THE EFFECTS OF FREQUENCY AND HEIGHT OF CUTTING ON TILLERING, HERBAGE YIELD AND NUTRITIVE VALUE OF FOUR VARIETIES OF NAPIER GRASS

By

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DECLARATION

I declare that this thesis is my original work and has not been submitted for a degree in any other University.

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This thesis has been submitted for examination with my approval as the University supervisor.

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ABSTRACT

The effects of six-, eight-and ten-weeks cutting intervals and 0, 10 and 20 cm cutting heights and their combinations on tillering, herbage yield, crude protein and <u>in vitro</u> dry matter digestibility of four varieties of napier grass, namely, French Cameroon, Clone 13, Bana and a Bajra x napier hybrid were tested in a deep sandy loam soil of Embu Research Station.

Results from the first seven months of productive life indicated a major difference in the tillering pattern of the four grasses. Regrowth from Bana and Bajra x napier hybrid was dominated by basal and terminal shoots while that from French Cameroon and Clone 13 was dominated by basals and axillary shoots (tillers). The Hybrid napier consistently maintained the highest number of basal and terminal shoots.

Herbage yield (dry matter basis) responded linearly to the length of the cutting interval. Varieties French Cameroon, Bana and Hybrid napier outyielded Clone 13 but the overall yield range was narrow (7.4 - 9.4 t/ha).

Hybrid napier maintained superiority in crude protein content over the other three varieties throughout the duration of the study with a mean crude protein content of 15.46% as opposed to 12.73% in French Cameroon (lowest). The overall mean crude protein content dropped

from 14.58% to 12.91% when the cutting interval was increased from six to ten weeks.

Hybrid napier had a consistently lower in vitro dry matter digestibility (D-value) than the other three varieties. The range of D-values between French Cameroon, Clone 13 and Bana was extremely narrow at each defoliation. The effect of cutting interval on the D-value was inconsistent, initially assuming a negative relationship but subsequently showing a quadratic trend. Cutting height had no significant effect on the dry matter yield, crude protein content or D-value.

The results of this study indicated that within the range of cutting intervals and heights tested, herbage yield was a more appropriate criterion for choice of variety than crude protein content and D-value. They also indicated that so long as sufficient time for regrowth was allowed, cutting height was not a limiting factor to herbage yield. Visual observation however indicated a gradual weakening of the stand frequently defoliated (every six weeks) at the ground level.

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CHAPTER ONE

1.0 INTRODUCTION AND OBJECTIVES

Napier or Elephant grass (*Pennisetum purpureum* Schum.) is a robust, erect-stemmed perennial which occurs naturally throughout tropical Africa. It is widely grown in the rest of the tropical world between 10°N and 20°S and to a lesser extent in the temperate areas. It was identified originally by Schumacher in the late 18th century and may have been named later on after Colonel Napier of Rhodesia (now Zimbambwe) who popularised it as a fodder by recommending it to the Rhodesia Department of Agriculture in 1908 (Paterson, 1933). Other authorities thought it was named after Sir George Thomas Napier, Governor of Cape Colony in 1939-43 (Boonman, unpublished).

Napier grass grows in a wide range of climatic and other environmental conditions from sea level to well over 2000 m altitude, the upper limit being determined by its temperature requirement. It requires a high level of soil fertility and a liberal amount of soil moisture and can tolerate mild waterlogging. It is relatively more drought tolerant than most herbage grasses and owes this survival mechanism to a complex network of rhizomes.

Napier grass grows wildly along river banks and fallow land in the moist areas. Under cultivation, it is mainly established from cane cuttings or rooted splits. As a herbage grass it is highly valued because of its high yields, competitive vigour, persistence, palatability and quality especially during the early stages of growth (Bogdan, 1977). It has a special role as a dry season feed and may be conserved as silage or simply as standing forage. It has also been used extensively as mulch in coffee (Robinson and Chenery, 1958), as well as a soil and water conservation measure.

In Kenya, napier grass is increasingly gaining popularity as a forage crop especially in the small scale mixed farming areas of Central and Western Kenya. According to the 1980 rural survey statistics (Anon, 1980), the mean value of assets per holding in all the provinces is topped by livestock (Table 1.1). Yet within the total area under crops, the area under forage crops is neglibible. This is consistent with the findings of Chudleigh (1974) and Goldson (1977) that there was a trend towards zero grazing in Central and Western Provinces of Kenya.

Research on napier grass in Kenya has been mainly confined to the National Agricultural Research Station, Kitale, and Embu Agricultural Research Station. In spite of the available agronomic packages, there are information gaps. The obvious heterogeneity of cutting height (stubble) observed in farmers' fields is an indication of lack of definite recommendation based

Table 1.1. Mean value small-scale farmers' assets (all provinces)[1]

Item	Value (Ksh.)
Livestock	2,462
Land	1,800
Buildings	1,796
Crops in store	259
Transport equipment	234
Planted crops	174
Farm equipment	146
Inputs in store	14

[1] Source: Rural Survey Statistics, Statistical Abstracts 1978-80

on research data. Similarly, the wide range of recommended defoliation intervals (6-10 weeks) needs refinement. The frequency and intensity of defoliation have been found to influence the tillering pattern (Muldoon and Pearson, 1979a) and subsequent herbage yields of napier grass (Watkins and Severen, 1951). There is no documentary evidence of work done on napier tillering in East Africa.

The main objective of this study was to determine the effects of frequency and height of cutting on growth, productivity and nutritive quality of four varieties of napier grass.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 BOTANY

Pennisetum purpureum (Schum.) probably owes its species name "purpureum" to the purple tinge of its young spikelets (Boonman, unpublished). It is easily propagated from stem cuttings and stubble splits and once established regrows rapidly after cutting (Paterson, 1933; Khan and Syed, 1970). It grows to a height of 5-7 m with an average of 20 nodes per stem (Bogdan, 1977) but Boonman(unpublished) recorded 10.5 m with 105 nodes in Kitale, Kenya. However, the difference in node number may be a varietal effect. It has an underground rootstock with a complex network of rhizomes which form a clump up to 2 m in diameter and perpetuates regrowth even at the lowest stuble height.

The leaves are grabrous or pubescent and are borne at each node with their prominent and overlapping leaf sheaths enclosing a dormant axillary bud at each node. These buds normally remain dormant until the apical meristem is removed but in some varieties they develop into axillary shoots even when the apical meristem is intact (Bogdan, 1977).

The pre-flowering period of uninterrupted growth varies with varieties from as low as two months in French

Cameroon variety to nine months or more in Bana napier (Karanja, 1981). It produces a terminal cylindrical panicle with strongly protogynous flowers and although most varieties are capable of reproducing sexually, some varieties are known to be apomictic (Bogdan, 1977). Sexual reproduction in napier grass has been beneficially exploited. For instance, because of its low nutritive value and high oxalic acid content, napier grass was crossed with Bajra millet (Pennisetum typhoides (Burm.) S & H) and the resultant hybrid was said to be quick growing, high yielding and highly digestible (Gupta, 1975). High water soluble oxalate content in napier grass (1-3%) has been reported to lower the herbage palatability and intake by cattle (Muldoon and Pearson, 1979c). Existence of such hybrids has been documented and they are widely grown in India, Hawaii, South Africa and Australia (Muldoon and Pearson, 1979c).

2.1.1 Varieties

Napier grass varieties differ markedly in vegetative and floral characteristics as well as the chromosome number (Bogdan, 1977). There are diploids (2n = 28), tetraploids (2n = 56) and even irregular numbered varieties such as 2n = 27. While open pollination does intensify variability, plants within a variety are usually uniform as long as they are vegetatively propagated (Bogdan, 1977).

Being a native of tropical and sub-tropical Africa with subsequent widespread distribution, numerous cultivars do exist (Bateman and Decker, 1962).

Most cultivars were developed through intensive selection of local material with desirable characteristics (Goldson, 1977) and were named after the country or area of origin (e.g. Gold Coast and Ex-Meru respectively), the research station where developed (e.g. San Carlos) or simply given a serial number such as K5487, where K stands for the name of a station (e.g. Kitale). While quantitative rather than qualitative differences are obvious in napier varieties, varietal identification on sight is often difficult due to an overlap of morphological characteristics. The better known cultivars are Merker and Merkeron, (popular in South America), Napier (at times used to refer to a particular cultivar), Capricorn (developed in Australia), Mineiro (popular in South America) Uganda hairless or Uganda, Cubano, Domira, Panama and Gold Coast. These have been characterised briefly by Bogdan (1977).

In Kenya, the most popular varieties are French Cameroon, Gold Coast and Cameroon (from West Africa), Uganda hairless (from Uganda) and Bana, a controversial variety from Southern Africa (Karanja, 1981). The West African varieties were introduced in East Africa in the early 1950's while Uganda hairless was bred at Kawanda, Uganda in the early 1930's (Boonman, unpublished). The earliest record of a napier x millet hybrid in Kenya dates back to 1954. Boonman (unpublished) has in record an entry K5487 in the Kitale collection, an alleged Babala millet x napier hybrid imported from South Africa. The hybrid was, however, found to be a poor herbage yielder relative to other napier varieties and was discarded.

2.2 ESTABLISHMENT

2.2.1 Planting material

Napier grass may be established from seeds, stem cuttings or stubble splits (Khan and Syed, 1970; Bogdan, 1977; van Gastel, 1978). Establishment from cane cuttings is by far the most popular. Use of seeds is mainly confined to glasshouses due to poor germination under field conditions. On the other hand, stubble splits are not only difficult to dig up manually but also require a large source area (Oyenuga, 1958; Ranjhan and Talapatra, 1967; Capiel and Ashcroft, 1971; van Gastel, 1978; Boonman, unpublished; Chew, Ramli and Majid, 1982). The rate of establishment and the uniformity of a stand established from stem cuttings are largely dependent on the age of the stems, position along the stem length and the angle of placement into the ground. Khan and Syed (1970) reported the best establishment of a napier - bajra hybrid from cuttings planted vertically and obtained from the lower two-thirds of three months old stems.

2.2.2 Spacing

Within certain limits, spacing within the high rainfall areas is not a crucial problem. The documented range for both napier and its hybrids is quite narrow. On the upper side, Wilsie, Akamine and Takahashi (1940) reported a spacing of 120 cm x 60 cm in Hawaii while

Muldoon and Pearson (1977a) preferred 100 cm x 100 cm in Australia, a spacing that was, until recently, recommended for all napier varieties in Kenya. On the lower side, Diaz (1968) reported a spacing of 50 cm x 50 cm while Chew et al. (1982) reported an extremely close spacing of 30 cm x 20 cm in Malaysia. Intermediate spacings have been reported in Trinidad (Paterson, 1933), Kenya (Maher, 1936; Boonman, unpublished) and Nigeria (Oyenuga, 1958). The choice of spacing mainly depends on the rainfall, growth habit of the napier variety and the weed control method. Wider spacing is recommended in the lower rainfall areas and in areas where mechanised weed control is practised while closer spacing is recommended for non-rhizomatous cultivars such as the Napier-Bajra hybrid.

2.2.3 Weed control

In spite of its size and vigour, napier grass is highly susceptible to weed competition especially within the first two years (Goldson, 1977). A seedbed free from perennial grass weeds such as couch grass (Digitaria scalarum. L.) and nut sedge (Cyperus sp. L.) is strongly recommended. Post-planting weed control measures include manual weeding, mechanical means such as inter-row cultivation, rotovation or ridging (Bateman and Decker, 1962; Ure and Jamil, 1957) and use of herbicides such as Atrazine and Paraquat (Capiel and Ashcroft, 1971; Williams, 1980).

2.3 TILLERING

Tillering is important in determining dry matter yields in forage grasses. In his extensive investigations on some components of yield in Lolium perenne (L.), Gurnah (1968) considered the final dry matter yield as a function of the number of tillers, the size of the tillers and the proportion of the tillers harvested. This is true for most grasses especially under cutting management.

Considerable amount of work on tillering has been conducted under controlled environments, mainly on temperate grasses (Weinmann, 1948; Alberda, 1966; Gurnah, 1968). In spite of their physiological differences, the temperate and tropical grasses have shown many similarities in their tillering pattern and response to defoliation. For instance, the two types of grasses have been shown to depend heavily on non-structural carbohydrate reserves for their early regrowth (2-7 days after cutting). The predominant carbohydrates in temperate grasses are sucrose and fructosans while sucrose and starch predominate in tropical and sub-tropical grasses (Weinmann, 1948, White, 1973). In general, the main factors affecting tillering in herbage grasses are variety, plant spacing, frequency and intensity of defoliation, soil nutrient status, temperature and soil moisture content.

2.3.1 Effect of frequency of defoliation on tillering

After defoliation, napier grass regenerates through terminal regrowth or bud development (axillary or basal). The predominance and subsequent vigour of basal, axillary or terminal shoots in a napier regrowth will be determined by the severity of defoliation.

Paterson (1933) reported poor tillering and subsequent death of napier stools cut every four weeks in Trinidad. He reported a 42% stool survival as opposed to 83 and 88% survival in 8 and 12 weeks cutting intervals respectively and concluded that frequent cutting reduced the vigour of the plants and probably predisposed them to *Helminthosporium* infection and hence the high mortality. This was in line with the work of Wilsie *et al.* (1940) in Hawaii, who reported the lowest tiller density (13.4 tillers/plant) in the six-weeks cutting interval compared to 23.5 and 26.6 tillers/plant in the 8 and 12 weeks cutting interval, respectively. Muldoon and Pearson (1977b) found that the proportion of hybrid napier tillers cut above the apical meristem decreased linearly with time. With a fixed cutting height of 20 cm, they found that the apical meristems were below the cutting height during the first five weeks after defoliation but subsequent stem elongation resulted in over 50% apical meristems above the cutting height by the ninth week.

The foregoing discussion indicates that frequent defoliation is likely to reduce the number of tillers per plant through tiller mortality due to reduced vigour or poor tiller development due to inadequate non-structural carbohydrate reserves in the storage organs. This is likely to affect the herbage yields and the stand persistence adversely.

2.3.2 Effect of intensity of defoliation on tillering

Documented information on the effect of cutting height on tillering in napier grass is scant. Results from other bunch type perennial grasses however indicate that low cutting heights are detrimental to tillering especially under frequent defoliation. Huokuna (1966) reported a 50% reduction in tiller density in a meadow fescue (*Festuca elatior, L.*) sward cut frequently (6 times in summer) at 1 cm relative to a similar sward cut twice in summer at 15 cm above the ground. Colby, Drake, Oohara and Yoshida (1966) obtained similar results in Massachusetts, U.S.A. and Hokkaido, Japan. Working with *Dactylis glomerata* (L.) cut at early heading and full flower and at 3.5 and 7.0 cm, they found the best recovery in the early heading, 7.0 cm treatment and the worst recovery from the full flower, 3.5 cm treatment.

In napier grass, Wilsie *et al.*(1940) found that beyond 6-weeks cutting interval, most apical meristems were above the 5 - 7.6 cm cutting height and hence were removed, leading to basal and axillary tillering.

This was in agreement with subsequent findings by Muldoon and Pearson (1979a) who recorded 13 and 7.5 new tillers from hybrid napier plants with decapitated and intact apical meristems respectively, 16 days after defoliation. While new growth, especially leaves, was initiated earlier in intact plants, subsequent extensive tillering in decapitated plants resulted in rapid increase in new growth.

