutting although varietal differences were insignificant ($P>0.05$).

1.0 INTRODUCTION

Dairy farming is an important enterprise in Kenya and constitutes about 11% of the nation's cattle herd (Anon., 1981). Due to rise in human population, farm sizes have decreased in dairying areas with less land being allocated for pasture and more for food crops (Jaetzold, 1983). Needless to say, an increase in human population will mean an increased, demand for milk. The dairy cattle, therefore, must be adequately fed in terms of both quantity and quality to meet the rising milk needs and one of the options open is the use of high yielding fodders.

Napier grass (*Pennisetum purpureum*) is already established as a popular fodder plant for the small-scale farmers in Kenya and is the most widely grown (Chuldleigh, 1974; Goldson, 1976; Potter, 1985). The main reason for its adoption is its high yields, ease of harvesting and the fact that it retains good quality longer (Mwakha, 1972; Odhiambo, 1974; Thomas, 1976; Van Gastel, 1978; Boonman, 1979 ; Karanja, 1981).

Although thirty to forty types of napier grass have been tested in Kenya (Anon., 1985a) studies have been restricted to a few cultivars, Bana grass and French Cameroon being the two major ones. Over the last 15 years, however, seemingly contradictory data as to the superiority of Bana grass over French Cameroon and the converse have been reported. This can be attributed partly to inadequate information on the two varieties as regards their nutritive value and utilization (Anindo and Potter, 1985). In practice, farmers feed the grass to animals at various stages of regrowth from one month to well over three months (Wouters, 1985) depending on animal needs and availability of other feed resources with little consideration being paid to nutritive quality. In addition there is insufficient information available regarding the best stage to harvest for optimum nutritive value and yield although maturity stage is known to affect both yield and chemical composition. Since the nutritive value of the fodder is greatly influenced by its stage of growth, herbage of different ages can be considered as different feeds. Therefore, to maximise the milk output from the dairy cow it is desirable to feed the forage at the stage of growth when both quality and quantity are optimum. The published work, from Kenya, relating the stage of harvest to chemical composition and digestibility both *in vivo* and *in vitro* is scanty.

To develop more information on the nutritive value of the two varieties and allow more effective utilization of napier grass this study was initiated with the following main objectives:-

1. To determine the effect of cutting

stage (regrowth stage) on chemical composition, dry matter yield, leaf:stem ratio and grass height at harvesting.

2. To study the *in vitro* digestibility and ruminal dry matter disappearance *in sacco* of the two varieties.

2.0 LITERATURE REVIEW

2.1 Origin and botanical characteristics:

Napier grass (*Pennisetum purpureum*) also called elephant grass is a native of tropical Africa (Bogdan, 1977; Karanja, 1984; Palacpac, 1985). It is widely grown in the rest of tropical world between 10^{0}N and 20^{0} S and to a lesser extent in the temperate areas. Original identification was done by Schumacher in the late 18th century as reported by Paterson (1933). It was first cultivated in Zimbabwe in 1890 and recommended as a fodder by the then Rhodesian Department of Agriculture in 1908 (Paterson, 1933).

Elephant grass is a robust, erect-stemmed perennial growing to a height of 2-6m (Bogdan, 1977; Gohl, 1981; Vancoppenol, 1983;and Palacpac, 1985) with upto 20 nodes per stem (Goldson, 1977). The grass grows in clumps spreading by stem bases and rooting from nodes or by short rhizomes. The leaves range from 30-120cm in length, 1-5cm in width and are glabrous or hairy. Mature napier grass forms large bamboo-like clumps. The panicle is only found at the end of the main stem and the branches. Flowers are normally narrow and 13-25cm long. Although most cultivars are capable of reproducing sexually, some cultivars are known to be apomictic (Bogdan, 1977). The grain is 2mm long (Bogdan, 1977 and Palacpac, 1985).

2.2. Cultivars

A large number of cultivars have been tested over a wide range of environmental conditions in Kenya. Most of these have been developed by the selection and propagation of local materials with desirable agronomic and nutritive value characteristics. There are differences in thickness of stems, size of leaves, hairiness of stems and leaf sheaths, general vigour, the size of tufts, the number of tillers and height of plant (Bogdan, 1977). These characteristics make elephant grass varieties easy to recognize and identify because they consist of one genotype only (Boonman, 1979).

In this country the most commonly grown cultivars of napier grass are Bana grass, French Cameroon and Uganda hairless (Wouters, 1986). Bana grass and French Cameroon predominate and have been studied most (Thairu and Tessema , 1987) although the information on chemical composition is scanty (Abate *et al*, 1987). Most of the studies have been on agronomic attributes rather than on nutritive value (Potter, 1985). Two other cross-bred types of napier grass namely, Pakistan napier and Clone 13, have gained prominence at one time or another. Pakistan napier (Bajra), a cross between napier grass and Bulrush millet

(*P. purpureum* and *P. typhoides*) has drought tolerance qualities but its adoption as a fodder has been hampered by its low dry matter yields, low leaf:stem ratio and a very fast growth rate which renders it stemmy too soon (Anon., 1985b; Wouters, 1985). Clone 13 was bred from French Cameroon and Bajra at Kitale, Kenya. Although this cultivar is resistant to the fungal disease, snow mould (*Beniowskia sphaeroides*), it has not been popular due to its low dry matter yields, poor establishment and reduced tolerance to drought conditions (Kusewa *et al*, 1983; Anon.,1985b).

Until recently French Cameroon was known as the " standard variety " (Goldson, 1977; Boonman, 1979). Among the reasons advanced for its popularity are; highest total yields, highest dry season yields, reduced hairiness, high clump density and relatively higher palatability compared to the other cultivars (Strange, 1959; Boonman, 1979). The cultivar has numerous relatively thin stems and narrow leaves (Bogdan, 1977). The leaves are almost hairless except on the leaf sheaths (Wouters, 1986). However, the cultivar is susceptible to snow mould (*Beniowskia sphaeroides*) particularly during the wet season (Boonman, 1979).

Bana grass has variously been referred to as Gold Coast, Potha Bana, and Ghana (Bogdan, 1977; Boonman, 1979 ; Wouters, 1985). Although Bogdan (1977) reported Bana grass as a hybrid between

Bulrush millet (*Pennisetum typhoides*) and napier grass (*Pennisetum purpureum*), tests done at Kitale, Kenya, demonstrated that Bana grass is a cultivar of napiergrass (Boonman, 1979). The grass has thick stems and both the leaf sheaths and leaves are covered with stiff hairs. The stems are relatively soft and some investigators have reported that it has higher dry matter intake compared to other napier grass varieties (Anon., 1985b). Bana grass has been valued for its high herbage yields, competitive vigour, persistence, palatability and good herbage quality (Anon.,1985a).

Bana grass and French Cameroon outyield Bajra, Uganda hairless and Clone 13 and hence their popularity over the latter (Boonman, 1979 ; Anon., 1985b ; Wouters , 1986).

2.3. Ecological requirements and cultural practices:

Napier grass can be planted in virtually all types of well drained soils but for high production, fertile soils are essential (Bogdan, 1977 ; Palacpac, 1985). It is an ideal crop for unirrigated lands and rolling hills (Palacpac, 1985). It grows well in a wide range of climatic conditions from sea level to well over 2000m altitude the upper limit being determined by its temperature requirements. Maximum growth is attained at between 30 and 35^{O}C and is greatly reduced at the range of 10 and 15^{0}C (Cooper and Tainton, 1968). The plant ceases to grow at temperatures below 10^{0}C (Bogdan , 1977). Elephant grass is more drought tolerant compared to other common pasture grasses (Bogdan, 1977).

Napier grass is mainly cross-pollinated and the resulting seeds of low genetic stability are few and give small and weak seedlings (Bogdan, 1977). Vegetative propagation is either by canes (stems) or root splits . The normal spacing is 0.5-1.0m within the rows and 1.0m between the rows (Goldson, 1977; Palacpac, 1985). The splits are planted upright with the roots below soil surface whereas canes are laid horizontally in furrows or slanting at an angle (Goldson , 1977). Canes in furrows are completely covered with soil while the slanting ones are partially buried.

Planting is done at the beginning of rains in the areas with well defined seasons or at any time where rains are continuous or under irrigation. Weed control is necessary to maintain high yields (Gosnell, 1963). The growth of elephant grass is affected by perennial grasses such as couch grass (*Digitaria scalarum*), stargrass (*Cynodon dactylon*) and Kikuyu grass (*Pennisetum clandestinum*). Gosnell (1968) corroborated general observations that the productivity of napier grass is greatly reduced by the presence of perennial grasses. This is in contrast to the work of Tiley (1960) who thought that napier grass controlled couch grass in Uganda. Despite the fact that napier grass is a large vigorous plant, it is highly susceptible to weed competition of all types and clean weeding is recommended to maintain good yields.

Fodder production in the tropics closely follows the seasonal rainfall pattern. Use of supplemental water for sustained plant growth during periods of water stress in the dry season has been suggested as a means of improving animal output. The cost of irrigation is however prohibitive to many farmers. It has been stated that for continuous production, at least 2-3 cm of water as irrigation or as precipitation is needed weekly for continuous forage production (Crowder and Chheda, 1982) and this is enhanced when nitrogen fertilizers are added (Rivera-Brenes *et al*, 1961; Osman, 1979; Koch, 1987). Water supply affects dry matter yields, percent crude protein, silica content, ash and nitrogen free extractives (Oyenuga, 1960).

In Kenya napier grass is rarely grazed. Rather, it is cut and fed fresh or occasionally conserved. Napier grass responds well to fertilizers especially nitrogen application (Bogdan, 1977; Goldson, 1977; Wouters, 1985).

2.4. Dry matter yields:

The dry matter yield of napier grass has been extensively studied in many parts of the world although yields have varied from one region to the other depending on varieties, climate, prevailing weather conditions, water supply, soil fertility cultural practices and cutting interval (Bogdan, 1977; Crowder and Chheda, 1982; Karanja, 1984).

In East Africa, dry matter yields of 10 to 40 tons/ha are often quoted (Goldson, 1977). A dry matter yield of 25 tons/ha/year was reported by Thairu *et al.*,(1968) in Kenya. Under good weather conditions, Ware-Austin (1963) estimated that yields of 15-20 tons/ha/year can be expected in Kenya and 25% of this yield is produced during the dry season. In a 1984/85 survey covering several districts in Kenya, the highest dry matter yield at farm level of 28.5 tons/ha/year was recorded in Kakamega with a rainfall of 1910 mm and cutting intervals of 7 weeks while Kilifi with a low annual rainfall of 612 mm recorded only 5.5 tons/ha dry matter in 542 days at cutting intervals of 18 weeks (Wouters, 1986). These findings show similar trends to others obtained from a countrywide trial encompassing 9 sites ten years earlier. The fertilizer rates applied were 50 kg P_2O_5/ha at planting and a nitrogen dressing of 40 kg N/ha after every harvest and the results obtained are shown in Table 2.1.

Table 2.1. Average annual yields of dry matter (tons/ha/year) over three year period (1975-77) in 9 locations in Kenya (Boonman, 1979).