It can be concluded that, so long as the apical meristem is not affected by a defoliation regime, the effect on tillering is minimal. Where the apical meristem is affected, the effect on the tillering pattern will depend on the cutting height - that is, low cutting encourages basal tillering while high cutting encourage axillary tillering.

2.3.3 <u>Effect of reserve substances on tillering</u>

Within the first 2 - 7 days after severe defoliation, herbage grasses utilize reserve non-structural carbohydrates stored in the basal stem, rhizomes or other underground organs for regrowth. Weinmann (1948) and White (1973) considered sugars, fructosans, glueosans and starches as the most important reserve substances but Dilz (1966), Davidson and Milthorpe (1966) suggested that proteins were also mobilised for regrowth. Fructosans and sucrose have been associated with temperate grasses while sucrose and starch have been associated with tropical and sub-tropical grasses. Bommer (1966) reported a gradual increase in sucrose and fructosans in three temperate grasses in Germany while Adegbola (1966) reported more sucrose than fructosan in the roots and rhizomes of Cynodon dactylon (L.) in California, U.S.A.

Most grazing and cutting regimes aim at high level of non-structural (soluble) carbohydrates in the roots and basal stem of forage grasses and a leaf area index leading to maximum net photosynthesis (Humphreys and Robinson, 1966). This will ensure rapid post-defoliation regrowth. Alberda (1966) and Dilz (1966) reported a rapid decline in soluble carbohydrates in the stem and roots of Lolium perenne (L.) reaching a minimum about 7 days after defoliation after which there was a steady increase due to resumption of photosynthetic activity. Alberda (1966) found that when the stubble soluble carbohydrate content was less than 10% there was high tiller mortality since this level could not support all the available tillers. They concluded that frequent cutting before the original carbohydrate level is restored leads to a gradual stool weakening and eventual death.

In Australia, Muldoon and Pearson (1979a) reported carbohydrate movement from the stems and leaf sheaths into new growth of hybrid napier plants for up to 8 days after defoliation. None of the carbohydrates came from the roots and although most of the translocated carbohydrates came from the ethanol soluble fraction, there was evidence of possible protein and polysaccharide mobilization.

2.3.4 Other factors affecting tillering

There is now sufficient evidence to associate tiller development with reserve carbohydrates. Factors that affect the level or mobility of these carbohydrates are therefore likely to affect tillering. Weinmann (1948) considered seasonal effects, nutrient level, temperature, soil moisture and light as the most important factors.

2.3.4.1 Seasonal effects

These have been reviewed in detail by Weinmann (1948) in a wide range of tropical and temperate grasses. He concluded that soluble carbohydrates increased progressively during the growing season reaching a maximum soon after flowering, after which they were translocated to the underground storage organs to be used during the next growing season. Singh, Dogra and Bhatia (1973) reported a gradual increase in soluble carbohydrate, cellulose and lignin in hybrid napier even after flowering but a gradual decline in the levels of protein and total minerals.

2.3.4.2 Nutrients

Both the level of reserve carbohydrates and tillering respond positively to balanced N-P-K application (Weinmann, 1948; Langer, 1963). Individually, the effect of nitrogen application has been rather inconsistent. In his review, Weinmann (1948) noted cases where nitrogen fertilization either increased, decreased or had no effect on carbohydrate reserves. On tillering, Muldoon and Pearson (1977a) reported a steady increase in tiller number in irrigated hybrid napier with nitrogen application up to 500 kg N/ha but a drastic decrease at 1000 kg N/ha. Under dryland conditions, there was positive response only up to 250 kg N/ha. Similar results were reported by Colby et al. (1966) who cautioned that liberal amounts of nitrogen were likely to depress the soluble carbohydrate reserves to critical levels especially in the hot and dry weather leading to plant injury and death.

Available evidence on the effect of other nutrients on underground development and tillering is also contradictory. Langer (1963) reported significant N x P and N x K interactions indicating that at low levels of N the effects of phosphorus and potassium were less marked. In his extensive review, Weinmann (1948) cited the works of Sprague (1933) who found no correlation between soil phosphorus and root development of various perennial grasses, and Haynes (1943) who reported positive correlation between the levels of available potassium and phosphorus and root growth of New Jersey blue grass (Poa sp.,L.) He attributed the inconsistency to the diversity of conditions under which the investigations were carried out.

2.3.4.3 Temperature

Temperature plays a dominant role in determining the seasonal pattern of carbohydrate reserves. Colby *et al.* (1966) reported a drastic drop in soluble carbohydrates level in *Dactylis glomerata* (L.) from 20 to 4% within 16 days towards the onset of summer in U.S.A. More recently, Muldoon and Pearson (1979b) reported an increase in the rate of mobilization of soluble carbohydrates in hybrid napier with increase in temperature within 18/13 - 30/25°C (day/night) range. In a separate investigation, Muldoon and Pearson (1979a) reported an increase in tiller number with increase in temperature up to 21/16°C.

It can be concluded that, within certain limits, increase in temperature results in increase in the rate of mobilization of soluble carbohydrates and hence tiller emergence. The actual optimal temperature ranges are, however, characteristic of individual grass species.

2.3.4.4 Light

In his review of the effect of light on tillering in *Lolium perenne* (L.), Gurnah (1968) concluded that tiller numbers were positively related to the total light energy receipt. In line with this, Mitchell and Glanday (1958) considered the presence of dead leaf sheaths around the base of herbage grasses as a restriction to tiller development, and their removal through defoliation as a "stimulant" to tillering. This was consistent with the work of Boonman (unpublished) who reported a steady increase in tiller density (tillers/m^2) in a napier grass stand (c.v. French Cameroon) up to 3 weeks after clean cutting in Kitale, Kenya. Thereafter, there was no more tillering as the leaf canopy had closed in. He also reported a higher tiller mortality among the tillers that emerged late. Huokuna (1966) associated high cutting height of meadow fescue (Festuca elatior, L.) (15 cm) with basal shading and hence higher tiller mortality compared to low cutting (1 cm).

It can be concluded that light has a marked influence on tillering and that any form of shading is likely to affect tillering adversely. Defoliation appears to stimulate tillering in two ways; firstly through removal of the shading effect and hence exposure of basal buds to light, secondly through removal of apical meristems and hence activation of the axillary buds.

2.4 DRY MATTER YIELDS

Extensive investigations on dry matter yields in napier grass have been conducted in the Carribean Islands (mainly Puerto Rico), Central and South America, East, Central and West Africa, Australia and the Orient (Mwakha, 1972; Muldoon and Pearson, 1979c). Documented yields have varied from one region to the other depending on the varieties and cultural practices. Yields of up to 86 t/ha dry matter (DM) have been reported (Vincente-Chandler, Silva and Figarella, 1959) under intensive management and heavy nitrogen fertilization of up to 2 t/ha N. In East Africa, yields of 10 - 40 t/ha are often quoted (Goldson, 1977) while in Australia and Southern Asia, yields of 11 - 43 t/ha for hybrid napier have been reported (Muldoon and Pearson, 1977a and 1979c).

2.4.1 Effect of cutting frequency on dry matter yields

A positive correlation between dry matter yields and the length of defoliation interval has been reported by various investigators. In Puerto Rico Vincente - Chandler et al.(1959) reported a steady increase in both DM yield and per cent DM content with increase in cutting interval from 40 to 90 days at all levels of N tested over a three year period. The 90-days cutting interval also produced a higher residual DM yield six months after the end of the trial. At all levels of N, the 90-days interval gave about three times the DM yield of the 40-days interval. The mean DM content in the study were 14.1, 17.1 and 25.1% for the 40, 60 and 90-days treatments, respectively. In the same area, Rivera-Brenes, Cestro and Sierra (1962) reported DM yields of 27.17 and 46.53 t/ha for 60 and 90 days cutting intervals, respectively, while Capiel and Ashcroft (1972) obtained 35.85 and 42.88 t/ha DM with 14.45 and 16% DM content from 45 and 60 days cutting intervals, respectively. Their findings were consistent with those of other Puerto Rican investigators, notably Figarella, Vincente - Chandler, Silva and Caro-Costas (1964), Caro-Costas and Vincente-Chandler (1961), Vincente-Chandler and Figarella (1962) and Little, Vincente-Chandler and Abruna (1959) who reported a DM yield range of 26.05 - 66.70 t/ha with 16.24 - 18.50% DM content from a fixed cutting interval of 60 days.

In Hawaii, Wilsie et al.(1940) more than doubled the DM yield from 20.12 to 48.55 t/ha with a corresponding increase in DM content from 12.54 to 19.81% by increasing the cutting interval from 42 to 98 days, a trend which was also reported in El Salvador (Watkins and Severen, 1951). In Brazil, Gomide, Noller, Mott, Conrad and Hill (1969)reported a linear increase in DM content from 12.20 to 43% with an increase in cutting interval from 28 to 252 days while Rodriguez and Blanco (1970) reported an increase in DM content from 16.52 to 31.69% and 8.94 to 22.31% for leaf and stem fractions, respectively, with an increase in cutting interval from 30 to 60 days in Venezuela. Significant increases in fresh herbage yields were also reported in Sri Lankha where de Mel and Joachim (1937) reported an increase from 114.73 to 163.57 t/ha with an increase in cutting interval from 30 to 60 days. In absence of DM content data, however, fresh herbage yields are likely to be misleading especially in the high rainfall areas such as Sri Lankha where 2415 mm of rainfall per annum was recorded.

Similar trends have been reported in hybrid napier. In India, Ranjhan and Talaptra (1967) reported a steady increase in DM content from 17% at 57 days to a peak 29% at 120 days followed by a drop to 22.50% at 186 days. No explanation was offered for this final drop. In Australia, a 42-days cutting interval has been adopted for hybrid napier and DM yields of about 11.00 t/ha are often quoted (Muldoon and Pearson, 1977a).

In Nigeria, Oyenuga (1958) reported increase in both DM yield and DM content from 4.79 t/ha and 16.50% to 13.72 t/ha and 25.90%, respectively, with increase in cutting interval from 21 to 84 days. He reported an almost linear relationship between DM content and cutting interval but an inverse relationship with the amount of rainfall. In Kenya, Mwakha (1972) reported significant increases in DM yields with increase in cutting interval from 60 to 240 days. He also reported a steady increase in the stem fraction and the stem DM yield with increase in cutting interval. A similar trend was reported in Embu, Kenya (Anon. 1973) where an increase in cutting interval from 60 to 120 days increased the DM yields from 18.07 to 28.24 t/ha with a corresponding increase in the stem fraction from 24.90 to 39.67%.

From the forage utilization viewpoint, the leaf; stem ratio is an important aspect of forage yields. An inverse relationship between leaf: stem ratio and the length of the cutting interval has been reported. Oyenuga (1958) reported a rapid drop in leaf: stem ratio from 12:1 to 1.3:1 with an increase in cutting interval from 21 to 42 days while in India, Ranjhan and Talapatra (1967) reported a drop from 2.6:1 to 1:1 and finally 0.3:1 when the cutting interval was progressively increased from 57 to 64 and finally to 172 days. The relatively stable leaf: stem ratio between 64 and 172 days was a reflection of the combined effect of reduced leaf emergency and loss of leaf through senescence after flowering in hybrid napier. This was consistent with subsequent investigations by Mwakha (1972) in Kenya who reported a gradual decrease in the leaf: stem ratio from 2.1:1 at 60 days to 0.77:1 at 120 days and finally 0.28:1 at 240 days.

2.4.2 Effect of cutting height on DM yields

The effect of cutting height on DM yields of napier is a rather controversial subject. Recommendations vary from cutting at the ground level to well over 100 cm (Wilsie *et al*. 1940).

In Puerto Rico, Caro-Costas and Vincente-Chandler (1961) reported higher DM yields from close cutting (0-7.60 cm) compared to high cutting (17.80 - 25.40 cm).

They obtained 31.31 and 26.05 t/ha DM from low and high cutting, respectively. This was in line with the conclusion drawn by Boonman (unpublished) in East Africa that cutting at the ground level removed old and dead shoots which inhibit basal bud development, thus encouraging tillering and high DM yields. Kusewa, Kamau and Wanjala (1977) however reported beneficial effects of low cutting only in the first production year. They reported a reduction in DM yields from 14.57 to 12.15 t/ha with increase in cutting height from ground level to 30 cm within the first production year, after which the trend was reversed, with the ground level cutting giving 22.47 t/ha DM compared to 24.66 t/ha in the 30 cm cutting height. A similar trend was reported at Embu, Kenya (Ngare, 1978).

The effect of cutting height on tillering and subsequent DM yield in herbage grasses is known to be cummulative (May, 1960). Continuous close cutting is therefore likely to be detrimental to the productive life of a napier stand and this probably explains the decline in yield in low cutting beyond the first year. Most investigators recommend a certain amount of stubble for rapid regrowth. Thus, Goldson (1977) recommended a stubble height of at least 25 cm. Citing the work of Tomer, Singh and Bishnoi (1974) he reported a gradual increase in fresh herbage yield from 112.40

to 124.80 t/ha with increase in cutting height from 15 to 45 cm. He attributed the low yields from the low cutting height to the removal of the growing points resulting in slow regeneration and leading to poor persistence. In El Salvador, Watkins and Severen (1951) obtained the maximum DM yields (85.47 t/ha) from 20 cm cutting height and associated the relatively lower yields in the close cutting treatment (10 cm) with a stand reduction to 30% as opposed to 66% in the high cutting (30 cm).

Documentary evidence of significant interaction between cutting frequency and cutting height is scant. Watkins and Severen (1951) however reported the highest DM yields from 90 days cutting interval at 20 cm cutting height. He reported a severe stand reduction due to stool mortality in the low cutting height. Similar significant interaction effects were suggested by Boonman (unpublished) in his discussion on the work of Dirven (unpublished) in Surinam. He reported that a lower cutting height was more effective with infrequent cutting, while a more frequent defoliation regime demanded a higher stubble height.

2.4.3 The varietal effects

Significant differences in DM yields between napier varieties have been reported by many investigators. In Costa Rica, Bateman and Decker (1962) reported highly significant differences in DM yields between nine varieties of napier cut at three and six weeks intervals within a six months period. In Venezuela, Rodriguez and Blanco (1970) reported significant varietal differences in leaf and stem DM content in 21 varieties of napier grass. The leaf and stem DM content ranges were 20.23 - 29.10% and 11.23 - 20.97%, respectively. Similar results were reported by Mozzer, Carvalho and Emrich (1970) in Brazil, where they obtained a DM yield range of 2.23 - 28.93 t/ha in 12 varieties and hybrids of napier.

Significant differences in DM yields have also been reported among different strains of hybrid napier. Muldoon and Pearson (1979c) attributed such differences to genotypic and phenotypic differences, ecological adaptation and variations in climatic and cultural conditions. Khan (1966) reported a fresh herbage yield range of 72.70 - 112.80 t/ha in 12 strains of hybrid napier in Pakistan. Similar results were reported in Malaysia where Ure and Jamil (1957), working with a local napier variety and four imported strains of hybrid napier obtained a fresh herbage yield range of 68.60 - 109.80 t/ha, with the local variety outyielding all the hybrid napier strains.