Location	DM yields tons/ha/year Bana	French Cameroon	no. of cuts over 3 years	Rainfall (mm)	Mean temp (°C)
Kakamega	21.4	25.3	14	2000	20.1
Kisii	20.0	13.4	14	2180	19.3
Lanet	11.2	11.2	10	850	16.8
Embu	13.3	16.9	10	1100	20.7
Kitale	16.0	12.9	10	1186	18.2
Naivasha	10.4	11.6	10	660	17.3
Ol Joro Orok	10.0	7.5	8	1023	13.7
Eldoret	12.8	13.9	10	1189	15.5
Baraton	6.6	7.4	12	1500	17.4

Lanet and Naivasha stations recorded low yields and this could have been a result of low rainfall and high altitude which could have led to low temperatures. Similarly, Baraton and Ol Joro Orok had low yields despite the impressive rainfall data. These locations are at fairly high altitudes of over 2000m above sea level (Jaetzold, 1983) and have low temperatures. Ol Joro Orok for instance has absolute minimum temperatures of between 0 and 2^{0}C in all months. All the four stations were above 1900m in altitude and there was no clear relationship between rainfall and yield level. Soil factors, including the weed status, undoubtedly had important effects but from the soil analysis it was difficult to draw conclusions (Boonman, 1979).

In Trinidad, (Paterson, 1938) reported dry matter yields of 41.4 tons /ha/year. Watkins and Lewy van Severen, (1951) documented a yield of 38.1 tons/ha/year in El Salvador. In Puerto Rico, dry matter yields of 11-15 tons/ha/year have been recorded (Rivera-Brenes, 1962; Caro-Costas *et al*,1960; and Caro-Costas and Vicente-Chandler (1956, 1961).

On heavily fertilized humid, lowland tropics, yields of up to 100 tons DM/ha have been obtained (Crowder and Chheda, 1982). In this experiment carried out in the Carribbean, unusually high fertilizer levels, at a rate of 1320 kg N /ha and supplemental irrigation both of which are known to boost dry matter yields considerably, were applied. In Australia and southern Asia, DM yields of 11 to 43 tons/ha have been reported (Muldoon and Pearson, 1977 and 1979). Under farm conditions, lower herbage yields are realized and these may range from 2 to 10 tons/ha in unfertilized stands and from 6 to 30 tons/ha per year in fields well fertilized with nitrogen and given a basic dressing of phosphorus (Bogdan, 1977). The use of fertilizers therefore alters the dry matter yields (Crowder and Chheda, 1982). An almost linear increase of dry matter yields with successive increments of nitrogen fertilizer has been noted in different grasses (Oyenuga and Hill, 1966; Vicente-Chandler *et al.*, 1974; Crowder, 1977).

It is well established that as the cutting interval increases so does the dry matter yield. Vicente-Chandler *et al.*, (1959), reported a steady increase in both dry matter yield and dry matter content with increase in cutting interval from 6 weeks to 12 weeks at all levels of nitrogen tested over a period of three years. The yields ranged from 27.2 to 46.5 tons/ ha for cutting intervals of 6 and 12 weeks respectively while the dry matter percent rose steadily from 14.1% at 6 weeks to 25.1% at 12 weeks. Gomide *et al.(1969)* in Brazil, observed a linear increase in dry matter percent from 12.2 at 4 weeks to 43.0% at 36 weeks. In Nigeria an increase of dry matter yields and percent dry matter content from 4.8 tons/ha and

16.6% to 13.7 tons/ha and 25.9% respectively were noted (Oyenuga, 1959). The cutting interval ranged from 3 to 12 weeks. In Kenya, Van der Kamp (1987) reported a significant increase in percent dry matter content from 11.5 to 16.6% with increase in cutting interval from 6 to 12 weeks while the yields recorded varied from 3.3 tons/ha to 11.2 tons/ha per year when 100 kg N/ha and 70 kg P_2O_5 were applied.

2.5. Nutritive quality:

2.5.1. Chemical composition

A satisfactory appraisal of napier grass as a fodder for livestock requires the determination not only of agronomic factors such as productivity and ecological suitability under conditions of defoliation but also an adequate assessment of the nutritive value. It is well known that the chemical composition of a forage is an important criterion in deciding which forages should be planted and fed to the ruminant animal. The overall quality of forage is dependent on the relative proportion of high quality fractions. Although leaves and stems are nutritionally of equal value in early growth, the rate of decline in quality for the different components varies as the plant matures. The nutritive value of napier grass is determined by changes in chemical composition and digestibility and these two are dependent on stage of growth , height of cutting , season of the year and fertilizer application (Ware-Austin, . 1963 ; Goldson , 1977). Advancing forage maturity is accompanied by increase in dry matter yield, a rise in cell wall constituents and a decrease in percent cell contents.

Unlike in the majority of tropical grasses , elephant grass has a large proportion of water during the early stages of growth and the dry matter percent is only 12-18 (Bogdan, 1977). The percent dry matter content is the lowest of all important grasses in East Africa (Boonman, 1979). This is in contrast to the recorded percent dry matter variations in other tropical grasses for instance *Setaria sphacelata*, *Digitaria decumbens*, *Cynodon dactylon*, (Coastal Bermuda), *Brachiaria decumbens* and *Chloris gayana* with ranges of 14.8-20.7, 14.8-28.6, 19.1-35.4 and 19.5-42.1 percent respectively (Miller and Brair-Rains, 1963; Butterworth, 1967; Bogdan, 1977). Low dry matter content leads to inadequate dry matter intake (Dirven and Ehrencron, 1963) especially in the wet season and subsequently reduced milk yields compared with sown pastures (Osborne and Allan, 1971). During the dry season however, elephant grass is superior since it is able to retain its nutritive quality longer (Boonman, 1979; Karanja, 1981). In addition the dry matter percent increases as the grass matures.

It is established that the crude protein percent declines with increase in stage of maturity. Paterson (1933) and Wilsie and Takahashi (1934) reported a negative correlation between crude protein and harvest interval. In their studies a CP value of 10% was reported at four weeks growth , and this dropped to 6% CP when harvest was delayed to 14 week intervals. In Puerto Rico, a gradual decline in CP content from 12.10% to 6.73% with increase in cutting interval from 6 weeks to 13 weeks was demonstrated (Vicente-Chandler,*et al* 1959). Mwakha (1972) reported a decline in the leaf and stem CP content in Kenya from 13.8 and 8.4% to 8.7 and 2.8% respectively with increase in the cutting interval from 9 weeks to 34 weeks. Crude protein content was shown to decrease from 15.46 at 5 weeks to 3.8 % at 14 weeks with delayed cutting (Gutierrez and Faria, 1978). With heavy fertilization of 600-1000 kg N/ha Arias (1980) reported a CP content of 9.6% at 7 weeks and 6.3% at 10 weeks. Decrease in napier grass CP content with increase in cutting interval have also been reported by other workers in Hawaii (Wilsie, 1940), El Salvador (Watkins and Severen, 1951) , India (Ranjhan and Talapatra, 1967) , Brunei (Williams, 1980) and Kenya (Karanja, 1984 ;Potter, 1985 ; Wouters, 1985 Van der Kamp, 1987).

Fertilizer application to napier grass alters both the yields and chemical composition but the magnitude is modified by climate, cultural practices and other environmental factors. The fertilizers may substantially increase the levels of protein and minerals in the grass. In the Caribbean, Folkertsma (1981) has cited CP values of 12, 8 and 6 weeks old napier grass ranging from 8.3 to 17.6, 6.5 to 11.9 and 4.9 to 9.6% respectively when fertilizer rates varied between 0 and 2250 kg N/ha/annum. From Kenya CP ranges of 4.9 to 9.5, 5.4 to 12.2 and 5.4 to 12.2% were observed between 18 and 6 weeks of age when 0, 50 and 100 kg N/ha/year was applied (Wouters, 1985). This observation has been reported by many other researchers but the response to applied nitrogen depends on stage of growth, amount and time of N application, soil moisture and climatic conditions (Crowder and Chheda, 1982). However, at levels of 0, 100 and 200 kg N/ha per year, Gomide *et al.* (1959) concluded that nitrogen fertilizers had no effect on calcium, phosphorus and potassium content.

Many soils in tropical areas respond to modest applications of phosphorus with pronounced increases in forage production (Cloutier, 1971; Vicente-Chandler *et al.*, 1974) but in general applied P increases the content of this nutrient in herbage with no substantial effect on CP content. Crowder and Chheda, (1982), have similarly reported that raising application rates for potassium only affects the nutrient levels in plant tissue but not the CP content.

Increase in structural components of the plant cells partly explains the gradual decline in the herbage quality with napier grass maturity. Muldoon and Pearson (1979), reported crude fibre values of 39 and 44% at 2 weeks and 4 weeks respectively in Australia. The workers further noted increases in total carbohydrates , cellulose and lignin as the napier grass matured. This is in conformity with the trend in most grasses where it is well established that as the grass matures , the proportion of cell walls and constituent fractions increase (Holmes, 1980). In Kenya, though the data is limited, increase in fibre contents including Van Soest fractions has been reported (Karanja, 1984 ; Potter, 1985 ; Van der Kamp,1987). Cell wall contents of 69.4% and 71.1% for Bana grass and Pakistan napier were reported by Brown and Chavalimu (1985) at 5 weeks of age. Other workers have also noted rising fibre content with increasing age as reported by Butterworth (1967). Increasing van Soest fibre fractions have also been demonstrated by Vicente-Chandler *et al*, (1959), Da Silva *et al*, (1965), Gomide *et al*, (1969), Johnson *et al*, (1973) and Potter and Anindo (1985).

Relatively high ash contents have been reported for napier grass. In Venezuela, ash was shown to decline as the grass matured from 15.4% at 4 weeks to 9.2% at 10 weeks regrowth (Butterworth, 1967). In Kenya, ash contents of 19.5% at 6 weeks and 15.6% at 18 weeks were observed (Wouters, 1985). Van der Kamp (1987) reported almost similar findings of ash contents that decreased with age from 21.7% at 6 weeks to 14.2% at 18 weeks. However, ash determination gives no indication of the specific elements present , or the combination in which a given mineral occurs in the forage (Maynard *et al.*, 1979). In the work from Kenya, the napier grass was irrigated while in the Caribbean it was rainfed and therefore the very high ash contents may partly be due to the marked splash from the water sprinklers.

High potassium contents in napier grass were noted in Kenya (Robinson and Cheney, 1958). Moltavo *et al* (1987), has also demonstrated high potassium contents in napier grass, the highest concentration being in the leaves. It would therefore be expected that as leaf:stem ratio decreases percent potassium in the plant would go down. In that experiment the leaves were also seen to be richer in phosphorus. Under irrigation conditions , Paretas and Gomez (1972) observed declining calcium and phosphorus contents with less frequent cutting of napier grass. These results are corroborated by findings of Gutierrez *et al.*, (1978) who recorded a decrease in calcium from 0.48% at 7 weeks maturity to 0.15% at 14 weeks while the phosphorus content ranged from 0.45% to 0.11% between 7 weeks and 14 weeks respectively. For these two minerals, not only must the forage provide adequate amounts but the ratio between the two is important. Ratios of between 2:1 and 1:1 are optimum in animals (Maynard, *et* *al.*, 1979). However, in Kenya, little work has so far been done to partition the ash into the constituent elements or minerals for napier grass.

Percent ash content decline with increase in nitrogen application has been reported (Wouters, 1986). This worker reported that for napier grass the percent decrease was 1% for every 50 kg N added per hectare. This may be a dilution effect and it is expected that the ash constituents would similarly decline. High ash content in feeds is undesirable because it decreases the amount of digestible energy (Holmes, 1980).