Varietal differences have also been reported in Kenya where varieties French Cameroon, Bana and Gold Coast have consistently outyielded other local and introduced varieties such as Ex-Meru, Ex-Limuru, Uganda Hairless and Cameroon. In Embu, an annual fresh weight yield range of 55.70 - 116.00 t/ha and a subsequent DM yield range of 12.00 - 21.70 t/ha in six napier varieties was reported (Anon., 1971, 1972). Kusewa et al. (1977) reported a DM yield range of 8.20 - 28.40 t/ha over a three - year period in three sites in Western Kenya, while in a similar trial in Embu, Karanja and Ngare (1979) reported a DM yield range of 21.24 - 29.17 t/ha.

These findings underscore the wide genetic variability in napier which could be used in selecting high yielding varieties.

2.5 CRUDE PROTEIN CONTENT AND DM DIGESTIBILITY

During the early stages of napier regrowth (up to four weeks), its crude protein content (% CP) has been reported to be extremely high. Values of up to 22% CP have been reported in Trinidad (Paterson, 1933), Costa Rica (Bateman and Decker, 1962) and Australia (Muldoon and Pearson, 1979c). There is, however, an inverse relationship between herbage CP content and the length of the cutting interval. Available documentary evidence suggests varietal differences in CP content and possible environmental effects.

2.5.1 Effect of cutting frequency on CP content and CP yield

Paterson (1933) reported a drop in CP content from

9.85 to 6.09% with increase in cutting interval from 28 to 84 days. The corresponding CP yield was 855 and 1308 kg/ha. In Puerto Rico, Vincente-Chandler et al. (1959) reported a gradual decline in CP content from 12.10 to 6.73% with increase in cutting interval from 40 to 90 days. This decline was recorded at all levels of N tested up to 2.25 t/ha. They recommended a 60-days cutting interval as a reasonable compromise between dry matter (DM) yields and CP content. The CP yield trend was similar to that reported by Paterson (1933). These findings were in agreement with those of Rivera-Brenes et al. (1962) and Capiel and Ashcroft (1971). The CP yield trend reported by Capiel and Ashcroft (1971) however was in sharp contrast to that reported by the other investigators. They reported a slight drop from 4.62 to 4.33 t/ha CP with increase in cutting interval from 45 to 60 days. Such inconsistency may have been due to varietal and soil factor differences.

Decreases in herbage CP content with increase in cutting interval have also been reported in Hawaii (Wilsie et al., 1940), El Salvador (Watkins and Severen, 1951) Costa Rica (Bateman and Decker, 1962), India (Ranjhan and Talapatra, 1967) and Brunei (Williams, 1980). Bateman and Decker (1962) reported an extremely high CP content (22%) in the first cut of a 21-days cutting interval treatment. Subsequent cuts gave lower values with an overall three-cuts mean of 16.50 and 14.20% CP for the 21 and 42 days cutting interval, respectively.

Gomide *et al.* (1969) reported a drastic drop in CP content from 23.80nto 12.40% with increase in cutting interval from 28 to 56 days. Beyond 56 days, the drop was more gentle with 6.30% CP at 224 days. Wilsie *et al.* (1940) reported a steady drop in herbage CP content with increase in cutting interval from 42 to 98 days. However, he reported that there was no significant correlation between CP yield and cutting frequency.

Although the leaf fraction contains a higher CP content than the stem fraction, the trend of decline in CP content with maturity in the two fractions is similar. In Brazil, Rodriguez and Blanco (1970) reported a decline in leaf and stem CP content from 12.75 and 7.54% to 6.14 and 2.07%, respectively with increase in cutting interval from 30 to 90 days. This was consistent with subsequent findings by Mwakha (1972) in Kenya, who reported a decline in leaf and stem CP content from 13.8 and 8.4% to 8.7 and 2.8%, respectively with increase in cutting interval from 60 to 240 days. Oyenuga (1958) also reported a steady decline in leaf CP content from 14.74 to 84 days. Once again, he reported that there was no significant correlation between leaf CP yield and cutting frequency.

The gradual decline in the herbage CP content with napier maturity has been attributed partly to the gradual increase in structural components at the expense of the non-structural components of plant cells. Structural components include cellulose, hemicellulose, lignin, cutin, silica and polyphenols while the non-structural components include soluble carbohydrates, starch, protein, organic acids and pectin (van Soest, 1973). Muldoon and Pearson (1979c) reported a decrease in CP from 22% at two weeks to 9% at 16 weeks in hybrid napier, while crude fibre (CF) and nitrogen-free-extract (NFE) increased from 17 to 32% and 39 to 44%, respectively, over the same period. They also reported an increase in total carbohydrates, cellulose and lignin. Reduction in CP content with napier maturity may also occur due to the dilution effect especially where soil nitrogen is a limiting factor (Vincente-Chandler *et al.*, 1959).

2.5.2 Effect of cutting height on CP content and yield

While no significant responses of CP content to cutting height have been documented, the CP yield has been shown to follow the DM yield trend. In El Salvador, Watkins and Severen (1951) reported no effect of a cutting height range of 10-30 cm on CP content. Caro-Costas and Vincente-Chandler (1961) recorded very slight differences in both CP content and yield in response to low (0-8 cm) and high (17-25 cm) cutting in Puerto Rico. The respective CP content and yield were 9.20 and 10.30%, 2.88 and 2.68 t/ha. In Kenya, Ngare (1978) reported a three-year mean CP content of 12.75, 12.17 and 12.39% for 0, 15 and 30 cm cutting heights, respectively at Embu. The corresponding CP yields were 3.45, 3.16 and 2.92 t/ha, a trend which was consistent with that of the DM yields.

2.5.3 Varietal effects

Varietal differences in CP content and CP yields have been reported. Rodriguez and Blanco (1970) reported a CP content range of 5.31 - 8.10% in 21 varieties and hybrids of napier in Brazil. No DM or CP yields were reported. Other investigators have reported insignificant varietal differences in CP content. Under such circumstances, the CP yield has varied directly with DM yields. In Malaysia, Ure and Jamil (1957) reported a fairly uniform CP content and CP yields in a local napier variety and four Hawaian hybrids. This was consistent with subsequent findings in Embu, Kenya, where no significant differences in CP content have been detected in all the varieties tested so far (Anon.,1973, 1978, 1979). The CP yields, however, have been extremely variable and varieties French Cameroon, Gold Coast and Bana, by virtue of their superiority in DM yields, have outyielded all the other varieties.

The stability of CP content of napier grass means that by maximising the DM yields, the CP yield will also be maximised.

2.5.4 Effect of frequency and height of cutting on digestibility

Generally, the soluble carbohydrates content decreases while the structural carbohydrate content increases with herbage maturity. Paterson (1933) reported an increase in crude fibre (CF) content from 24.01 to 31.47% with increase in cutting interval from 28 to 84 days. He however considered this difference insignificant from the animal nutrition point of view especially because of the high DM and nutrient yield associated with the infrequent defoliation. Although no digestibility data was reported, he observed that Zebu cattle consumed the coarse material with obvious relish and assumed that within the defoliation interval range tested, digestibility was not significantly affected. He concluded that appreciable change in digestibility took place only after lignification has started, and that was, in most varieties, at the flowering and seeding stage. Similar trends were reported in Hawaii (Wilsie *et al* 1940), Nigeria (Oyenuga, 1958) Costa Rica (Bateman and Decker, 1962), Venezuela (Butterworth, 1965), Brazil (Gomide *et al*. 1969; Rodriguez and Blanco, 1970) and Brunei (Williams, 1980).

Lignin is essentially indigestible and considerably lowers the digestibility of the associated cellulose and hemicellulose (van Soest, 1973). Vincente-Chandler *et al*. (1959) reported an increase in lignin content from 7.17 to 10.78% with increase in cutting interval from 40 to 90 days. This was consistent with subsequent findings by Muldoon and Person (1979c) who quoted a lignin content of 11% for a 63-days old hybrid napier herbage.

The herbage in vitro digestibility is often reported in form of dry matter digestibility (DMD), organic matter digestibility (OMD) or cellulose digestibility (cellulose - D) and in all cases, an inverse relationship with herbage maturity has been reported. Thus, Gomide et al. (1969) reported a sharp and early decline in cellulose digestibility from 75.6 to 52.2% and finally 31% with increase in cutting interval from 28 to 84 and finally 252 days,respectively. They attributed the early drop to early lignification in tropical grasses, reported to start as early as four weeks after defoliation in napier grass (Oyenuga, 1958). This was contrary to Paterson's views (Paterson, 1933) who errered in assuming that herbage intake and digestibility were synonymous.

Muldoon and Pearson (1979c) reported in vitro DMD and OMD ranges of 52 - 62% and 52 - 67%,respectively in hybrid napier. These ranges were close to but not within the ranges they had obtained earlier on (Muldoon and Pearson, 1977a and b). In one trial, they found a leaf OMD range of 54.2 - 72.1% under a 42-days cutting regime. In a subsequent trial, the leaf in vitro OMD range was 50 - 75% with a peak at 28 days after defoliation. The stem OMD was on the average 7.7% higher than leaf OMD and the latter decreased at the rate of 0.17 units per day prior to an increase after the eleventh week. They concluded that a six to seven weeks defoliation interval would yield a reasonable quality forage with about 8.75% CP and 62% OMD.

No varietal or cutting height effects on digestibil: have been reported in the limited literature reviewed.

From the foregoing review, it is evident that in spite of the general wealth of information on napier gra: establishment and management at the international level, there are still a lot of information gaps. The subjects of tillering and the role of reserve carbohydrates in regrowth have not been tackled in Africa. Similarly, th effects of frequency and height of cutting on the nutritive value, particularly organic matter digestibili has not been determined in East Africa. In view of the general trend towards intensive livestock feeding system in the high potential small-scale farming districts of Kenya it is important to fill existing information gaps to ensure a complete forage establishment, management and utilization package for the farmer.

The objectives of this study thereforewere to determine the effect of frequency and height of cutting on the tillering pattern, herbage yield, crude protein content, CP yield and in vitro DM digestibility of four varieties of napier grass.

CHAPTER THREE

3.0. MATERIALS AND METHODS

3.1 SITE DESCRIPTION

The trial was conducted at Embu Agricultural Research Station, Kenya, located at 0^{o} 30'S and 37^{o} 27'E at an altitude of 1460 m above sea level. The trial was laid down in a gently sloping field broken up from natural pasture in 1979. This field was under bananas up to 1974 when it was ploughed and planted with sweet potatoes which gave way to a volunteer natural pasture two years later and was finally ploughed down in 1979.

3.1.1 Soils

The soil was a deep sandy loam, derived from Mt. Kenya volcanic ash (Mt. Kenya phonolite) classified (FAO/UNESCO) as Dystric Nitosol (Siderius and Muchena, 1977). The soil analysis report (Table 3.1) indicated that the site had a strongly acid top soil, low to deficient in calcium, deficient in phosphorus and moderately supplied with organic carbon, and hence nitrogen. The soil had a high exchangeable acidity (Hp). Table 3.2 shows the deficiency and sufficiency ranges for soil nutrients.

3.1.2 Weather conditions

The prevailing weather conditions during the study period are shown in Tables 3.3 and 3.4. The station receives a bimodal type of rainfall, the long rains

Table 3.1 Soil analysis report

parameter	Top Soil range	Top Soil mean	Sub Soil range	Sub Soil mean
pH	4.7 - 5.4	4.9	4.4 - 5.4	4.9
Na m.e.%	0.11 - 0.19	0.15	0.11 - 0.17	0.13
K m.e.%	0.43 - 0.92	0.68	<u>0.11</u> - 0.64	0.34
Ca m.e.%	<u>1.0</u> - 5.0	2.84	<u>1.0</u> - 4.0	2.5
Mg m.e.%	2.6 - 4.0	3.37	1.9 - 4.0	2.91
Mn m.e.%	1.0 - 1.34	1.19	0.92 - 1.40	1.15
P p.p.m	<u>4.0</u> - <u>6.0</u>	<u>4.5</u>	<u>4.0</u> - <u>8.0</u>	<u>4.5</u>
C %	1.62 - 2.01	1.77	- -	-
Hp m.e.%	0.1 -(1.2)	0.65	0.1 -(2.8)	0.9

(Toxicities bracketed), <u>deficiencies underlined</u>

Table 3.2 Deficiency and sufficiency ranges for soil nutrients*

Nutrient	Deficient	Sufficient	Rich
Na m.e.%	Seldom	0 - 2.0	2.0 +
K m.e.%	Less than 0.2	0.2 - 1.5	1.5 +
Ca m.e.%	Less than 2.0	2.0 -10.0	10.0 +
Mg m.e.%	Less than 1.0	1.0 - 3.0	3.0 +
Mn m.e.%	Less than 0.1	0.1 - 2.0	2.0 +
P p.p.m.	Less than 20	20 - 80	80 +

* This generalised guide is adapted from Kempton, 1962.

(March - June) normally accounting for up to 65% of the total annual rainfall while the short rains (October - December) accounts for about 20%. The remaining 10 - 15% comes in form of isolated showers. The periods mid-December to mid-March and mid-August to mid-October are normally very hot and dry.

3.2 PLANTING MATERIAL

Four varieties of napier grass, namely French Cameroon, Clone 13, Bana and a napier x Bajra millet hybrid were used. French Cameroon was first introduced from West Africa in the 1950's and has been grown extensively in East Africa with outstanding herbage yields in spite of its susceptibility to snow mould disease (Beniowskia sphaeroidea).

Clone 13 is a French Cameroon selection developed at the National Agricultural Research Station, Kitale, that is resistant to the snow mould disease. In areas where the incidence of snow mould is severe (e.g. Kitale) Clone 13 has been reported to outyield French Cameroon (Boonman, unpublished).

Bana was once thought to be a hybrid between Babala millet (or Bulrush millet) and napier grass (hence its name). Later it was conclusively proved to be a pure napier grass. The original material was introduced from Central or Southern Africa and was first grown around Elmenteita, then Machakos, from where it spread into research stations and hence to farmers all over the country. It has gained much popularity because of its

Table 3.3 Weather conditions during the establishment period (October - December, 1980)

Month	Total rainfall (mm)	Rainy days	Mean temp.(°C)	Mean rel. humidity (%) 9.00 a.m	3.00 p.m	Mean daily evapor. (mm)
October	179.0	12	20.3	79	39	5.4
November	268.4	21	19.3	85	65	4.8
December	33.9	4	18.8	75	59	5.5
Mean	481.3*	35*	19.5	79.7	54.3	5.23

* Totals.

Table 3.4 Weather conditions, 1981

Month	Total Rainfall (mm)	Rainy Days	Mean Temp. (°C)	Mean Rel. 9.00 a.m.	Humidity (%) 3.00 p.m.	Mean daily Evap.(mm)
Jan.	4.3	1	19.4	70	46	6.6
Feb.	5.2	1	20.5	67	39	7.5
Mar.	206.1	15	20.4	84	55	5.3
Apr.	394.0	13	19.2	87	69	5.2
May	298.9	18	18.8	91	72	4.2
June	19.0	4	17.6	89	65	3.2
July	12.1	5	16.2	90	70	2.3
Aug.	39.6	8	17.7	86	61	3.3
Sept.	209.4	4	19.2	84	48	4.5
Oct.	112.5	10	20.4	82	45	5.6
Nov.	85.0	14	19.6	82	57	5.0
Dec.	41.5	6	18.5	83	58	5.3
Mean	1427.6*	99*	18.96	83	57	4.8

* Total

high herbage yields and favourable leaf:stem ratio.

Bajra x napier hybrid was introduced from Pakistan in 1978. Indian and Pakistani reports indicate that it is a high herbage yielder, at times outyielding some napier varieties. Although no herbage yield data is yet available under Kenyan conditions, it is hoped that it is likely to be more drought tolerant than Kenyan napier varieties since one of its parents (millet) is a prominent dry land crop.

3.3 EXPERIMENTAL DESIGN AND TREATMENTS

A 4 x 3 x 3 factorial in a randomised complete block design with three replicates was used. The main factors were:

(a) 4 varieties: V_1 - French cameroon
V_2 - Clone 13
V_3 - Bana napier
V_4 - Napier x Bajra hybrid.

(b) 3 cutting heights: H_1 - 0 cm (Ground level)
H_2 - 10 cm
H_3 - 20 cm

(c) 3 cutting frequencies: F_1 - 6 weeks
F_2 - 8 weeks
F_3 - 10 weeks

In all there were 36 treatment combinations. The layout and the various treatments are shown in Fig. 3.1

→ N

18	4	29	22	1	13	10	7	12	28	32	11	2	23	17	36	9	33	
30	19	26	6	16	15	27	24	8	20	25	31	14	5	3	21	34	35	REP I
13	32	18	26	30	36	35	1	31	22	11	34	17	21	6	28	4	7	
12	29	8	16	20	24	2	3	25	9	19	27	33	15	14	5	10	23	REP II
23	7	29	6	4	34	8	5	10	24	20	19	17	2	25	32	15	28	
14	30	31	22	27	16	12	18	35	1	9	26	33	21	11	3	13	36	REP III

— 2m paths

Fig. 3.1. Field plan and the treatments

Key to fig.

1.	$V_1H_1F_1$	10.	$V_2H_1F_1$	19.	$V_3H_1F_1$	28.
2.	$V_1H_1F_2$	11.	$V_2H_1F_2$	20.	$V_3H_1F_2$	29.
3.	$V_1H_1F_3$	12.	$V_2H_1F_3$	21.	$V_3H_1F_3$	30.
4.	$V_1H_2F_1$	13.	$V_2H_2F_1$	22.	$V_3H_2F_1$	31.
5.	$V_1H_2F_2$	14.	$V_2H_2F_2$	23.	$V_3H_2F_2$	32.
6.	$V_1H_2F_3$	15.	$V_2H_2F_3$	24.	$V_3H_2F_3$	33.
7.	$V_1H_3F_1$	16.	$V_2H_3F_1$	25.	$V_3H_3F_1$	34.
8.	$V_1H_3F_2$	17.	$V_2H_3F_2$	26.	$V_3H_3F_2$	35.
9.	$V_1H_3F_3$	18.	$V_2H_3F_3$	27.	$V_3H_3F_3$	36.

3.1.

$V_4H_1F_1$	V_1 - French Cameroon	F_1 - 6 weeks
$V_4H_1F_2$	V_2 - Clone 13	F_2 - 8 weeks
$V_4H_1F_3$	V_3 - Bana	F_3 - 10 weeks
$V_4H_2F_1$	V_4 - Bajra - Napier hybrid	
$V_4H_2F_2$	H_0 - Ground level	
$V_4H_2F_3$	H_1 - 10 cm	
$V_4H_3F_1$	H_2 - 20 cm	
$V_4H_3F_2$		
$V_4H_3F_3$		

3.4 PLANTING

Ploughing and harrowing was done in July 1980 and on July 24, soil samples for chemical analysis were taken. The trial site was irrigated on October, 6 and 7, 1980 to facilitate layout and subsequent planting. Layout was done on October 8.

Planting was done between October 17 and 21, 1980. The plot size was 4m x 3m with one-metre path between the plots and two-meter paths between replicates. All the plots were planted with rooted splits to ensure rapid and uniform establishment. The spacing between and within the rows was 100 and 50 cm, respectively. Planting holes were dug with jembes (hoes) and 22 kg/ha P applied in form of single superphosphate (8.7% P and 12% S). The site was irrigated during the planting period but this was discontinued soon after the short rains started.

The trial was kept weed free by manual weeding throughout the trial period. On January 5, 1981, all the plots were cut back to their respective heights and all the cutting frequencies were subsequently based on this date. Nitrogen in form of calcium ammonium nitrate (C.A.N., 26% N) was applied at the rate of 50 kg N/ha per annum in three split applications, two of which were within the trial period.

3.5 SAMPLING

3.5.1 Tiller count

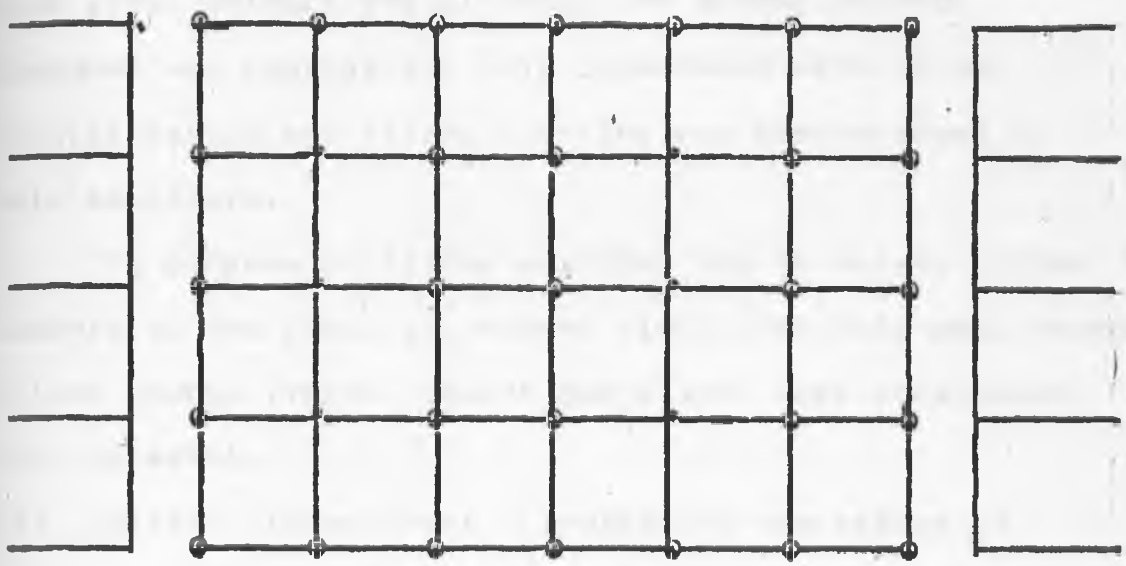
Whenever possible tiller counting was done fortnightly in all the plots with effect from February 22, 1981. Excluding the guard rows (perimeter rows) tillers were counted from the first and fourth stools of each of the remaining three rows of each plot as shown in Fig. 3.2. The choice of the stools had no specific significance but the intention was to get a convenient representative sample of the plot because of the expected variation in tiller number per stool within a plot. The tillers were classified as:

(a) Basal tillers - tillers emerging right from the ground level or below it and with no evidence of a previous defoliation.

(b) Axillary tillers - tillers emerging between the ground level and the apical meristem but with no evidence of a previous defoliation.

(c) Terminal shoots - all other shoots with intact apical meristem and with evidence of previous defoliation.

Between May 1 and June 21, no tiller counting was done because the forage was too tall and dense to allow



• stools involved in tiller counting.

⊙ other stools.

Fig. 3.2 Location of the 6 stools/plot for tiller count.

proper tiller counting and classification. On June 17, some plots in the third replicate were disturbed by some stray animals and although the actual herbage consumed was negligible, this interfered with tiller classification and tiller counting was discontinued in this replicate.

The purpose of tiller counting was to relate tiller numbers to the final dry matter yield. To this end, three tiller counts (first, fourth and sixth) were considered most relevant.

(a) Initial tiller count - indicating the effect of cutting back and six weeks regrowth during the dry season.

(b) Fourth count - indicating the early post-defoliation effect.

(c) Sixth count - indicating the late post-defoliation effect and just prior to the next defoliation.

The other tiller count were considered to have limited meaning because of the defoliation frequency factor which made comparisons between frequencies inappropriate.

3.5.2. Herbage dry matter yields

At the time of cutting, the perimeter row (guard row) of each plot to be harvested was cut first and discarded. The remaining herbage was cut and weighed in the field. A representative herbage sample weighing about 500 - 1000 gms was taken from each plot, weighed in the laboratory and dried in an Unitherm drying oven at a temperature of 60°C for about 48 hours. The final dry weight was recorded and the DM yield computed as follows,

$$DM\ (kg/ha) = Fresh\ wt.\ (kg/plot) \times 1333 \times \frac{dry\ wt.(sample)}{fresh\ wt.(sample)}$$

where 1333 is the reciprocal of the net harvested plot size as a fraction of a hectare (i.e. $\frac{7.5}{10,000}$ ha)

3.5.3 Chemical analysis

The crude protein (CP) was determined by the improved micro-Kjeldahl nitrogen determination method as described by Horwitz (1970) where % CP = %N x 6.25. *in vitro* digestibility was determined by the two-stage *in vitro* digestibility technique described by Tilley and Terry (1963).

3.5.4 Statistical analysis

All the data was subjected to the analysis of variance and other statistical tests in accordance with the procedures proposed by Snedecor and Cochran (1967).

CHAPTER FOUR

4.0 RESULTS

4.1 TILLERING

4.1.1 Effect of cutting back on basal tillers

Table 4.1 shows the mean basal tillers per 6 stools as affected by varieties and cutting height, six weeks after cutting back. There were highly significant ($p = 0.001$) varietal and cutting height effects on the mean basal tiller number. Hybrid napier had a higher ($p = 0.001$) tiller number than the other varieties. French Cameroon and Clone 13 did not differ significantly but they were significantly superior ($p = 0.01$ and 0.05 respectively) to Bana which had the least number of basal tillers.

There was a significant decline ($p = 0.001$) in basal tiller number with increase in cutting height up to 20 cm especially in Bana and Hybrid napier (Fig. 4.1). Since no defoliation had taken place yet, no frequency of cutting effect was expected.

4.1.2 Effect of cutting back on axillary tillers

There were highly significant ($p = 0.001$) varietal and cutting height effects on axillary tiller number (Table 4.2). The variety x cutting height interaction effect was also significant ($p = 0.05$). Hybrid napier

Table 4.1 Effect of variety and cutting height on mean basal tillers/ 6 stools*, in the first tiller count.

Variety	Cutting Interval (weeks)				Cutting Height (cm)			
	6	8	10	mean	0	10	20	mean
F. Cameroon	44	70	66	60	90	54	35	60
Clone 13	31	70	59	53	81	46	32	53
Bana	22	34	36	31	67	20	5	31
Hybrid	99	150	137	129	192	118	76	129
Mean	49	81	74		107	60	37	
Cutting Ht. (cm)								
0	90	127	106	107				
10	36	70	73	60				
20	22	46	44	37				
Mean	49	81	74					

S.E. Variety means ± 7.15 (0.376)

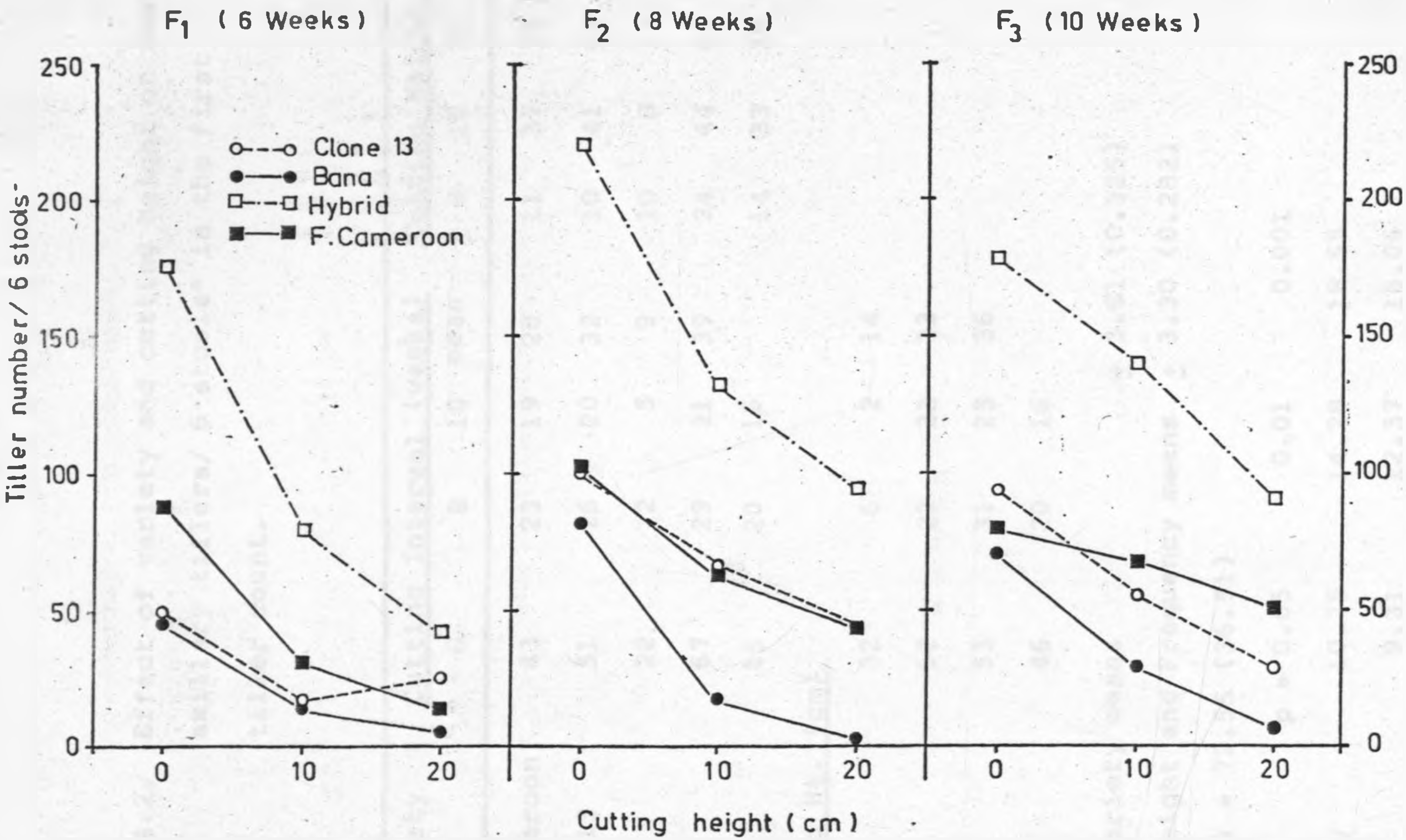
S.E. Height means ± 6.19 (0.326)

S.E. Frequency means ± 6.19 (0.326)

C.V.(%) = 54.55 (25.83)

L.S.D.	p = 0.05	0.01	0.001
Variety	20.20	26.83	34.84
Height	17.49	23.24	30.17

* This data was subjected to $\sqrt{(x + 1)}$ transformation before statistical analysis. Values in brackets refer to the transformed data.



4.1 Effect of cutting height on the number of basal tillers/6 stools in the first tiller count.

Table 4.2. Effect of variety and cutting height on mean axillary tillers/ 6 stools* in the first tiller count.