Grasses are known to contain appreciably high amounts of silica and this may constitute 30-60% of the ash (Jones, 1967). Van Soest and Lovelace (1969) reported that silica is unevenly deposited throughout the plant. Johnson (1973) observed a highly variable growth stage effect on silica content of napier grass. The worker noted a rapidly increasing silica content during the first eight weeks of growth and a tendency of levels becoming constant in later stages. Tessema (1975), however, reported uneven changes in silica content with age. On the whole, reported changes in silica content as the plant matures seem contradictory.

2.5.2. Digestibility

Digestibility is known to be an important factor affecting the performance of ruminants fed on forages. Study of aging and maturation has been of particular interest since the two are known to be inversely related to digestibility. Working with French Cameroon cultivar, Said (1976) noted *in vivo* organic matter digestion coefficients of 71.1%, 77.7% and 66.6% at 3, 5 and 7 weeks regrowth stages respectively. Butterworth (1967) has quoted *in vivo* organic matter digestibility of napier grass to range from 64.9% at 4 weeks regrowth to 59.8% at 10 weeks. Wouters (1986) working with Bana grass demonstrated a declining *in vitro* organic matter digestibility from 75% at 6 weeks of age to 63% at 12 weeks of age. A rather high digestibility of organic matter *in vitro* of 77.4% at 6 weeks and a low one at 18 weeks of 54.1% (Van der Kamp, 1987) were recorded for French Cameroon. Arias (1980) reported a decline in *in vitro* digstibility from 72% at 7 weeks to 65% at 10 weeks with heavy fertilization of of 600-1000kg N/ha. These results corroborated previous findings by Mwakha (1972), Ogwang and Mugerwa (1976) Reid *et al* (1973), Olubajo and Oyenuga (1974), and Leon *et al.*, (1987).

Among the factors that are known to affect digestibility are fertilization, environmental conditions and age of the plant. With advancing maturity, cellulose, hemicellulose and lignin contents rise (Van Soest and Robertson, 1980). Lignin is a primary factor causing a decline in digestibility with maturity. Grasses also tend to accumulate silica as a secondary protective factor for plant cell wall and it is known to depress digestibility (Van Soest and Jones, 1968).

Chemical composition and in particular structural components are known to markedly affect digestibility (Jones, 1973). The in vitro digestibility of napier grass was reported to increase with increased level of nitrogen application from 64.3 to 71.25% for 0 and 300 kg N /ha fertilizer rates respectively (Ogwang and Mugerwa, 1976). Environmental conditions namely light, temperature and moisture influence vegetative development of the forage species (Smith, 1976) and this affects both chemical composition and subsequently digestibility.

The nylon bag technique has been used for many years to study the ruminal microbial breakdown (degradability) of forages (Fina *et al.*, 1958; Hopson, *et al.*, 1963). Little, however, is known of the relative degradabilities of a wide range of tropical forages (Ørskov, *et al.*, 1980). The nylon bag incubations have advantages in that the digestion takes place in the *in vivo* rumen environment. Studies made during *in vivo* rumen fermentation have the added advantage that there are no problems of temperature control and removal of end-products which have to be coped with as soon as rumen fluid is taken into a laboratory for *in vitro* fermentation (Ørskov *et al.*, 1980). The worker has further reported that sometimes the *in* *vivo* digestibility is quite similar to degradation at 48 hours incubation.

3.0 MATERIALS AND METHODS

3.1 Study sites

The study was carried out at the following two places:-

1. National Animal Husbandry Research Station (N.A.H.R.S.), Naivasha.

2. University of Nairobi, Kabete.

The napier grass cultivars were grown at Naivasha and the bulk of laboratory analytical work was done at the same station. At Kabete, *in vitro* digestibility and ruminal dry matter disappearance *in sacco* were carried out.

3.2 Site description (Naivasha)

The station is situated at 0° 40'S and 36° 26' E at an altitude of 1900 m. This high altitude modifies the tropical climate. The mean annual temperature is 16.8°C with the highest temperature at 28.3°C in the month of March and the lowest at 6.8°C in February. Generally, temperature and humidity fluctuations are small.

Though the average annual rainfall is moderate at 653 mm (Jaetzold. 1983), the amount time, and intensity of rainfall is so variable that prediction is difficult. April, May and

November are the wettest months with averages of 121 mm, 103 mm and 71 mm respectively. January , the driest month receives only 32 mm. The area is in agro-ecological zone IV and rainfed agriculture is uneconomical (Jaetzold, 1983). In addition the area tends to be windy and while this has a cooling influence it has the disadvantage of increasing the evapo-transpiration thereby reducing the moisture available for plant growth. The water received by the napier grass during the experimental period can be seen in the bar chart in Figure 3.1. This shows rainfall plus the irrigation water supplied. Table 3.1 shows the changes in minimum, maximum and mean temperatures over the same experimental period.

The soils are of volcanic origin having developed from volcanic ashes. The soil is dark greying brown, deep and imperfectly drained. It is sodic and of low fertility with a humic topsoil (Jaetzold, 1983). The terrain is fairly level and the natural vegetation consists of open short grass highland savannah with scattered tall acacia trees (Kimenye, 1978).

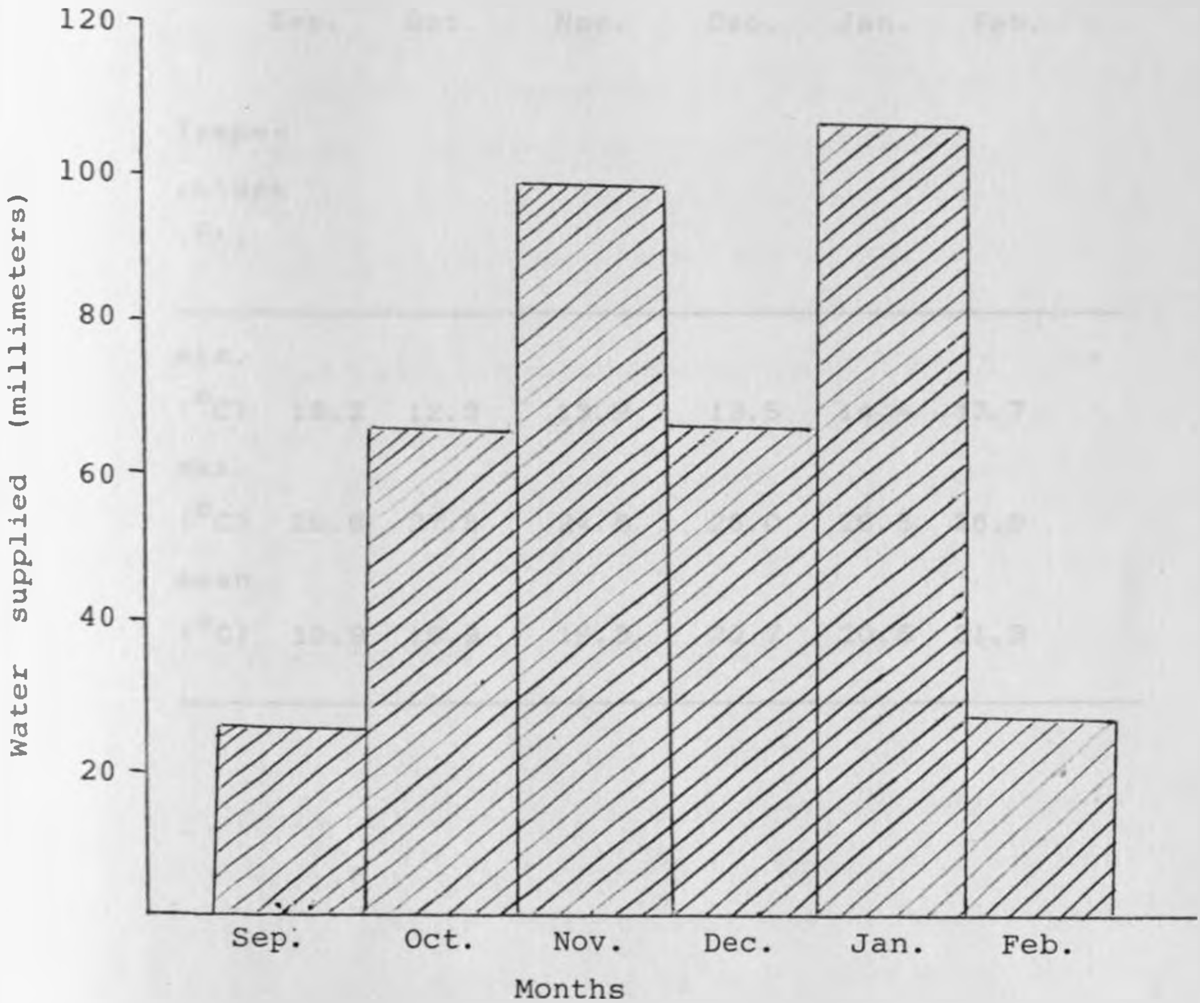

Fig. 3.1: Moisture received by the napier grass (Rainfall plus irrigation)

Table 3.1 Changes in minimum, maximum and mean temperatures during the experimental period (September, 1987 to February, 1988).

Temperature (°C)	Month					
	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
min. (°C)	13.2	12.3	13.9	13.5	14.4	13.7
max. (°C)	26.6	27.5	24.8	28.0	26.5	28.9
mean (°C)	19.9	19.9	19.3	20.7	20.5	21.3

3.3 Experimental field

The two cultivars (Bana and French Cameroon) were planted in April, 1987 at a spacing of 0.9m x 0.6m. The experimental field of 97.2m x 25.2m was subdivided into 36 plots of 2.7m x 4.2m.

A clean cut leaving a stubble height of 5cm from the ground was done in September, 1987. This was followed by weeding and then fertilizer application at the rate of 50kg, 90kg and 200kg per ha for nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) respectively. Every two weeks the field was irrigated for 12 hours continuously. This was equivalent to 26mm water per month. The field was kept weed free and one top dressing with N at a rate of 50kg/ha was done at six weeks of regrowth.

3.4 Experimental and Treatment Design

The design was a split-plot with cutting stage (subplot) nested within variety (main plot). There were two varieties and six cutting stages. Variety was treated as a fixed effect and stage of cutting as a random one. There were three replications per treatment. The stages of cutting were 4, 6, 8, 10, 12 and 14 weeks. Treatment allocation to plots was randomly done.

3.5 Harvesting and Sampling Procedures

Sampling commenced in October, 1987.

The height of napier grass was measured by means of two methods. The first method was carried out by lowering a disc of polystyrene foam (diameter 75 cm, thickness 1.5 cm) on the grass and reading the height with a graduated measuring stick. This method was applied when the plant height was 25 cm and below. The second method was by visual observation of the average height of the shoots and measuring with the same measuring stick. All plants in an experimental plot were measured and from these results, the average height for the plot was calculated.

The experimental plots were cut manually using sickles on the day of harvest. The grass was cut as closely as possible to ground level but on average a stubble height of 5 cm remained. At the time of harvesting, the perimeter (guard row) of each plot was cut first and discarded. The cut herbage from the plot was weighed by means of a weighing balance (to the nearest 0.2 kg).

The sampling of the grass for dry matter and chemical analysis was carried out by chopping a bulk sample of about 15 kg from each plot with a hand operated chaff-cutter into pieces of about 2.5 cm after which a sample of about 5 kg chopped material was taken. This sample was spread on a line ridge. Sub-sampling was done by taking two segments of the ridge. For each treatment two samples were taken for dry matter analysis (dried at 105°C) and one for chemical analysis (dried at 70°). Sampling for the determination of the leaf:stem ratio was done by picking at random a number of shoots from the heap of cut napier grass after weighing. The samples were separated into fractions of leaf, stem (including leaf sheath) and dead material. These fractions were dried at 105°C for 48 hours in a Memert oven and later weighed. The weights were used to calculate the leaf:stem ratios.

The dry matter yield per plot was calculated as follows:-

$$\text{Dry matter yield tons/ha} = \frac{\text{Fresh wt. (kg/plot)}}{1000} \times \frac{10000}{\text{Area of plot (m}^2)} \times \text{Percent dry matter}$$

3.6 <u>Analytical Procedures</u>

3.6.1 <u>Chemical Composition</u>

Analysis for proximate components was done by methods of AOAC (1984). Acid detergent fibre

(ADF), Neutral detergent fibre (NDF) and acid detergent lignin (ADL) values were determined following the procedure of Goering and Van Soest (1970). The silica values were obtained as the ash after ADF ash was leached with 48% hydrobromic acid (HBr) for one hour.

For mineral analysis, the dry ash was dissolved in 20% HCl and necessary dilutions made with deionized water. Calcium (Ca) and Potassium (K) were estimated with a flame photometer (Beckmann, Klina flame). Ultra-violet electrophotometer was used to estimate phosphorus content of the samples.

3.6.2 Digestibility Estimates

The *in vitro* digestibility of dry matter (IVDMD) and *in vitro* organic matter digestibility (IVOMD) were estimated using the two-stage Tilley and Terry technique ((Tilley and Terry, 1963).

3.6.3 Ruminal Dry matter degradability *in sacco*

Three Red Maasai sheep were used in this investigation. The animals ranged in age from 48 to 56 months and liveweights varied from approximately 45 to 50 kg. The sheep were kept in metabolism cages.

The animals were fistulated and had a basal diet of Rhodes grass hay (*Chloris gayana*) offered *ad libitum*. A dairy meal concentrate was given at the rate of 250 g per sheep per day. Chemical composition of these feeds on offer is given in the appendix (Appendix III).

Sub-samples of napiergrass at different stages of growth were dried at 70°C and ground with a Wiley hammer mill through a 2 mm screen. For each growth stage six sub-samples of 3 g each were weighed and put into nylon bags (7 cm x 14 cm). The pore density was 1600/cm^2. Samples in nylon bags were marked and inserted into the rumen at 8.00 a.m and 8.00 p.m. Every 12 hours a new set of bags were introduced and at the end of 72 hours, all the bags were removed. Therefore samples incubated for 12, 24, 36 48, 60 and 72 hours were obtained to determine the rate of dry matter disappearance. At the end of incubation, the bags were rinsed in tap water for 30 minutes, suspended in the air for water to drip and then oven-dried at 70°C for 48 hours. They were again weighed to give the dry matter loss in the rumen. To estimate disappearance at zero-time, another set of six samples for each growth stage were washed in tap-water for 5 minutes. These were then dried in the oven in a manner similar to the incubated samples.

Three replications of the experiment were conducted. Data were blocked by sheep with a randomized block design in which time and stage of growth of the forage were the factors considered.

The data obtained was described by equation of Ørskov and McDonald (1979). The percentage of napiergrass degraded (p), was described as follows:

$$p = a + b(1 - e^{-ct}) \qquad (1)$$

where a, b and c are constants.

Thus we have several terms:

p = the actual degradation after time 't'

a = degradation at zero time

b = proportion of napiergrass which will be degraded given sufficient time

c = the rate constant for the degradation of 'b'.

t = time of incubation in hours.

The determination of c is particularly important because it provides information on factors affecting intake of roughages, namely digestibility and rate of digestion (Orskov, 1986). The values of (b) can be obtained by extrapolation. The (a + b) value gives some expression for the potential digestibility for the fibrous feed. The sketch in Figure 3.2 attempts to show some of these components.

The half-life ($T_{1/2}$) is the time taken to reduce the incubated sample by one half both by dissolving in the rumen liquor and through microbial break-down. To obtain the degradability rate at a given time (t), the components are

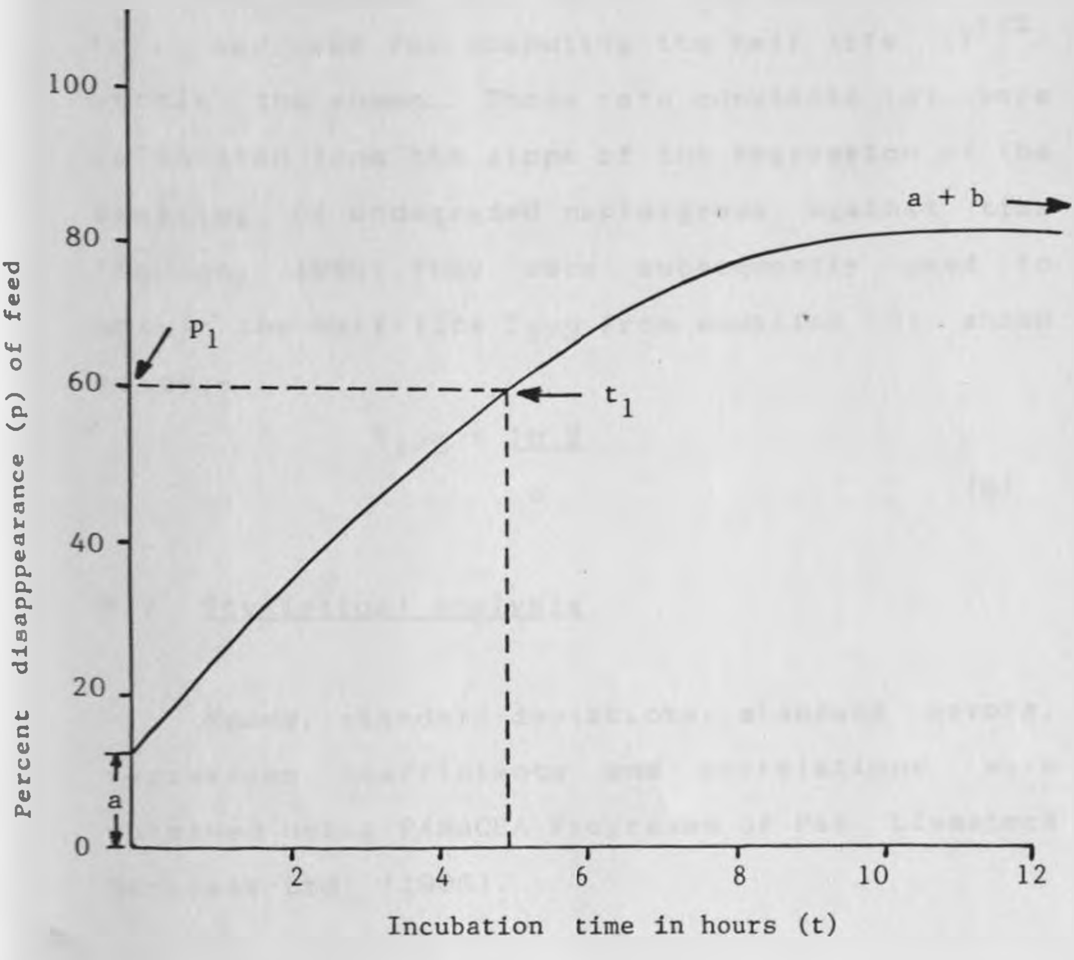

Fig. 3.2: Illustration of degradation curve component (Sketch).

fitted in equation (2) and thus:-

$$e^{-Ct} = \frac{a + b - p}{b} \qquad (2)$$

and by taking the natural logarithm on both sides of the equation, it is found that:

$$-Ct = \frac{\ln (a + b - p)}{b}$$

The average dry matter degradability rate (c), was used for computing the half life ($T^{1/2}$) within the rumen. These rate constants (c) were calculated from the slope of the regression of the semi-log of undegraded napiergrass against time (Mapoon, 1980).They were subsequently used to obtain the half-life $T_{1/2}$ from equation (3) shown below:-

$$T_{1/2} = \frac{\ln 2}{c} \qquad (3)$$

3.7 Statistical analysis

Means, standard deviations, standard errors, regression coefficients and correlations were obtained using PANACEA Programme of Pan Livestock Services Ltd. (1986).

The analyses of variance were obtained using the procedures described by Steel and Torrie (1980) and mean separation was accordingly done by use of least significant difference (LSD) at $P<0.05$.

4.0 RESULTS AND DISCUSSION

4.1 Dry matter yields, grass height at cutting and leaf:stem ratio

Table 4.1 shows the means for dry matter yield, plant height at harvest and leaf:stem ratio.

4.1.1 Dry matter yield

Dry matter yields increased significantly ($P<0.05$) from 1.37 to 9.00 tons/ha and from 1.24 to 10.01 tons/ha for Bana grass and French Cameroon respectively as napier grass matured. Varietal difference in dry matter yield was insignificant ($P>0.05$). Increase in dry matter yields as the grass matures are consequences of additional tiller and leaf formation, leaf elongation and stem development (Akinola *et al*, 1971; Dovrat *et al*., 1971; Fisher, 1973; Michelin *et al*., 1968; Robertson, 1976). Assuming unchanging climatic and cultural practices, the yields recorded in the experiment would range from 16.12 to 37.18 tons/ha/year. This yield falls within the range reported in East Africa of 10-40 tons/ha/year (Thairu *et al*. 1968; Mwakha, 1972; Goldson, 1977; Karanja, 1984; Wouters, 1985). However, much higher yields have been reported elsewhere for instance Colombia

Table 4.1: Influence of cutting stage on dry matter yields, grass height at harvesting and leaf:stem ratio

Cutting stage (weeks)	Dry matter (tons/ha)		Height at harvesting (cm)		Leaf:Stem ratio	
	B	F	B	F	B	F
4	1.37_a [1]	1.24_a	22.11_a	27.51_a	3.77_a	5.03_a
6	2.71_a	3.06_b	56.86_b	68.61_b	2.53_b	2.40_b
8	4.14_b	4.96_c	58.52_b	92.16_c	2.23_b	1.33_c
10	5.24_{bc}	5.14_c	75.52_c	108.48_c	1.50_c	1.00_c
12	6.18_c	7.68_d	92.54_d	151.88_d	1.20_{cd}	0.87_d
14	9.00_d	10.01_e	124.88_e	189.99_e	0.93_d	0.53_d

B indicates the columns for Bana grass while F indicates the columns for French Cameroon.

[1] Means with different subindices within the same column differ significantly ($P < 0.05$).

(Crowder and Chheda, 1982), Puerto Rico (Vicente-Chandler *et al.* 1959), and El Salvador (Watkins and Lewy-Van Severen, 1951), a possible effect of the comparatively higher fertilizer application rates in the Caribbean and ample water supply. This is an illustration that differences in dry matter yields exist in napier grass grown under different environmental and agronomic conditions.