Variety	Cutting Interval (weeks)				Cutting Height (cm)			
	6	8	10	mean	0	10	20	mean
F. Cameroon	43	23	19	28	11	37	37	28
Clone 13	51	26	20	32	10	41	45	32
Bana	22	2	5	9	10	8	10	9
Hybrid	67	29	21	39	24	44	49	39
Mean	46	20	16		14	33	36	
Cutting Ht. (cm)								
0	32	6	2	14				
10	52	22	23	33				
20	53	31	23	36				
Mean	46	20	16					

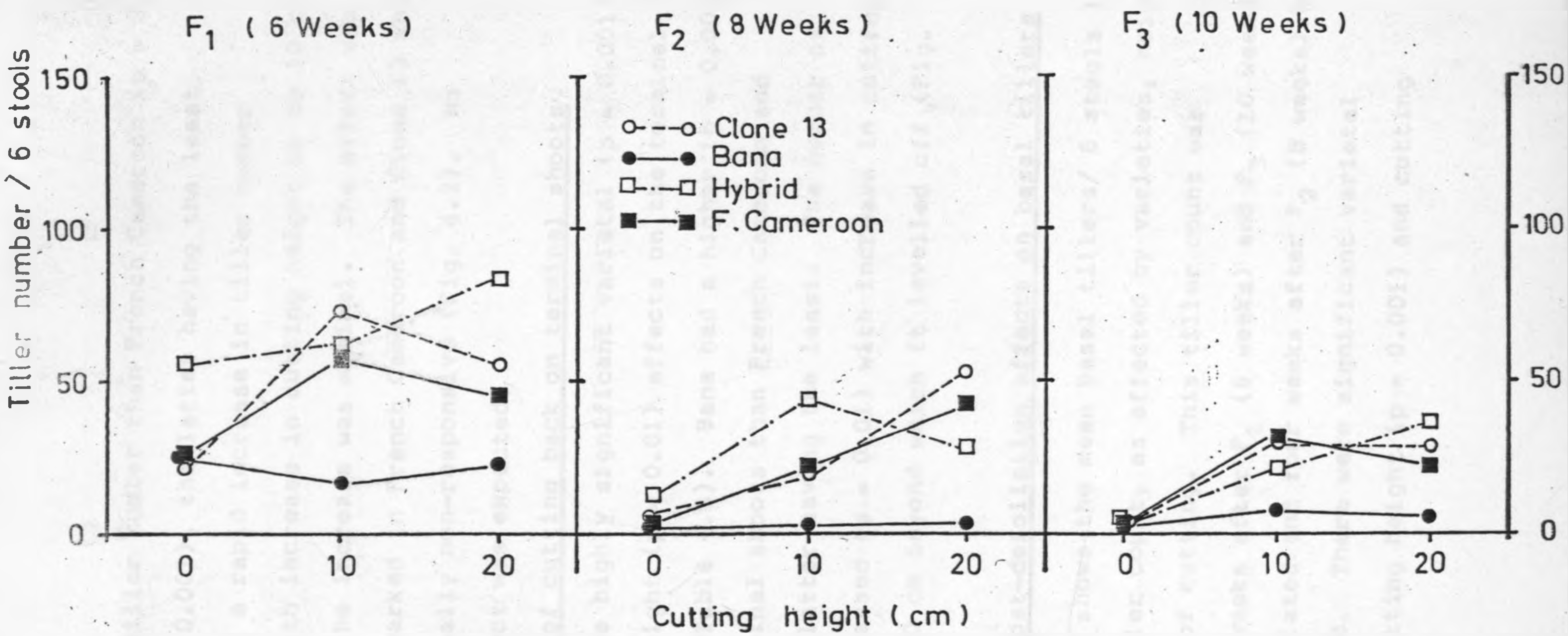
S.E. Variety means ± 3.81 (0.325)

S.E. Height and Frequency means ± 3.30 (0.282)

C.V (%) = 72.55 (36.51)

L.S.D.	p = 0.05	0.01	0.001
Variety	10.75	14.28	18.55
Height	9.31	12.37	16.06

* This data was subjected to $\sqrt{X + 1}$ transformation before statistical analysis. Values in brackets refer to the transformed data.



4.2 Effect of cutting height on the number of axillary tillers/6 stool in the first tiller count.

had a higher tiller number than French Cameroon (p = 0.05) and Bana (p = 0.001), the latter having the least.

There was a rapid increase in tiller number (p = 0.001) with increase in cutting height up to 10 cm beyond which the increase was minimal. The effect was particularly marked in French Cameroon and Clone 13 while Bana was virtually non-responsive (Fig. 4.2). No frequency effect was expected.

4.1.3 Effect of cutting back on terminal shoots

There were highly significant varietal (p = 0.001) and cutting height (p = 0.01) effects on the terminal shoot number (Table 4.3). Bana had a higher (p = 0.001) number of terminal shoots than French Cameroon and Clone 13, the latter having the least. The number of terminals increased (p = 0.01) with increase in cutting height up to 10 cm beyond which it levelled off (Fig. 4.3).

4.1.4 Early post-defoliation effects on basal tillers

Table 4.4 shows the mean basal tillers/ 6 stools in the fourth tiller count, as affected by varieties, height and frequency of cutting. This tiller count was conducted two weeks after F_1 (6 weeks) and F_3 (10 weeks) had been defoliated and four weeks after F_2 (8 weeks) had been defoliated. There were significant varietal (p = 0.01), cutting height (p = 0.001) and cutting

Table 4.3. Effect of variety and cutting height on mean terminal shoots/6 stools* in the first tiller count.

Variety	Cutting Interval (weeks)				Cutting Height (cm)			
	6	8	10	mean	0	10	20	mean
F. Cameroon	31	32	37	33	22	35	42	33
Clone 13	22	32	28	27	19	35	28	27
Bana	57	55	53	55	43	60	62	55
Hybrid	33	42	74	50	33	62	54	50
Mean	36	40	48		29	48	46	
Cutting Ht. (cm)								
0	23	29	37	29				
10	40	51	53	48				
20	45	41	54	46				
Mean	36	40	48					

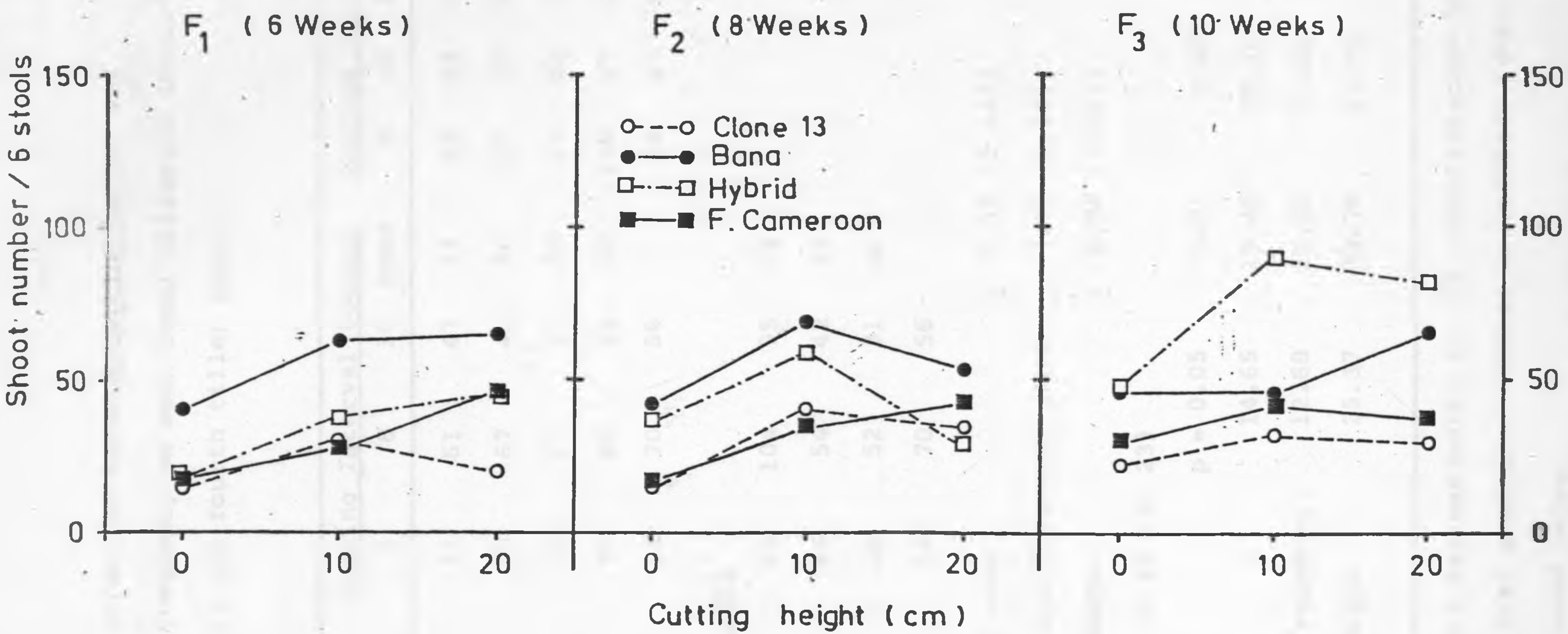
S. E. Variety mean $\pm$ 4.38 (0.313)

S. E. Height and Frequency mean $\pm$ 3.80 (0.271)

C.V.(%) = 55.29% (26.17)

L.S.D. p =	0.05	0.01	0.001
Variety	12.39	16.45	21.37
Height	10.73	14.25	18.50

* This data was subjected to $\sqrt{X}$ transformation before statistical analysis. Values in brackets refer to the transformed data.



4.3 Effect of cutting height on the number of terminal shoots/6 stools in the first tiller count.

Table 4.4. Effect of variety, cutting height and frequency on mean basal tillers/6 stools* in the fourth tiller count.

Variety	Cutting Interval (weeks)				Cutting Height (cm)			
	6	8	10	mean	0	10	20	mean
F. Cameroon	51	61	47	53	68	49	43	53
Clone 13	38	67	45	50	59	50	42	50
Bana	58	67	37	54	73	50	38	54
Hybrid	70	85	95	83	176	37	36	83
Mean	54	70	56		94	47	40	
Cutting Ht. (cm)								
0	83	104	95	94				
10	44	54	42	47				
20	36	52	31	40				
Mean	54	70	56					

S.E. Variety mean ± 5.18 (0.445)

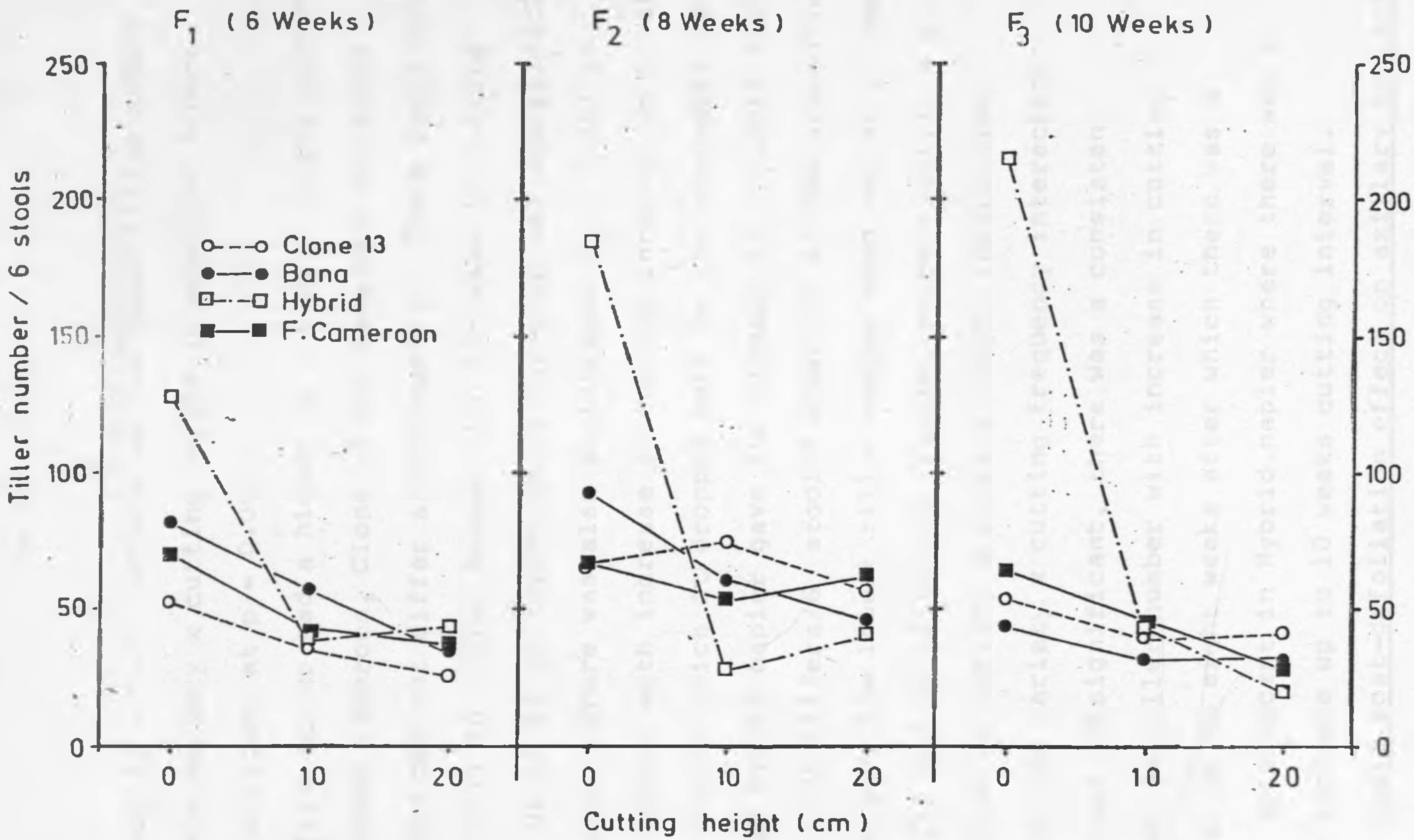
S.E. Height and Frequency means ± 4.49 (0.385)

S.E. V x H means ± 8.98 (0.667)

C.V.(%) = 39.59 (21.23)

L.S.D.	p = 0.05	0.01	0.001
Variety	14.65	19.46	25.26
Height and Frequency	12.68	16.85	21.88
Variety x Height	25.37	33.70	43.76

* This data has subjected to $\sqrt{X}$ transformation before statistical analysis. Values in brackets refer to the transformed data.



4.4 Effect of cutting height on the number of basal tillers/6 stools in the fourth tiller count.

frequency (p = 0.05) effects on the basal tiller number while the variety x cutting height interaction effect was significant at p = 0.001.

Hybrid napier had a higher (p = 0.001) tiller number than French Cameroon, Clone 13 and Bana but the three varieties did not differ significantly. There was a drop (p = 0.001) in tiller number with increase in cutting height up to 10 cm beyond which the drop was insignificant (Fig. 4.4). There was also an increase (p = 0.05) in tiller number with increase in cutting interval up to eight weeks, beyond which it dropped back to the six-weeks level. Although Hybrid napier gave the highest (p = 0.001) tiller number (176 tillers/6 stools) when cut at the ground level, it also gave the lowest tiller number when cut at 10 and 20 cm (37 and 36 tillers/6 stools, respectively), a clear indication of variety x cutting height interaction. Although the variety x cutting frequency interaction effect was not significant, there was a consistent increase in tiller number with increase in cutting interval up to eight weeks after which there was a slight drop except in Hybrid napier where there was a steady increase up to 10 weeks cutting interval.