4.1.2 Grass height at cutting

At four weeks the mean heights were 22.11 cm and 27.51 cm for Bana grass and French Cameroon respectively. This increased significantly ($P<0.05$) with increase in napiergrass maturity up to 124.88 and 189.99 cm at 14 weeks respectively. Cultivar French Cameroon showed insignificantly higher ($P>0.05$) heights at all stages of growth studied. A number of previous experiments have been conducted with the aim of using height as a criterion for optimum cutting stage. It is generally agreed that with delayed cutting there is a corresponding increase in total dry matter yield and that height is a reflection of dry matter yields (Boonman, 1979). The results obtained in the experiment supported this view since for both varieties the taller the grass, the higher the dry matter yields. Tiley (1970) as reported by Boonman (1979) observed that napier of 100cm height corresponds with a crude protein percent of about 10%, an organic matter digestibility of 57% and a leaf:stem ratio of 1.0. At the same height Wouters (1986) reported a CP percent of 6.8 and organic matter digestibility of 64.9% for Bana grass which had received 50 kg N/ha and cut at 12 weeks of age. In the current study 1m height was achieved at about 12 weeks for both cultivars. The corresponding CP content and *in vitro* OM digestibilities were 5.89 and 64.54% for Bana grass and 5.68 and 64.64% for French Cameroon respectively. However, nutritive value parameters derived from grass height should be treated with caution since height is a function of climate and cultural practices. For instance higher nitrogen and water application will considerably increase the rate of growth and at 1 metre cutting height crude protein content, dry matter yield and digestibility is expected to be much higher.

4.1.3 Leaf:Stem ratio

As the napier grass matured, leaf:stem ratio significantly declined ($P<0.05$). This ranged from 3.77 to 0.93 and 5.03 to 0.53 for Bana grass and French Cameroon at 4 and 14 weeks respectively. After 6 weeks the decrease was more gradual. However, differences between the varieties were insignificant ($P>0.05$). The ratios recorded in this experiment compare with the declining ranges of between 2.10 and 0.28 reported by Mwakha (1972) between 2 and 8 weeks. Although the ratios for Mwakha (1972) are for different ranges of growth stages, a trend similar to the one observed in the current experiment is seen. It should be noted however that it is important to include leaf sheath to avoid giving a misleading leaf:stem ratio.

Elephant grass is capable of producing high yields but half or more of this is composed of inedible stem, which may be wasted under a cutting feeding system (Boonman, 1979). Strange (1959) and Boonman (1979) reported that Bana grass produces more leaf than any other variety of napier grass. Except for the 4 weeks regrowth, which demonstrated particularly high leaf:stem ratio of 3.77 and 5.03 for Bana and French Cameroons respectively, the findings in this study are comparable to the results of other investigators. The decrease in leaf:stem ratio as the grass matured was more drastic in French Cameroon than was the case with Bana grass over the same period. Crowder and Chheda (1982) reported that leaves have a higher digestibility than stems in mature herbage. Leaf:Stem ratio is known to affect digestibility and chemical composition of forages (Van Es, 1982, Crowder and Chheda, 1982). Calcium and iron contents are known to be higher in leaves than in stems (Moltavo *et al.*, 1987). As the plant matures, the percentage of leaf declines due to stem elongation and death of older leaves. High leaf:stem ratio is desirable since it may improve forage intake. Whereas this may be true in unchopped napiergrass due to animal selection for leaves, the increase in intake may be partially masked by chopping. This is a common practice with many farmers.

4.2 Chemical composition

4.2.1 Proximate composition

Data in Table 4.2 indicate that the dry matter content increased significantly ($P<0.05$) with increase in cutting age. The values varied from 15.81% to 17.67% and 14.52% to 17.70% for Bana grass and French Cameroon respectively at 4 weeks to 14 weeks. From 10 weeks to 14 weeks the increases in dry matter percent were however gradual for both cultivars. Differences between the cultivars were not significant ($P>0.05$).

The observed dry matter percent is low and confirms the observations reported by Butterworth (1967), Gomide *et al.*, (1969), Vicente-Chandler *et al.*, (1974), Wouters (1985) and Van der Kamp (1987). The percent dry matter content of elephant grass is the lowest of all important grasses in East Africa. The thick fleshy stems are responsible for the high water content (Boonman, 1979). The high moisture content is likely to be a limiting factor to dry matter intake in animals particularly in the early stages of growth. Spoilage in ensiled napier grass has also been attributed to this high moisture content and this almost rules out hay making from napier grass (Boonman, 1979).

The proximate analysis data presented in Table 4.2 and 4.3 showed considerable variations in the crude protein, ash and carbohydrate contents. The percentage values of ether extract indicated relatively narrow ranges. Varietal differences were evident ($P<0.05$) for crude protein, crude fibre, ether extract and ash. The rise in crude fibre from 23.39 to 36.30% for Bana grass and 23.41 to 39.01% for French Cameroon at 4 and 14 weeks respectively shows a significantly ($P<0.05$) rapid increase during the early regrowth stages (4-8 weeks) while the increase became gradual in later stages.

Crude protein content varied from 14.84 to 3.98% and 13.85 to 5.01% for French Cameroon and Bana grass respectively. Similar trends have previously been reported by other workers (Paterson, 1933; Wilsie and Takahashi, 1934; Vicente-Chandler *et al.*, 1959; Mwakha 1972; Karanja, 1984; Potter, 1985; Wouters, 1985 and Van der Kamp, 1987). However, napier grass at the same stage of growth may have completely different crude protein content. Many researchers have shown that nitrogen application increases crude protein content of napier grass (Thairu *et al.*, 1968; Vicente-Chandler *et al.*, 1974; Wouters, 1985). Other studies have shown this to be true for Bermuda grass (Burton and Jackson, 1962) Pangola grass (Whitney and Green, 1969) and mixed natural pasture (Olsen and Santos, 1975).

Table 4.2: Influence of cutting stage on % dry matter, crude protein and crude fibre.

Cutting stage (weeks)	Dry matter percent		Crude Protein		Crude fibre	
	B	F	B	F	B	F
4	15.81_a	14.52_a	13.85_a	14.84_a	23.39_a	23.41_a
6	15.72_a	14.96_{ab}	10.87_b	10.23_b	26.86_b	29.59_b
8	16.43_b	15.12_{bc}	8.61_c	7.54_c	32.21_c	34.02_c
10	17.09_c	15.72_{cd}	7.24_d	5.68_d	34.93_d	37.14_d
12	17.24_c	16.09_d	5.89_e	4.07_e	34.56_{de}	38.45_d
14	17.67_c	17.70_e	5.01_f	3.98_e	36.30_e	39.01_d

B indicates the columns for Bana grass while F indicates the columns for French Cameroon.

[1] Means with different subindices within the same column differ significantly (P < 0.05).

Table 4.3: Influence of cutting stage on ether extract, nitrogen free extract and total ash.

Cutting stage (weeks)	Ether extract B	Ether extract F	Nitrogen free extract B	Nitrogen free extract F	Total ash B	Total ash F
4	2.74_{a}	3.42_{a}	33.74_{a}	35.07_{a}	26.41_{a}	23.27_{a}
6	2.62_{a}	2.85_{b}	34.46_{ab}	36.28_{b}	25.07_{ab}	20.93_{b}
8	2.08_{b}	2.20_{c}	35.46_{b}	36.41_{b}	23.32_{b}	19.97_{c}
10	1.78_{c}	1.96_{c}	36.10_{bc}	37.29_{b}	20.84_{cd}	18.60_{cd}
12	1.60_{cd}	1.91_{c}	36.80_{cd}	36.52_{c}	20.60_{de}	17.75_{d}
14	1.49_{d}	1.64_{d}	38.22_{d}	39.86_{d}	18.96_{e}	15.75_{e}

B indicates the columns for Bana grass while F indicates the columns for French Cameroon.

[1] Means with different subindices within the same column differ significantly (P < 0.05).

In this experiment, the water supplied was far above the weekly minimum requirement of 2-3cm for growth (Crowder and Chheda,1982). The low protein content observed especially after 6 weeks may therefore be due to dilution effect where foliage growth is rapid and the demand is thus higher than the nitrogen absorption rate from the soil (Crowder and Chheda, 1982). Bana grass had a crude protein drop of 48% from 4 to 10 weeks and a drop of 30% from 10 to 14 weeks. The corresponding percentage decline for French Cameroon were 55% and 40%. Therefore the drop in CP in French Cameroon appeared to be more drastic and this is positively correlated to the drop in leaf:stem ratio. The critical protein levels for optimum microbial activity of 6-7% (Milford and Minson, 1966) were not met after 10 weeks. These low values are likely to affect digestibility and may reduce dry matter intake. The low crude protein content after 8 weeks tend to suggest the need for protein supplementation if napiergrass is the only source of feed.

Ash was high in the dry matter but it significantly decreased ($P<0.05$) with age from 26.41% to 18.96% for Bana grass and from 23.27 to 15.75% for French Cameroon at 4 and 14 weeks of age respectively. High ash content for napier grass has been reported by other investigators and may be attributed to the fact that napier grass is a heavy mineral feeder (Boonman, 1979). In

Venezuela, Butterworth (1967) reported a range of 15.4 to 9.2% between 4 and 10 weeks of regrowth. In Kenya, ash contents of 19.5% at 6 weeks and 15.6% at 18 weeks have been observed (Wouters, 1985). Similar findings were reported by Van der Kamp (1987) when he recorded 21.7% ash at 6 weeks and 14.2% at 18 weeks. The latter two workers used irrigated napier grass. Soil contamination due to water splashing during irrigation and rain showers are likely to have caused these high figures. The findings of Van der Kamp (1987) and Wouters (1985) obtained under similar cultural practices and climate to the current study gave comparable results. The declining trend of ash content with age may be a result of reduction of soil splash by increased ground coverage by foliage. Conversely, the lower plant heights observed for Bana grass may have contributed to the recorded insignificantly ($P>0.05$) higher ash contents. In addition, mineral absorption rate may have been unable to cope with the increased growth rate in biomass due to continued depletion of the soil reserves.

Variations in potassium (K), phosphorus (P) and calcium content are presented in Table 4.4. At 4 weeks of growth, percent calcium and phosphorus were 0.36 and 0.29 ; 0.39 and 0.31% for Bana grass and French Cameroon respectively. These decreased insignificantly ($P>0.05$) with age to 0.30 and 0.22 ; 0.32 and 0.21% at 14 weeks for Bana grass and French Cameroon respectively. Potassium constituted about 50% of total ash and

Table 4.4: Influence of cutting stage on potassium, calcium and phosphorus.

Cutting stage (weeks)	Potassium		Calcium		Phosphorus	
	B	F	B	F	B	F
4	10.05_a [1]	11.70_a	.36	.39	.29	.31
6	9.98_{ab}	11.28_a	.35	.39	.29	.31
8	9.45_b	9.70_b	.35	.37	.26	.27
10	8.87_c	9.33_b	.32	.35	.24	.25
12	4.76_d	4.97_c	.31	.32	.22	.25
14	4.54_d	4.21_d	.30	.32	.22	.21

B indicates the columns for Bana grass while F indicates the columns for French Cameroon.

[1] Means with different subindices within the same column differ significantly ($P < 0.05$).

significantly ($P<0.05$) declined with age. There were no significant ($P>0.05$) cultivar differences in calcium, potassium and phosphorus contents. Crowder and Chheda (1982) have reported that advancing plant maturity depresses potassium content in herbage due to translocation to the roots.

High potassium contents have been reported not only in napier grass but also in other grasses. Luxury consumption of K is known in elephant grass (Robinson and Cheney, 1958; Annenkov, 1982; Vicente-Chandler *et al.*, 1974; and Moltavo *et al.*, 1987). Increased nitrogen and phosphorus application was observed to induce increased K consumption in *P. purpureum*, *P. maximum* and *Brachiaria mutica* (Vicente-Chandler *et al.*, 1959). However, the levels of K decreased ($P<0.05$) with increased cutting age and this was also true for calcium and phosphorus. The declining calcium and phosphorus content trends observed here corroborate with the findings of Gomide *et al.*, (1969); Paretas and Gomez (1972); and Vicente-Chandler *et al.*, (1974). Gutierrez *et al.*, (1978) noted a decline from 0.48 to 0.15 percent and 0.45 to 0.11 percent for calcium, and phoshorous respectively at 5 and 14 weeks of growth. Gomide *et al.* (1969) recorded a calcium content decrease from 0.61 at 4 weeks to 0.30 % at 36 weeks. Over the same period, phosphorus content decreased from 0.33 to 0.08%. Compared to the current experiment these levels showed a wide range. The trend may be explained by the dilution effect and soil depletion since Gomide *et al.*,(1969) found no nitrogen fertilizer effect on phosphorus and calcium levels at the rates of between 0 and 200 kg N/ha per year.

Mineral requirements in cattle is largely determined by the age of the animal, its physiological condition, and level of productivity (Annenkov, 1982). At the same time insufficient intake of minerals is known to impair acceptability and digestibility of a feed as well as reducing milk yield. A 400 kg cow with a yield 10 kg milk per day requires 51 and 41 g calcium and phosphorus respectively per day (Annekov, 1982). Given the observed levels of calcium and phosphorus and assuming a similar production and dry matter intake levels of 3% body weight, it may be necessary to supplement for these minerals if napiergrass is the sole feed. High potassium levels, ranging from 11.70% to 4.21% were recorded in the study and such levels may interfere with magnesium absorption (Newton *et al.*, 1962; Fontenot *et al.*, 1973). However, the ratio of calcium and phosphorus is within the optimum ranges of 1:1 and 2:1 (Maynard, *et al.*, 1979), thus interference with absorption of other mineral elements would not be expected.

4.2.2 Detergent Fibres and Lignin

Table 4.5 shows the mean values of neutral detergent fibre (NDF), acid detergent fibre (ADF), and acid detergent lignin (ADL) as the cutting stage was delayed. Neutral detergent fibre rose steadily from 52.18 to 72.68 for Bana grass and from 54.44 to 71.81% for French Cameroon at 4 and 14 weeks respectively. Acid detergent fibre (ADF) and Lignin (ADL) showed similar trends. For these three components the increase tends to level off after 12 weeks regrowth, although this is not very distinct in cultivar French Cameroon. No varietal differences ($P<0.05$) were observed for the constituents.

The above observation concur with the findings of Van der Kamp (1987), who reported ranges of 46.21 to 68.9%, 25.0 to 39.3% and 2.4 to 5.5% and for NDF, ADF and ADL respectively for French Cameroon between 6 and 18 weeks of age. Over a period of one year at Muguga, Kenya, ADL was recorded to vary from 3.3 to 5.7% with a cutting interval of 4 weeks for Bana grass (Potter, 1985). The variations in reported values of these constituents may be due to seasonal and climatic changes in the locality. Similar trends were observed by Mwakha (1972), Vicente-Chandler *et al.*, 1974), Karanja (1984) and Wouters (1985). The same trend is recorded for other grasses for

Table 4.5: Influence of cutting stage on detergent fibres, and lignin.

Cutting stage (weeks)	NDF		ADF		ADL	
	B	F	B	F	B	F
4	52.18_{a}[1]	54.44_{a}	27.10_{a}	25.97_{a}	2.31_{a}	2.26_{a}
6	56.48_{ab}	59.77_{a}	31.01_{b}	31.01_{b}	2.81_{a}	2.73_{a}
8	61.44_{b}	65.37_{b}	35.42_{c}	36.66_{c}	3.69_{b}	3.48_{bc}
10	69.29_{c}	68.55_{bc}	36.92_{c}	38.10_{c}	3.74_{bc}	3.51_{c}
12	72.22_{c}	69.74_{bc}	40.08_{d}	39.05_{cd}	4.28_{cd}	4.50_{d}
14	72.68_{c}	71.81_{c}	41.45_{d}	42.00_{d}	4.95_{d}	5.77_{e}

B indicates columns for Bana grass while F indicates the columns for French Cameroon.

[1] Means with different subindices within the same column differ significantly ($P < 0.05$).

instance as reported for *Melinis minutiflora* (Gomide *et al.*, 1969), *Cynodon dactylon* (Wilkinson *et al.*, 1970) and *Chloris gayana* (Abate, 1978).

4.3 *In vitro* Digestibility coefficients and silica content

Table 4.6 illustrates the silica percent content in the dry matter. The levels were high and constituted about 25% of the ash. The levels increased gradually as the cutting stage was delayed. This ranged from 4.07 to 6.67% and 4.57 to 6.35% for Bana grass and French Cameroon respectively at 4 and 14 weeks of age. French Cameroon had lower ($P<0.05$) silica contents than Bana grass. Probably the splashing effect was more on Bana grass since it had correspondingly lower recorded plant heights and possibly greater soil contamination of leaves.

Johnson (1973) and Singh, (1975) have reported silica levels that did not indicate a decreasing or increasing pattern as napier grass matured but rather fluctuated inconsistently with age. The current results however, concur with those of Jones (1967) and Jackson (1977). Grasses in general tend to accumulate silica as a secondary protective factor for plant cell wall, and this may explain the observed silica trends with napier grass. The contradictory results, from different investigators may be mainly due to the

Table 4.6: Influence of cutting stage on silica (percent in dry matter) and *in vitro* digestibility coefficients.

Cutting stage (weeks)	Silica		DM digest.		OM digest.	
	B	F	B	F	B	F
4	4.07_a	4.57_a	69.00_a	72.04_a	74.65_a	75.72_a
6	5.01_b	5.12_b	66.64_b	69.81_b	72.73_a	74.09_a
8	6.12_c	5.32_b	64.00_{bc}	63.50_c	69.15_b	68.67_b
10	6.31_{cd}	5.73_c	63.30_c	60.99_d	65.57_c	64.64_c
12	6.46_{cd}	6.06_{cd}	63.18_c	59.43_d	63.54_c	63.30_c
14	6.67_d	6.35_d	58.39_d	60.62_d	63.42_c	62.22_c

B indicates columns for Bana grass while F indicates the columns for French Cameroon.

[1] Means with different subindices within the same column differ significantly ($P < 0.05$).

fact that silica arising from soil contamination cannot be distinguished from plant metabolic forms (Van Soest and Jones, 1968).

Cellullose and hemicellullose, the major components of plant cell walls, though resistant to enzymatic breakdown are broken down by rumen microbes to simpler carbohydrates. However, their utilization is dependent on the silica and lignin levels of the forage (Crowder and Chheda, 1982). Lignin and silica have high resistance to chemical degradation and complex with carbohydrates making them unavailable for digestion. Lignin levels rose ($P<0.05$) as the grass matured and so did the silica levels ($P<0.05$). Silica is absorbed by forages along with water and reduces digestibility much in the same way as lignin (Van Soest, 1968). Therefore the higher the silica and lignin contents the lower the digestibility.

In vitro dry matter and organic matter digestibility (IVDMD and IVOMD) values are shown in Table 4.6. Dry matter digestibilities decreased ($P<0.05$) with age from 69.00 to 58.39% and 72.04 to 60.62% at 4 and 14 weeks for Bana grass and French Cameroon respectively. Organic matter digestibility coefficients at the same maturity stages decreased ($P<0.05$) from 74.65 to 63.42% and 75.72 to 62.22% for Bana grass and French Cameroon respectively. After 8 weeks the depression in digestibility is however gradual. Varietal differences for both dry matter and organic matter *in vitro* digestibility were insignificant (P>0.05) although the values for Bana grass seemed to be numerically higher after 8 weeks.

Reid *et al.*, (1973) observed *in vitro* dry matter digestibility values for napiergrass that decreased similarly from 70.2% at 4 weeks to 58.1% at 14 weeks. The author reported digestibilities of 63.2, 63.1 and 63.8% at 8, 10 and 12 weeks respectively. In this study Bana showed values close to those reported by Reid *et al.*, (1973) but French Cameroon had slightly lower values over the same range of growth stage. Van der Kamp (1987) has also reported digestibility coefficients that are similar to the findings of the present work. At 6 weeks the *in vitro* organic matter digestibility was 76.9% and this dropped to a low value of 54.15% at 18 weeks. Similar results have been obtained by Gomide *et al.* (1969), Mwakha (1972) Vicente-Chandler *et al.*, (1974), Said (1976), Karanja, (1984), Wouters (1985), and Potter, (1985).

These observed changes of digestibility with age can be attributed to changes in chemical composition particularly in fibre, lignin and silica content. The variation in digestibility between the cultivars may be a result of differences in genetic constitution among varieties since environmental conditions and management practices were uniform in the current experiment.

The leaf:stem ratio was noted to decrease with stage of growth, and a positive correlation was observed between this ratio and digestibility. This can be explained by the fact that the rate of lignification is much slower in leaves with increase in age than stems. This results in a rapid decline in digestibility of the stem fraction compared to the leaf fraction with advancing maturity (Raymond, 1969).

4.4 Relationships between chemical components and digestibility

The fibrous constituents, neutral detergent fibre, acid detergent fibre plus lignin and silica varied significantly ($P<0.05$) with age at cutting but they were negatively correlated to the estimated digestibility values. The correlation coefficients are shown in Table 4.7. Acid detergent fibre was significantly correlated to neutral detergent fibre and acid detergent lignin. The regression equations are presented in Table 4.8 (a) and (b). All the correlations were significant ($P<0.05$). Neutral detergent fibre was highly positively correlated ($P<0.05$) with silica and negatively correlated to crude protein. Crude protein showed negative correlations ($P<0.05$) with ADF, ADL and silica. These relationships concurred with those reported by Da Silva *et al.* (1965),

Table 4.7: Simple correlation coefficients for the chemical components and digestibility *in vitro* for different growth stages (underlined coefficients represent Bana grass while the others show French Cameroon).

	D.M. DIGES.	O.M. DIGES	CP	CF	NDF	ADF	ADL	SILICA	LEAF:STEM RATIO
DM DIGES	1	.84	.89	-.85	-.78	-.87	-.88	-.88	.90
TIBILITY	1	.96	.96	-.94	-.89	-.90	-.82	-.88	.87
O.M.diges		1	.94	-.94	-.91	-.86	-.86	-.91	.89
tibility		1	.94	-.93	-.89	-.86	-.84	-.93	.87
			1	-.94	-.87	-.94	-.90	-.95	.95
CP			1	-.89	-.92	-.91	-.83	-.93	.94
				1	.90	.92	.82	.91	-.92
CF				1	.95	.94	.80	.93	-.94
					1	.82	.79	.90	-.86
NDF					1	.91	.81	.95	-.88
						1	.84	.92	-.92
ADF						1	.84	.94	-.89
							1	.84	-.86
ADL							1	.80	-.76
								1	-.92
Silica								1	.86
									1
Leaf:stem ratio									1

Table 4.8: Relationship between detergent fibres, lignin, crude fibre, silica and *in vitro* dry matter (DMD) and (OMD) digestibility.