4.1.5 Early post-defoliation effect on axillary tillers

Table 4.5. shows the mean axillary tillers/6 stools as affected by variety, height and frequency of cutting in the fourth tiller count. There were significant

Table 4.5. Effect of variety, cutting height and frequency on mean axillary tillers/6 stools* in the fourth tiller count.

Variety	Cutting Interval (weeks)				Cutting Height (cm)			
	6	8	10	mean	0	10	20	mean
F. Cameroon	25	32	23	27	0	29	52	27
Clone 13	23	35	19	25	2	36	38	25
Bana	11	3	8	7	0	6	14	7
Hybrid	21	15	13	16	0	22	26	16
Mean	20	21	15		0.4	23	33	
Cutting Ht. (cm)								
0	0	0	1	0.4				
10	22	28	20	23				
20	38	35	24	33				
Mean	20	21	15					

S.E. Variety mean ± 2.56 (0.288)

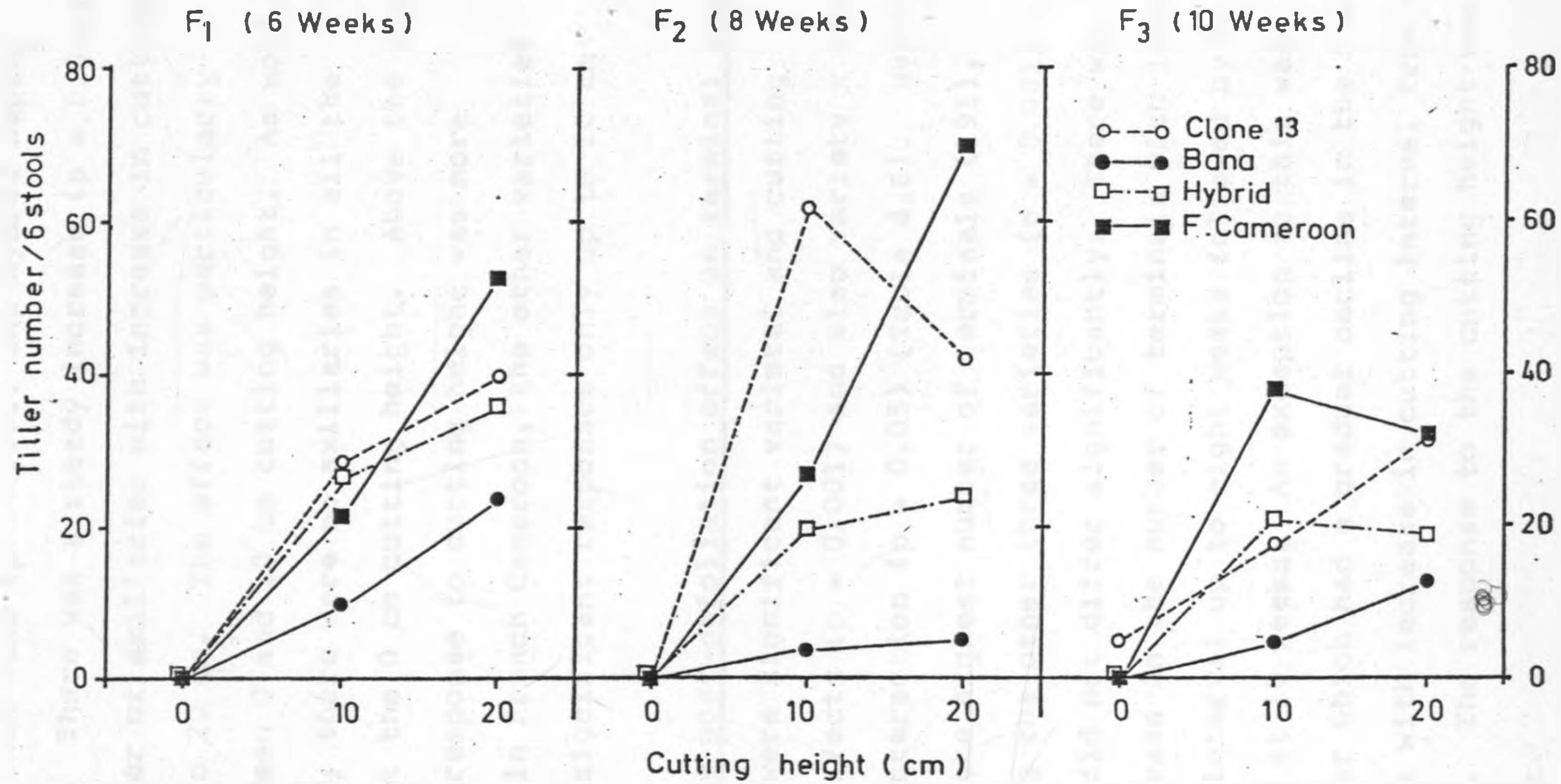
S.E. Height means ± 2.22 (0.249)

S.E. V x H means ± 4.44 (0.498)

C.V.(%) = 72.06 (34.14%)

L.S.D.	p = 0.05	0.01	0.001
Variety	7	10	12
Height	6	8	11
V x H interaction	13	17	22

* This data was subjected to $\sqrt{X + 1}$ transformation before statistical analysis. Values in brackets refer to the transformed data.



4.5 Effect of cutting height on the number of axillary tillers/6 stools in the fourth tiller count.

(p = 0.001) varietal, cutting height and variety x cutting height interaction effects on tiller number. French Cameroon and Clone 13 had higher number of axillaries than Bana (p = 0.001) and Hybrid napier (p = 0.05). There was a steady increase (p = 0.001) in the number of axillaries with increase in cutting height up to 20 cm. The effect was particularly marked between 0 and 10 cm cutting height. As would be expected, there were no axillaries in all the varieties at the 0 cm cutting height. Above the ground level, the response to cutting height was more pronounced in French Cameroon, the other varieties exhibiting significant responses only up to 10 cm (Fig. 4.5).

4.1.6 <u>Early post-defoliation effect on terminal shoots</u>

There were significant varietal and cutting frequency effects (p = 0.001) and also variety x height x frequency interaction (p = 0.05) (Table 4.6). Hybrid napier had the highest number of terminals (191), outnumbering the other three varieties (p = 0.001) but the latter did not differ significantly. There was a slight increase in the number of terminals with increase in cutting interval up to eight weeks followed by a drop (p = 0.001) at 10 weeks. An exception to this was Hybrid napier which had a gradual decline in the number of terminals with increase in cutting interval from six to 10 weeks. The response to the cutting height was inconsistent.

Table 4.6. Effect of variety, cutting height and frequency on mean terminal shoots/6 stools* in the fourth tiller count.

Variety	Cutting Interval (weeks)				Cutting Height (cm)			
	6	8	10	mean	0	10	20	mean
F.Cameroon	81	121	70	91	86	93	94	91
Clone 13	83	117	54	85	70	98	86	85
Bana	71	85	61	72	84	72	61	72
Hybrid	211	190	173	191	172	220	181	191
Mean	111	128	90		103	121	105	
Cutting Ht. (cm)								
0	116	119	74	103				
10	114	141	107	121				
20	104	125	88	105				
Mean	111	128	90					

S.E. Variety means ± 7.31 (0.421)

S.E. Frequency means ± 6.33 (0.365)

S.E. Height means ± 6.33 (0.365)

C.V.(%) = 38 (22)

L.S.D.	p = 0.05	0.01	0.001
Variety	21	27	36
Frequency	18	24	36

* This data was subjected to $\sqrt{x}$ transformation before statistical analysis. Values in brackets refer to the transformed data.

Table 4.7. Interaction of variety, height and frequency of cutting on mean terminal shoots/6 stools* in the fourth tiller count.

Variety	Cutting Frequency (weeks)	Cutting Height (cm) 0	10	20	mean
F.Cameroon	6	81	91	70	81
	8	99	120	145	121
	10	78	66	67	70
Clone 13	6	56	97	96	83
	8	113	112	125	117
	10	41	85	36	54
Bana	6	72	66	75	71
	8	111	91	54	85
	10	70	60	54	61
Hybrid	6	255	201	175	210
	8	154	241	174	190
	10	107	218	195	173
Mean		103	121	105	

S.E. V x F x H Interaction $\pm$ 21.93 (1.041)

C.V (%) = 34.58 (17.93)

L.S.D.	p = 0.05	0.01	0.001
	61.93	82.28	106.84

* This data was subjected to $\sqrt{X}$ transformation before statistical analysis. Values in brackets refer to the transformed data.

Table 4.7 shows the effect of variety x height x frequency interaction on terminal shoots. There was extreme variability in terminal shoot number among the treatments with a range of 36 - 255 shoots/6 stools, but there was no consistent trend among the varieties. Hybrid napier cut at six weeks interval and at the ground level gave the highest number of terminal shoots (255) while Clone 13 cut at 10 weeks interval at 20 cm cutting height gave the lowest number (36).

4.1.7 Late post-defoliation effect on basal tillers

There was a drop ($p = 0.01$) in tiller number with increase in cutting height from 0 to 20 cm (Table 4.8). This drop was particularly pronounced in Bana and Hybrid napier. There was also a highly significant ($p = 0.01$) height x frequency interaction effect, characterised by a drop ($p = 0.05$) in tiller number with increase in cutting height from 0 to 20 cm. This trend was confined to the eight and ten weeks ($F_2$and F_3) cutting frequencies only. Once again Hybrid napier had the highest tiller number (144) while Clone 13 had the lowest (113).

4.1.8 Late post-defoliation effect on axillary tillers

There were significant varietal and cutting height effects ($p = 0.001$), variety x height interaction effects ($p = 0.01$) and variety x frequency interaction effects ($p = 0.05$) (Table 4.9). French Cameroon and Clone 13 had higher ($p = 0.05$) tiller number than Bana and

Table 4.8. Effect of variety, height and frequency of cutting on mean basal tillers/ 6 stools* at the sixth tiller count.

Variety	Cutting Interval (weeks)				Cutting Height (cm)			
	6	8	10	mean	0	10	20	mean
F. Cameroon	117	111	128	118	128	130	98	118
Clone 13	106	113	118	113	118	114	106	113
Bana	139	130	101	124	147	121	103	124
Hybrid	138	141	154	144	185	121	126	144
Mean	125	124	125		145	121	108	
Cutting Ht. (cm)								
0	110	179	146	145				
10	136	99	128	121				
20	130	93	102	108				
Mean	125	124	125					

S.E. Variety means ± 9.50 (0.301)

S.E. Height means ± 8.23 (0.261)

S.E. H x F interaction means ± 14.25 (0.521)

C.V. (%) = 45 (21)

L.S.D. p =	0.05	0.01	0.001
Height	23	31	40
H x F interaction	40	53	69

* This data was subjected to $\sqrt{X}$ transformation before statistical analysis. Values in brackets refer to the transformed data.

Table 4.9. Effect of variety, height and frequency of cutting on mean axillary tillers/6 stools* in the sixth tiller count.

Variety	Cutting Interval (weeks)				Cutting Height (cm)			
	6	8	10	mean	0	10	20	mean
F. Cameroon	26	40	39	35	1	30	75	35
Clone 13	39	58	31	43	1	50	78	43
Bana	21	3	18	14	2	8	33	14
Hybrid	26	16	21	21	1	27	36	21
Mean	28	30	28		1	28	55	
Cutting Ht. (cm)								
0	0	0	3	1				
10	21	34	31	29				
20	63	55	48	55				
Mean	28	30	28					

S.E. Variety means ± 3.93 (0.227)

S.E. Height means ± 3.40 (0.196)

S.E. V x H interaction means ± 6.81 (0.393)

S.E. V x F interaction means ± 6.81 (0.393)

C.V. (%) = 71 (32)

L.S.D. p =	0.05	0.01	0.001
Variety	11	15	19
Height	10	13	17
Interactions	19	26	33

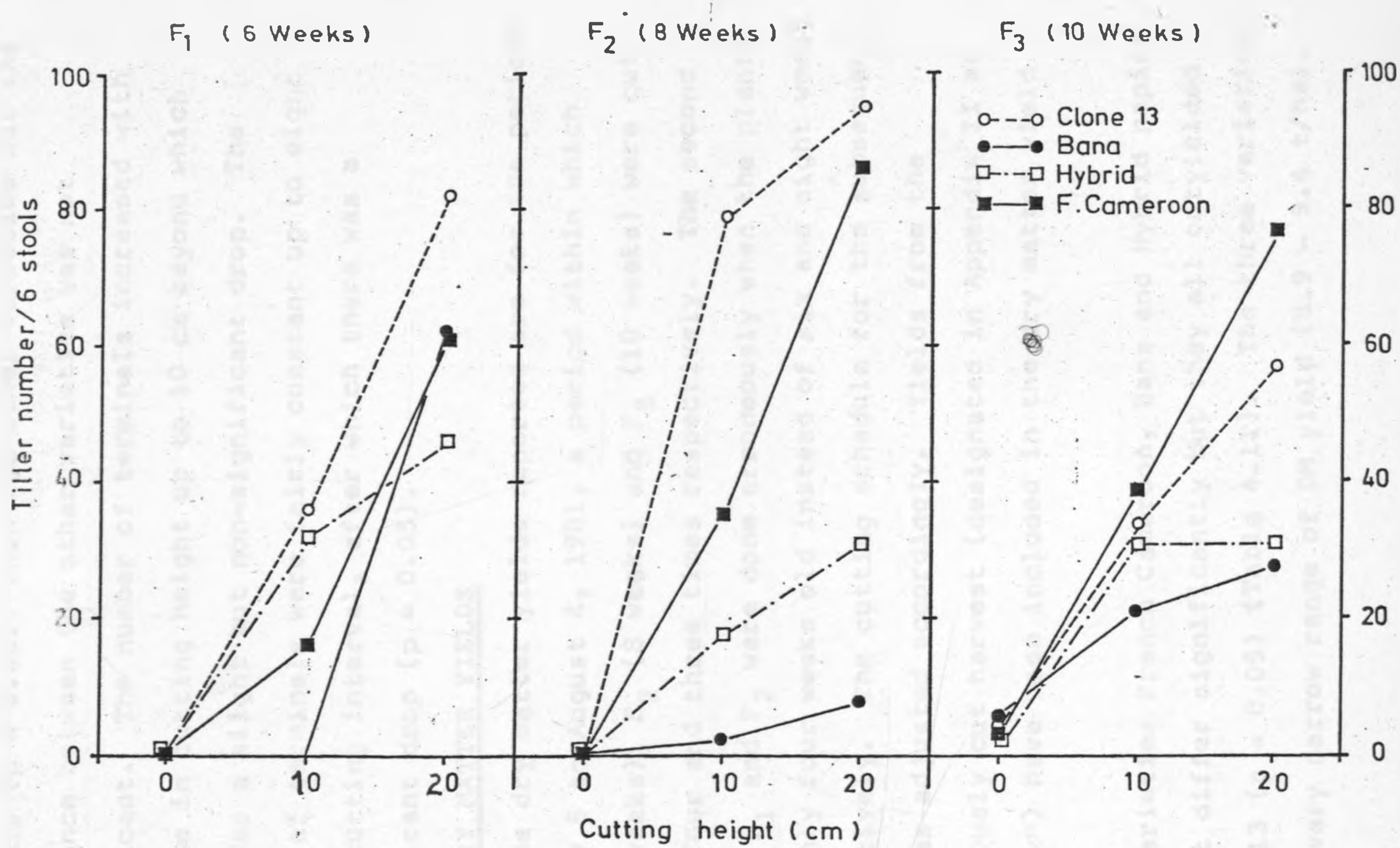
* This data was subjected to $\sqrt{X + 1}$ transformation before statistical analysis. Value in brackets refer to the transformed data.