(a) Bana grass

Y	X	Regression equation	R^2
DMD	NDF	Y = 87.76 - 0.37x	0.79
DMD	ADF	Y = 85.88 - 0.62x	0.88
DMD	ADL	Y = 77.34 - 3.65x	0.95
DMD	CF	Y = 84.21 - 0.64x	0.84
DMD	CP	Y = 55.39 + 1.01x	0.87
DMD	Silica	Y = 82.52 - 3.19x	0.82
OMD	NDF	Y = 103.56- 0.55x	1.00
OMD	ADF	Y = 98.57 - 0.86x	0.96
OMD	ADL	Y = 85.40 - 4.74x	0.90
OMD	CP	Y = 56.04 + 1.41x	0.96
OMD	CF	Y = 96.46 - 0.90x	0.94
OMD	Silica	Y = 93.89 - 4.45x	0.90

Table 4.8: Relationship between detergent fibres, lignin, crude fibre silica and *in vitro* dry matter (DMD) and (OMD) digestibility.

(b) <u>French Cameroon</u>

Y	X	Regression equation	R^2
DMD	NDF	Y = 114.70- 0.77x	0.95
DMD	ADF	Y = 94.83 - 0.86x	0.92
DMD	ADL	Y = 76.97 - 3.39x	0.66
DMD	CP	Y = 55.03 + 1.21x	0.94
DMD	CF	Y = 92.77 - 0.84x	0.95
DMD	Silica	Y = 105.39- 7.42x	0.84
OMD	NDF	Y = 123.10- 0.85x	0.97
OMD	ADF	Y = 101.36- 0.94x	0.93
OMD	ADL	Y = 83.02 - 4.02x	0.79
OMD	CP	Y = 58.01 + 1.31x	0.92
OMD	CF	Y = 98.69 - 0.91x	0.94
OMD	Silica	Y = 114.73- 8.44x	0.92

Gomide *et al.* (1969) and Pezo (1971). The correlation between lignin and silica contradicts the findings of Van Soest (1970) while they concur with those of Da Silva *et al.*, (1965), and Johnson (1973).

These results are in agreement with observations from not only napier grass but also other tropical grasses, (Smith *et al.*, 1971; Coward-Lord *et al.*, 1974; Kayongo-Male *et al.*, 1976; Abate *et al.*, 1981 and Onyango, 1986).

The fibre components, silica and lignin were highly negatively correlated with both dry matter and organic matter digestibility *in vitro*. The two napier grass varieties had similar trends. Silica was positively correlated to NDF, ADF, ADL and CF while it had high negative correlations with *in vitro* digestibility, crude protein and total ash. Van Soest and Jones (1968) reported that cell wall silica functions much in the same manner as lignin by complexing with the cell wall components and thus reducing digestibility. The findings tally with those of other investigators where silica content has been known to be an important determinant of digestibility (Van Soest and Jones, 1967; Butterworth, 1967).

4.5 Dry Matter degradability *in sacco*

The ruminal dry matter disappearance *in sacco* or degradability refers to the proportion of dry matter that is broken down by rumen microbes after a given time of incubation. When dealing with fibrous feeds the dry matter or organic matter degradation is of great value. As far as napier grass is concerned there is little published data available about its degradation characteristics.

The graphs in Figures 4.1 and 4.2 show the percent ruminal dry matter loss with time for Bana grass and French Cameroon respectively at different regrowth stages. The curves were fitted using the means of measurements shown in Appendix 1V. The degradability curves for the two cultivars showed similar patterns and dry matter loss with time was higher ($P<0.05$) the younger the napier grass was.

The values for the dry matter degradability equation (Orskov and McDonald, 1979) are presented in Table 4.9 (a) and (b). These are; DM loss in the rumen at zero time (a), potential napiergrass degradability with sufficient time (b) and the degradability rate (c) of 'b'. It was observed that as the napier grass matured the dry matter disappearance rate decreased and this was reflected by the decline in the ruminal dry matter loss. In the present study a significant

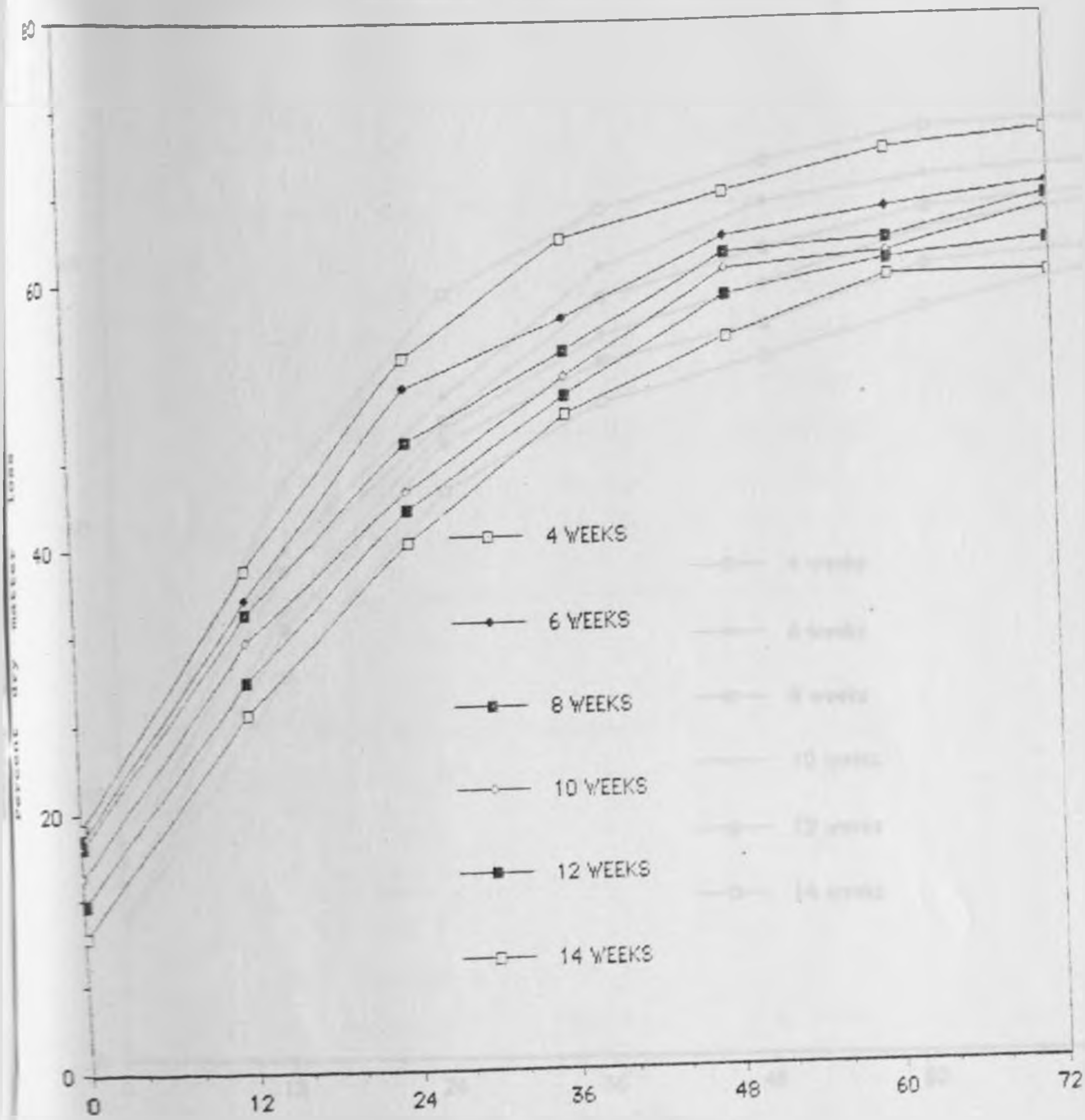

Fig. 4.1: Ruminal % DM loss in sacco using sheep (Bana grass)

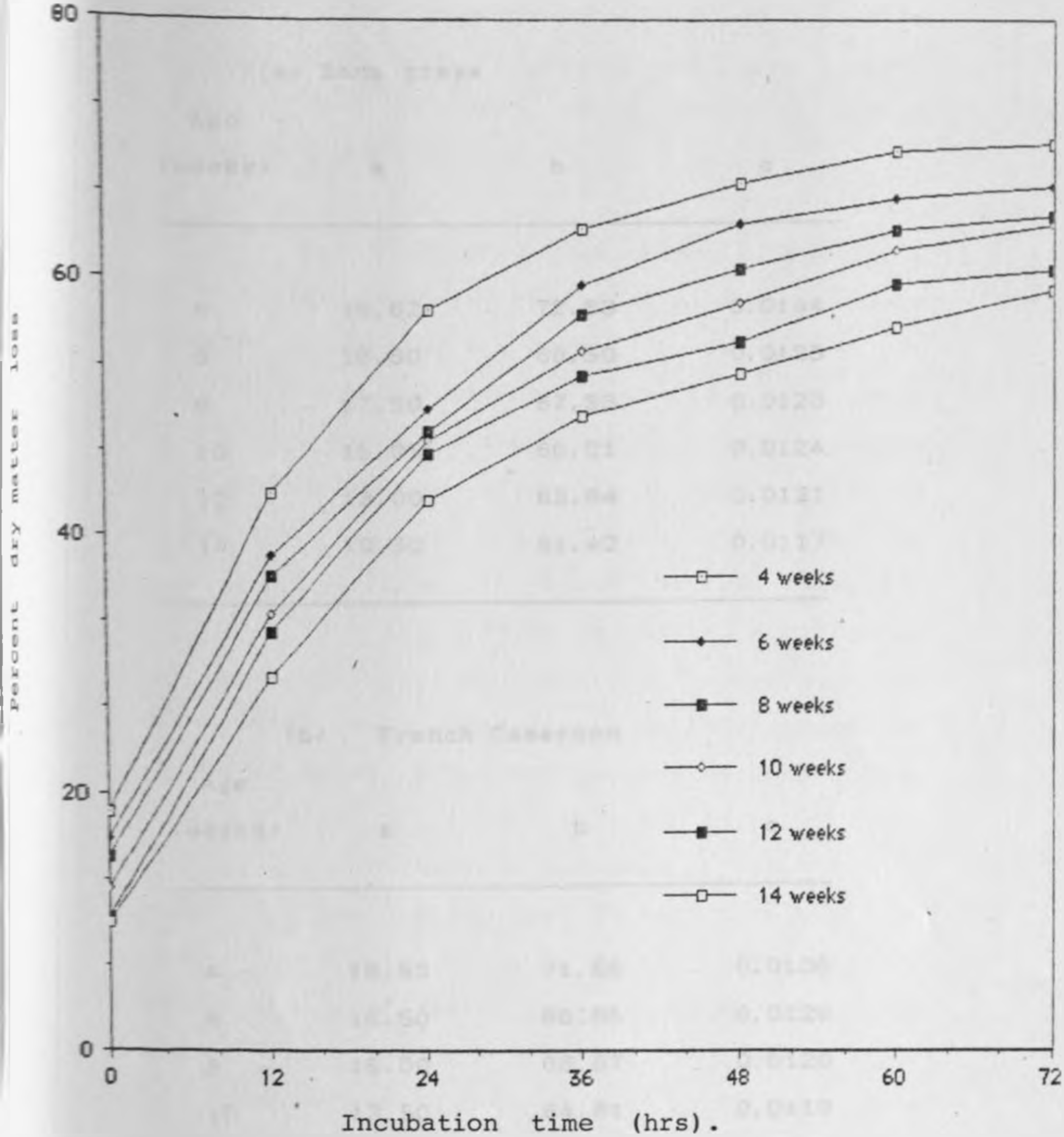

Fig. 4.2: Ruminal % DM loss <u>in sacco</u> using sheep (French Cameroon).