Hybrid napier but neither the former, nor the latter pair differed significantly. The virtual absence of axillaries in the 0 cm cutting height in all the varieties resulted in a highly significant ($p = 0.001$) increase in axillary tiller number with increase in cutting height up to 20 cm. At 10 cm cutting height, Clone 13 had a higher tiller number than French Cameroon, Hybrid napier (both at $p = 0.05$) and Bana ($p = 0.001$). At 20 cm cutting height, however, French Cameroon and Clone 13 were no longer significantly different but they were significantly superior to Bana and Hybrid napier, the latter pair having also achieved equality (Fig. 4.6).

At six weeks cutting interval, there were no significant varietal differences in tiller number. When the cutting interval was increased to eight weeks, there was an increase in tiller number in French Cameroon and Clone 13 but decrease in Bana and Hybrid napier. Consequently, Clone 13 achieved a higher tiller number ($p = 0.001$) than Bana and Hybrid napier. When the cutting interval was further increased to 10 weeks, there was a significant drop ($p = 0.05$) in tiller number in Clone 13 but an increase (though non-significant) in Bana and Hybrid napier while French Cameroon remained constant.

4.1.9 Late post-defoliation effect on terminal shoots

There were significant varietal differences



4.6 Effect of cutting height on the number of axillary tillers/6 stools in the sixth tiller count.

($p = 0.001$) as well as cutting height and frequency effects ($p = 0.05$) (table 4.10).

Hybrid napier produced a higher number of terminals ($p = 0.001$) than the other varieties but the difference between the other varieties was not significant. The number of terminals increased with increase in cutting height up to 10 cm beyond which there was a slight but non-significant drop. The number of terminals were fairly constant up to eight weeks cutting interval, after which there was a significant drop ($p = 0.05$).

4.2 DRY MATTER YIELDS

The dry matter yields reported are for the period January 5 to August 4, 1981, a period within which F_1 (6 weeks), F_2 (8 weeks) and F_3 (10 weeks) were cut five, four and three times respectively. The second cut of F_1 and F_2 were done erroneously when the plants were only four weeks old instead of six and eight weeks respectively. The cutting schedule for the subsequent cuts was adjusted accordingly. Yields from the erroneously cut harvest (designated in Appendix II as cut "2x") have been included in the dry matter yield data.

Varieties French Cameroon, Bana and Hybrid napier did not differ significantly but they all outyielded Clone 13 ($p = 0.05$) (Table 4.11). The three varieties had a very narrow range of DM yield (8.9 - 9.4 t/ha).

Table 4.10. Effect of variety, frequency and cutting height on mean terminal shoots/6 stools* in the sixth tiller count.

Variety	Cutting Interval (weeks)				Cutting Height (cm)			
	6	8	10	mean	0	10	20	mean
F. Cameroon	98	109	74	94	85	93	104	94
Clone 13	110	109	48	89	81	96	90	89
Bana	71	67	83	74	70	83	69	74
Hybrid	169	166	145	160	128	190	163	160
Mean	112	113	88		91	115	106	
Cutting Ht. (cm)								
0	116	91	66	91				
10	118	129	99	115				
20	103	119	98	106				
Mean	112	113	88					

S.E. Variety means ± 7.57 (0.347)

S.E. Height and Frequency means ± 6.56 (0.3)

C.V. (%) = 35 (18)

L.S.D. p =	0.05	0.01	0.001
Variety	21	28	37
Height	19	25	32
Frequency	19	25	32

* This data was subjected to $\sqrt{x}$ transformation before statistical analysis. Values in brackets refer to the transformed data.

Table 4.11. Effect of variety, frequency and cutting height on total dry matter yield (t/ha).

Variety	Cutting Interval (weeks)				Cutting Height (cm)			
	6	8	10	mean	0	10	20	mean
F. Cameroon	6.9	9.3	11.1	9.1b	8.9	9.4	9.0	9.1b
Clone 13	5.7	7.2	9.4	7.4a	7.3	7.5	7.5	7.4a
Bana	8.1	7.9	10.6	8.9b	8.5	9.2	8.9	8.9b
Hybrid	8.3	8.9	11.0	9.4b	8.9	9.9	9.4	9.4b
Mean	7.2	8.3	10.5		8.4	9.0	8.7	
Cutting Ht. (cm)								
0	6.7	8.2	10.3	8.4				
10	7.6	8.4	11.0	9.0				
20	7.5	8.4	10.2	8.7				
Mean	7.2	8.3	10.5					

S.E. Variety means ± 0.32

S.E. Height and Frequency means ± 0.28

S.E. V x H and V x F means ± 0.56

S.E. H x F means ± 0.48

C.V (%) = 19.23

Varietal means followed by a common letter do not differ significantly ($p = 0.05$) according to New Duncan's Multiple Range Test (DMRT).

There was a positive linear response ($p = 0.01$) of DM yield to cutting frequency up to 10 weeks, the response being especially prominent in French Cameroon and Clone 13 but less so in Bana (Fig. 4.7).

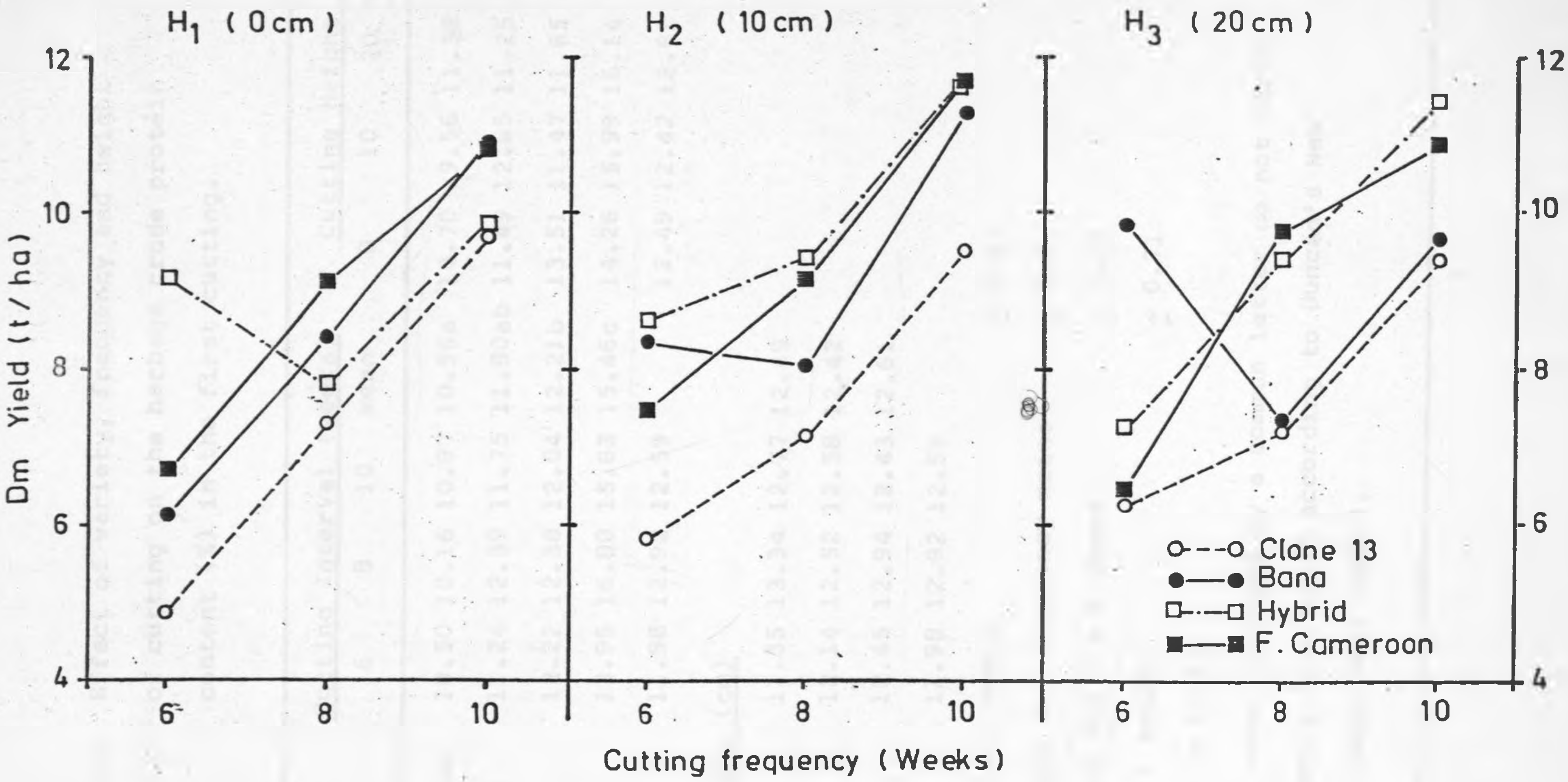
4.3 CRUDE PROTEIN CONTENT

The crude protein data reported is derived from the first three cuts of each frequency of cutting. The extra cuts in F_1 (6 weeks) and F_2 (8 weeks) were omitted because they had no corresponding values in F_3 (10 weeks) for comparison. The CP content for individual cuts as well as for the three cuts are reported.

4.3.1 First cutting

Varietal differences and variety x height interaction effects were significant ($p = 0.001$ and $p = 0.05$, respectively). Hybrid napier had higher ($p = 0.01$) CP content than French Cameroon, Clone 13 and Bana but these three varieties did not differ significantly (Table 4.12). However, Bana had a higher CP content than French Cameroon and Clone 13.

The overall varietal response to cutting height was inconsistent. There was a consistent increase in CP content with increase in cutting height in Hybrid napier but a consistent decline in CP content in Bana. The interaction was inconsistent in French Cameroon and Clone 13 which gave the lowest and highest CP values, respectively, at the 10 cm cutting height. Hybrid napier maintained the highest CP content while French Cameroon



4.7 Effect of cutting frequency on the total DM yield (t/ha).

Table 4.12. Effect of variety, frequency and height of cutting on the herbage crude protein content (%) in the first cutting.

	Cutting Interval (weeks)				Cutting Height (cm)			
	6	8	10	mean	0	10	20	mean
F.Cameroon	10.50	10.16	10.97	10.55a	10.70	9.56	11.38	10.55a
Clone 13	11.24	12.39	11.75	11.80ab	11.49	12.65	11.25	11.80ab
Bana	12.22	12.38	12.04	12.21b	13.51	11.47	11.65	12.21b
Hybrid	13.95	16.80	15.63	15.46c	14.26	15.99	16.14	15.46c
Mean	11.98	12.92	12.59		12.49	12.42	12.61	
Cutting Ht. (cm)								
0	11.35	13.34	12.77	12.49				
10	12.14	12.52	12.58	12.42				
20	12.45	12.94	12.43	12.61				
Mean	11.98	12.92	12.59					

S.E. Variety means ± 0.47

S.E. Height and Frequency means ± 0.41

S.E. V x H and V x F means ± 0.82

S.E. H x F means ± 0.71

C.V. (%) = 19.63

Varietal means followed by a common letter do not differ significantly ($p = 0.05$) according to Duncan's New Multiple Range Test (DMRT).

had the least in all the cutting heights (Table 4.13).

4.3.2 Second cutting

There was a significant quadratic response ($p = 0.001$) to the cutting frequency. All varieties had high CP content at six weeks (range 15.88 - 17.64%) which dropped sharply at eight weeks and remained more or less constant up to the tenth week (Table 4.14 and Fig. 4.8).

4.3.3 Third cutting

Hybrid napier had higher CP content than the other three varieties ($p = 0.05$). There was a slight increase in CP content with increase in cutting interval up to eight weeks followed by a slight drop at ten weeks (Table 4.15). Response to cutting height was inconsistent.

4.4. IN VITRO DRY MATTER DIGESTIBILITY

in vitro dry matter digestibility (D - value) was conducted on all the samples but as in CP, only the values for the first three cuts of each frequency of cutting are reported.

4.4.1 First cutting

Results from the first cutting indicated significant varietal differences, variety x height and variety x frequency interaction effects ($p = 0.05$). Varieties French Cameroon, Clone 13 and Bana were all superior to Hybrid napier but the three varieties did not differ significantly among themselves. French Cameroon and Bana showed a slight increase in D-value with increase in cutting interval up to 8 weeks followed by a drop at 10 weeks. D-values were

Table 4.13 Interaction of variety and height of cutting on the herbage CP content in the first cutting.

Variety	Cutting Height (cm)			
	0	10	20	mean
French Cameroon	10.70	9.56	11.38	10.55
Clone 13	11.49	12.65	11.25	11.80
Bana	13.51	11.47	11.65	12.21
Hybrid	14.26	15.99	16.14	15.46
Mean	12.49	12.42	12.61	

S.E. Variety x Height mean $\pm$ 0.82

C.V % = 6.56

Table 4.14. Effect of variety, frequency and height of cutting on herbage crude protein content (%) in the second cutting

Variety	Cutting Interval (weeks)				Cutting Height (cm)			
	6	8	10	mean	0	10	20	mean
F.Cameroon	15.88	9.50	8.54	11.31a	11.58	10.83	11.51	11.31a
Clone 13	16.97	10.30	10.28	12.51a	12.29	12.10	13.15	12.51a
Bana	15.91	10.52	10.61	12.35a	12.06	12.35	12.63	12.35a
Hybrid	17.64	10.93	10.56	13.05a	14.12	13.33	11.69	13.05a
Mean	16.60	10.32	10.00		12.51	12.15	12.25	
Cutting Ht. (cm)								
0	17.19	11.16	9.19	12.51				
10	16.66	9.37	10.43	12.15				
20	15.94	10.42	10.38	12.25				
Mean	16.60	10.32	10.00					