Table 4.9: DM degradability constants a, b and c used to fit in the degradation equation

(a) Bana grass

Age (weeks)	a	b	c
4	18.62	72.83	0.0144
6	18.50	68.50	0.0125
8	17.50	67.33	0.0123
10	15.05	66.21	0.0124
12	13.00	63.84	0.0121
14	10.50	61.42	0.0117

(b) French Cameroon

Age (weeks)	a	b	c
4	18.50	71.85	0.0136
6	16.50	68.85	0.0129
8	15.00	66.97	0.0120
10	12.50	64.81	0.0119
12	10.31	62.69	0.0109
14	10.00	61.07	0.0102

variation ($P<0.05$) in dry matter loss with incubation time and stage of growth was observed for both cultivars. Degradability was rapid between 0 and 36 hours after which a steady leveling off was observed.

The half-life ($T_{1/2}$) is shown in Table 4.10. The difference between half-life of the youngest napier (4 weeks) and the oldest is over ten hours. The time taken for half the dry matter incubated to be broken down was a reflection of the quality of the grass. Within half life it may be safe to assume that most of the material useful to the animal was degraded. The trend observed compares favourably with the changes in nutritive value as the napier grass matured. Cell wall components are known to increase with age and in this experiment a positive relationship was evident between crude fibre, detergent fibres, silica and lignin and the grass age. The remarkable decrease in percent dry matter loss and the increase in half-life was also probably due to the decrease in the crude protein content of the napier grass. Values of crude protein lower than 6-7% (Milford and Minson, 1966) are known to impair microbial activity and hence reduce digestibility and as observed from the proximate analysis data, the CP content after 8 weeks was lower than these critical limits for both varieties.

The relationship between the half-life ($T_{1/2}$) of dry matter degradation measured in the rumen

Table 4.10: The variation in half life ($T_{1/2}$) with changes in stage of growth.

Age (weeks)	Half-life $T_{1/2}$ (hours)	
	Bana grass	French Cameroon
4	48.16	51.03
6	55.44	53.72
8	56.57	57.75
10	57.32	58.09
12	58.18	63.35
14	59.18	67.88

Table 4.11: The relationships between half-life ($T_{1/2}$) and the detergent fibres, crude fibre, lignin and silica.

(a) Bana grass

Y	X	Regression	R^2
$T_{1/2}$	NDF	Y = 30.45 + 0.40X	0.75
$T_{1/2}$	ADF	Y = 32.35 + 0.66X	0.84
$T_{1/2}$	ADL	Y = 42.69 + 3.61X	0.76
$T_{1/2}$	Silica	Y = 34.54 + 3.68X	0.89
$T_{1/2}$	CF	Y = 33.71 + 0.71X	0.83

(b) French Cameroon

Y	X	Regression	R^2
$T_{1/2}$	NDF	Y = 2.93 + 0.86X	0.85
$T_{1/2}$	ADF	Y = 24.19 + 0.97X	0.86
$T_{1/2}$	ADL	Y = 40.65 + 4.85X	0.99
$T_{1/2}$	Silica	Y = 8.05 + 9.16X	0.93
$T_{1/2}$	CF	Y = 28.23 + 0.91X	0.80

and the crude fibre, detergent fibres lignin and silica content at different cutting stages are shown in Table 4.11 (a) and (b). As the CF, NDF, ADF, lignin and silica of the forage increased, the $T_{1/2}$ for degradation in the rumen increased indicating that the higher the level of fibres, lignin and silica in the forage, the longer it took to be degraded. This reflected the extent of microbial activity which seems to have been substantially curtailed by the increased levels of lignin and silica. The trend observed compares favourably with the results obtained for *in vitro* digestibility.

It was observed from the experiment that *in vitro* dry matter digestibility and the half life of the incubated napiergrass were highly correlated (r = -0.86). The relationship between half life (T1/2) and *in vitro* dry matter digestibility is illustrated graphically in Figure 4.3. It can be observed that when T1/2 is less than 56 hours, the digestibilty is greater than 64%. The linear regressions of $T_{1/2}$ against the digestibility coefficients are given in equations (4) and (5).

$$Y = 107.55 - 0.78X \qquad R^2 = 0.74 \qquad (4)$$

$$(r = - 0.86)$$

for Bana grass and,

$$Y = 107.56 - 0.74X \qquad R^2 = 0.74 \qquad (5)$$

$$(r = - 0.86)$$

for French Cameroon, where,

Y the dependent variable is the *in vitro* dry matter digestibility coefficient and X is the half life ($T_{1/2}$)

The greatest deviations in the relationships occur when fibres, lignin and silica contents are high and this explains the importance of these components in defining the nutritive value of napier grass.

5.0 CONCLUSION

The following inferences were drawn from the study:-

1. The dry matter matter yield, plant height, ash and percent dry matter were not significantly different between the cultivars Bana grass and French Cameroon. The components increased significantly with age for the two cultivars under study.

2. Crude protein, ether extract and potassium decreased with age. The numerical decline in phosphorus, potassium and calcium levels were not significant as the grass matured. The observed levels for calcium and phosphorus suggested supplementation for animals feeding on napier grass. In these, the two varieties were also not significantly different.

3. The detergent fibres (NDF and ADF), crude fibre and lignin increased as the grass matured. No significant differences were noted between the cultivars for detergent fibres and lignin. Silica declined with age while varietal differences were also significant.

4. Both digestibility *in vitro* and ruminal dry matter loss *in sacco* decreased with age. A high correlation between *in vitro*

digestibility and half-life, defined as the time taken for half the dry matter incubated to be broken down was observed.

5. Between 4 and 8 weeks cutting stages the crude protein levels were above the critical values (6-7%) and digestibility was high. However at 4 weeks both the dry matter yield and percent dry matter might be limiting. Thus 6 to 8 weeks is probably the appropriate stages to harvest since beyond 8 weeks crude protein becomes limiting although digestibility is reasonably high.

5.1 SCOPE FOR FURTHER WORK

1. Animal performance studies with napier grass alone or in combination with other feed resources (e.g. farm by-products) in terms of milk yield and liveweight gains.

2. Napier grass conservation methods to cater for feed deficit periods.

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6.0 APPENDICES

Appendix 1: ANALYSES OF VARIANCE TABLES

Appendix 1.1

Sources of variation	df	Error line	Mean Squares DMD	OMD	CP
Variety	1	a	.90	.50	6.57
Variety:Treatment (Error 1)	10	b	61.07*	81.00*	42.98*
Replication	2	b	.58	4.19	.53
Residual(Error 2)	22		1.58	1.71	.17

Appendix 1.2

Sources of variation	df	Error line	Mean Squares NDF	ADF	ADL
Variety	1	a	7.41	.35	.06
Variety:Treatment (Error 1)	10	b	178.06*	93.54*	3.79*
Replication	2	b	1.30	3.18	.22
Residual(Error 2)	22		15.08	3.78	.16

Key:

DMD = *In vitro* Dry Matter Digestibility
OMD = *In vitro* Organic Matter Digestibility
CP = Crude Protein
NDF = Neutral Detergent Fibre
ADF = Acid Detergent Fibre
ADL = Acid Detergent Lignin
a = Error 1
b = Error 2
* = $P<0.05$

Appendix 1.3

Sources of variation	df	Error line	Mean Squares CF	ASH	EE
Variety	1	a	38.23	89.59	.70
Variety:Treatment (Error 1)	10	b	92.55*	22.74*	1.10*
Replication	2	b	7.50*	4.79*	.10*
Residual(Error 2)	22		1.55	1.13	.02

Appendix 1.4

Sources of variation	df	Error line	Mean Squares K	Ca	P
Variety	1	a	3.15	0.00	0.00
Variety:Treatment (Error 1)	10	b	25.30*	0.01*	0.00*
Replication	2	b	0.00	0.00	0.00
Residual(Error 2)	22		.11	0.00	0.00

Key:
CF = Crude Fibre
EE = Ether Extract
K = Potassium
Ca = Calcium
P = Phosphorus
a = Error 1
b = Error 2
* = P<0.05

Appendix 1.5

Sources of variation	df	Error line	Mean Squares Si	DMY	L:S
Variety	1	a	14.03*	2.96	.25
Variety:Treatment (Error 1)	10	b	2.19*	25.74*	5.88*
Replication	2	b	.02	1.00	.04
Residual (Error 2)	22		.05	.67	.12

Appendix 1.6

Sources of variation	df	Error line	Mean Squares CH	NFE	DMP
Variety	1	a	10837.16	0.00	8.38
Variety:Treatment (Error 1)	10	b	6913.01*	0.00*	2.85*
Replication	2	b	4.79	0.00	.01
Residual(Error 2)	22		100.38	0.00	.15

Key:

Si = Silica
DMY = Dry Matter Yield
L:S = Leaf:Stem ratio
CH = Grass Height at Cutting
NFE = Nitrogen Free Extract
DMP = Percent Dry Matter content
a = Error 1
b = Error 2
* = P<0.05

Appendix II: Analysis of variance tables for ruminal dry matter loss

(a) Bana grass

Source	df	ss	ms	Fcal
Total	107	15066.52		
Blocks(sheep)	2	511.00	255.50	13.50
Treatments	35	13230.68	378.02	19.97
Incubation time	5	11222.87	2244.57	118.57
Stage of cutting	5	1314.68	262.94	13.89
I x S	25	693.13	27.73	1.46
Error	70	1324.84	18.93	

(b) French Cameroon

Source	df	ss	ms	Fcal
Total	107	16063.07		
Blocks(sheep)	2	74.81	37.41	1.60
Treatments	35	14332.00	409.49	17.31
Incubation time	5	11812.69	2362.54	99.85
Stage of cutting	5	2074.81	414.96	17.54
I x S	25	444.29	17.77	0.75
Error	70	1656.26	23.66	

<u>Appendix III:</u> Proximate composition of the feed offered to sheep under the nylon bag degradability trial

1. Rhodes grass (*Chloris gayana*)

Chemical constituent

%DM	CP	CF	EE	NFE	ASH
86.2	7.3	36.0	1.8	43.1	11.8

2. Dairy meal

Chemical constituent

%DM	CP	CF	EE	NFE	ASH
91.5	15.6	17.4	5.9	51.9	9.2

Appendix IV: Mean values of percent ruminal dry matter loss of napier grass at different stages of growth and varying incubation times.

(a) Bana grass

Time of Incubation (hrs)	Age in weeks 4	6	8	10	12	14
0	18.83	18.50	17.50	15.05	13.00	10.50
12	38.50	36.27	35.24	33.08	30.04	27.57
24	54.66	52.31	48.21	44.40	43.10	40.56
36	63.42	57.35	54.94	52.98	51.63	50.13
48	66.93	63.40	62.20	61.05	59.03	55.74
60	69.79	65.47	63.09	62.05	61.52	60.28
72	71.09	67.05	66.22	65.33	62.84	60.28

(b) French Cameroon

0	18.50	16.50	15.00	12.50	10.31	10.00
12	43.32	38.44	36.92	33.81	32.54	28.91
24	57.56	50.00	48.26	47.44	46.46	42.87
36	63.87	59.55	57.32	54.49	52.50	49.50
48	67.50	64.31	60.79	58.11	55.20	52.68
60	69.85	66.20	63.80	62.12	59.52	56.24
72	70.35	67.14	64.83	64.02	60.69	59.07