S.E. Variety means ± 0.61

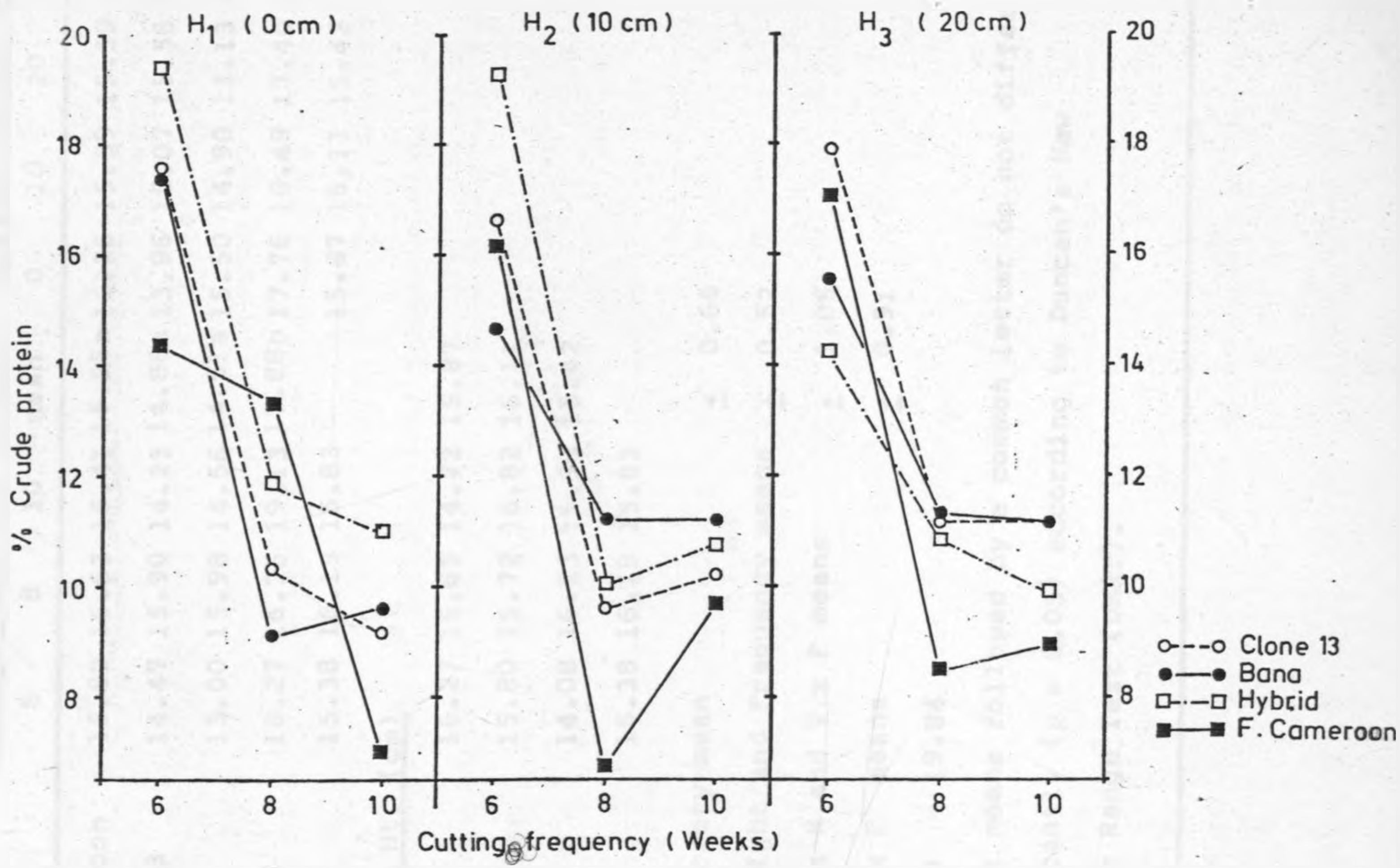
S.E. Height and Frequency means ± 0.53

S.E. V x H and V x F means ± 1.06

S.E. H x F means ± 0.92

C. V. (%) = 25.81

Varietal means followed by a common letter do not differ significantly (p = 0.05) according to Duncan's New Multiple Range Test (DMRT).



4.8 Effect of cutting frequency on herbage crude protein content (%) in the second cutting.

Table 4.15. Effect of variety, frequency and height of cutting on herbage crude protein content (%) in the third cutting

Variety	Cutting Interval (weeks)				Cutting Height (cm)			
	6	8	10	mean	0	10	20	mean
F.Cameroon	15.80	16.63	15.41	15.95a	16.26	15.99	15.59	15.95a
Clone 13	14.47	15.90	14.23	14.86a	13.96	15.07	15.56	14.86a
Bana	13.00	15.98	14.56	14.51a	15.50	14.90	13.13	14.51a
Hybrid	18.27	16.25	19.13	17.88b	17.76	18.49	17.40	17.88b
Mean	15.38	16.19	15.83		15.87	16.11	15.42	
Cutting Ht. (cm)								
0	16.27	16.63	14.72	15.87				
10	15.80	15.72	16.82	16.11				
20	14.08	16.23	15.96	15.42				
Mean	15.38	16.19	15.83					

S.E. Variety mean ± 0.60

S.E. Height and Frequency means ± 0.52

S.E. V x H and V x F means ± 1.05

S.E. H x F means ± 0.91

C. V (%) = 19.84

Varietal means followed by a common letter do not differ significantly (p = 0.05) according to Duncan's New Multiple Range Test (DMRT).

fairly constant in Clone 13 and Hybrid napier.

Apart from Hybrid napier, all the varieties showed a downward trend in D-value with increase in cutting height. Hybrid napier had the opposite trend (Table 4.16).

4.4.2 Second cutting

During the second cutting, French Cameroon, Clone 13 and Bana maintained their superiority in D-value over Hybrid napier ($p = 0.05$). There was a negative linear trend in D-value with increase in cutting interval (Table 4.17). Response to cutting height was inconsistent. There was a general increase in D-value with increase in cutting height up to 10 cm followed by a slight drop at 20 cm, expect in Hybrid napier where there was a downward trend up to 20 cm cutting height.

4.4.3 Third cutting

In the third cutting, Bana had the highest D-value (58.19%) being significantly superior to Hybrid napier ($p = 0.01$) and French Cameroon ($p = 0.05$). Clone 13 was also superior to Hybrid napier ($p = 0.05$) but not to French Cameroon (Table 4.18).

Herbage D-value responded quadratically ($p = 0.01$) to cutting frequency. This response was characterised by a peak D-value at 8 weeks followed by a drop at 10 weeks (Fig. 4.9). Response to cutting height showed a general decline in D-value with increase in cutting height up to 10 cm.

Table 4.16. Effect of variety, frequency and height of cutting on herbage in vitro D-value (%) in the first cutting.

Variety	Cutting Interval (weeks)				Cutting Height (cm)			
	6	8	10	mean	0	10	20	mean
F.Cameroon	58.57	62.71	61.27	60.85b	62.06	61.74	58.74	60.85b
Clone 13	61.32	59.68	59.11	60.04b	60.99	59.70	59.42	60.04b
Bana	60.16	61.19	58.77	60.04b	61.89	59.24	58.98	60.04b
Hybrid	55.98	54.52	55.59	55.36a	53.48	55.64	56.97	55.36a
Mean	59.01	59.53	58.69		59.61	59.08	58.53	
Cutting Ht. (cm)								
0	59.18	60.68	58.94	59.61				
10	59.50	58.95	58.80	59.08				
20	58.33	58.94	58.31	58.53				
Mean	59.01	59.53	58.69					

S.E. Variety means $\pm$ 0.59

S.E. Height and Frequency means $\pm$ 0.51

S.E. V x H and V x F $\pm$ 1.02

S.E. H X F $\pm$ 0.89

C.V. (%) = 5.20

Varietal means followed by a common letter do not differ significantly ($p = 0.05$) according to Duncan's New Multiple Range Test (DMRT).

Table 4.17. Effect of variety, frequency and height of cutting on herbage *in vitro* D-value (%) in the second cutting.

Variety	Cutting Interval (weeks)				Cutting Height (cm)			
	6	8	10	mean	0	10	20	mean
F.Cameroon	55.36	54.07	52.31	53.91b	52.40	53.89	55.44	53.91b
Clone 13	54.14	52.83	53.32	53.43b	53.59	53.84	52.87	53.43b
Bana	54.82	53.43	50.50	52.92b	53.54	54.39	50.82	52.92b
Hybrid	51.86	50.40	50.07	50.77a	53.02	50.33	48.97	50.77a
Mean	54.05	52.68	51.55		53.14	53.11	52.03	
Cutting Ht. (cm)								
0	54.35	53.05	52.00	53.14				
10	53.94	52.88	52.52	53.11				
20	53.83	52.12	50.13	52.03				
Mean	54.05	52.68	51.55					

S.E. Variety means ± 0.70

S.E. Height and Frequency means ± 0.61

S.E. V x H and V x F means ± 1.21

S.E. H x F means ± 1.05

C.V. (%) = 6.88

Varietal means followed by a common letter do not differ significantly (p = 0.5) according to Duncan's New Multiple Range Test (DMRT)

Table 4.18. Effect of variety, frequency and height of cutting on herbage *in vitro* D-value (%) in the third cutting.

Variety	Cutting Interval (Weeks)				Cutting Height (cm)			
	6	8	10	mean	0	10	20	mean
F.Cameroon	55.36	57.31	55.96	56.21ab	57.29	55.51	55.82	56.21ab
Clone 13	55.42	60.68	56.12	57.41bc	57.59	56.81	57.82	57.41bc
Bana	57.03	59.92	57.63	58.19c	59.73	58.22	56.63	58.19c
Hybrid	54.73	56.32	54.46	55.17a	54.40	54.49	56.62	55.17a
Mean	55.64	58.56	56.04		57.25	56.26	56.73	
Cutting Ht. (cm)								
0	56.51	59.21	56.04	57.25				
10	55.58	57.83	55.37	56.26				
20	54.82	58.64	56.72	56.73				
Mean	55.64	58.56	56.04					

S.E. Variety means $\pm$ 0.60

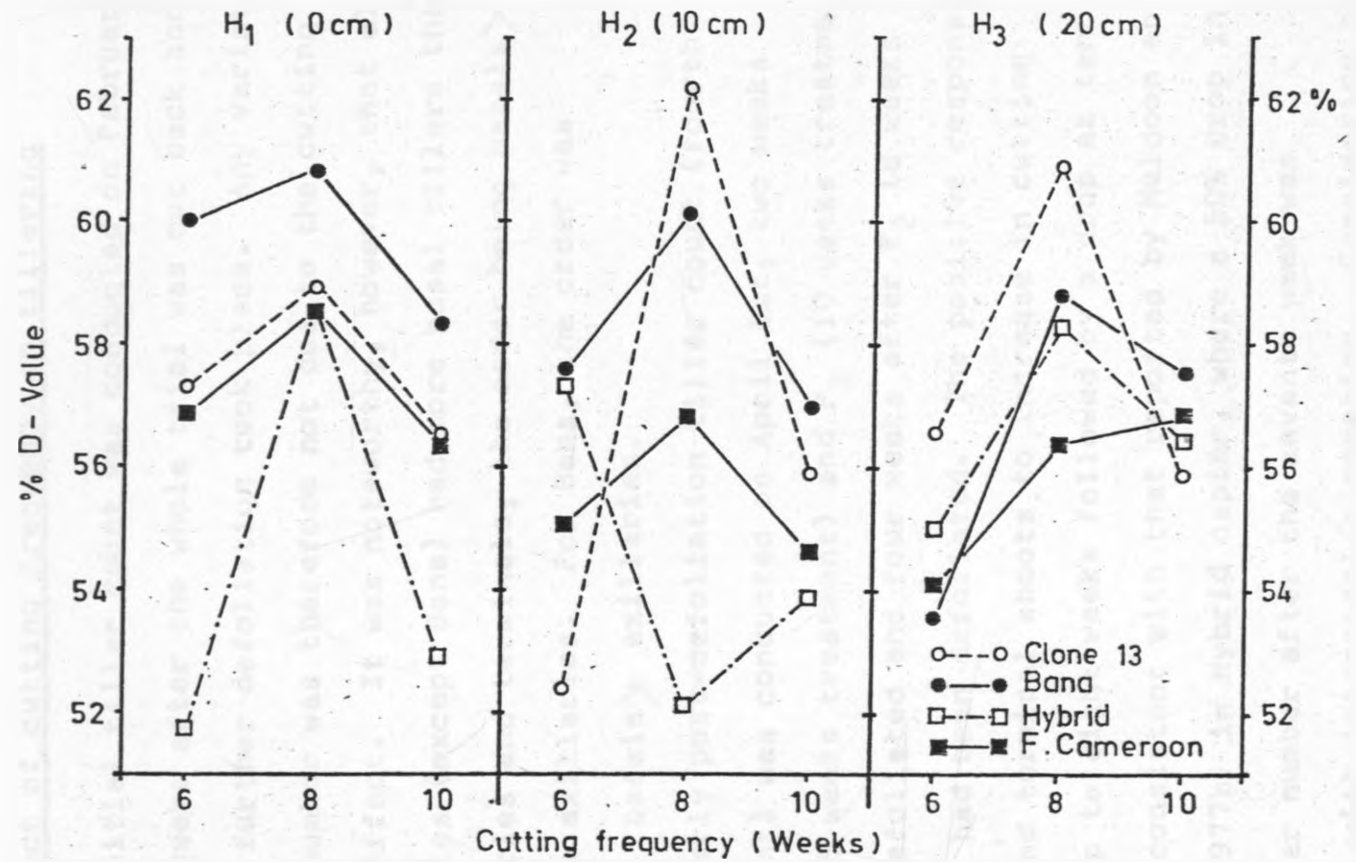
S.E. Height and Frequency means $\pm$ 0.52

S.E. V x H and V x F means $\pm$ 1.05

S.E. H x F means $\pm$ 0.91

C.V (%) = 5.47

Varietal means followed by a common letter do not differ significantly ($p = 0.05$) according to Duncan's New Multiple Range Test (DMRT)



4.9 Effect of cutting frequency on <u>in vitro</u> D-value (%) in the third cutting.

CHAPTER FOUR

5.0 DISCUSSION

5.1 TILLERING

5.1.1 Effect of cutting frequency on tillering

The initial tiller count was conducted on February 22, seven weeks after the whole trial was cut back and before any further defoliation took place. Any variation in tiller number was therefore not due to the cutting frequency effect. It was noteworthy, however, that all the varieties (except Bana) had more basal tillers than the axillaries and terminals, the order being basals > terminals > axillaries. For Bana, the order was terminals > basals > axillaries.

The early post-defoliation tiller count (fourth tiller count) was conducted on April 1st, two weeks after F_1 (6 weeks treatment) and F_3 (10 weeks treatment) had been defoliated and four weeks after F_2 (8 weeks treatment) had been defoliated. The positive response of basal and terminal shoots to increase in cutting interval up to eight weeks followed by a drop at ten weeks was consistent with that reported by Muldoon and Pearson (1977b) in Hybrid napier, where a 50% drop in total tiller number after the seventh week was associated with internodal elongation. Considering the post-defoliation period, however, it is apparent that the three frequency treatments were still within the stage of rapid tiller increase (Boonman, unpublished), hence, the older of the three frequencies (eight weeks treatment) had more tillers than the other two frequency treatments. The differences in tiller number are therefore probably more attributable to the length of the post-defoliation rest period than the defoliation frequency effect which has been reported to be cummulative (May, 1960).

The non-response of axillary tillers to the defoliation frequency effect was probably due to the weather conditions. The long rains started on March 16, only two weeks before this tiller count was conducted. The January-mid-March dry spell must have affected the vigour of the stand. Though no actual data was taken, there was a high mortality of shoots defoliated below the apical meristem during the dry season. The weather factor may have also affected the basal and terminal shoots pattern. Once again the order of tiller predominance in all varieties was terminals $>$ basals $>$ axillaries.

The late post-defoliation tiller count (sixth tiller count) was conducted on April 28, five and four weeks after the second cuts of F_1 (6 weeks) and F_2 (8 weeks), respectively, and six weeks after the first cut of F_3 (10 weeks). The absence of significant defoliation frequency effects on basal tillers was probably due to the effect of "cut 2x" in the F_1 and F_2 frequency treatments, both of which were defoliated prematurely when only four weeks old. This rather "severe" defoliation may have affected basal tillering negatively. Frequent defoliation at low cutting heights has been reported to cause high tiller mortality through gradual reduction in carbohydrate reserves and possible predisposition to fungal diseases such as Helminthosporium (Paterson, 1933; May, 1960; White 1973). On the other hand, the infrequently defoliated treatment (F_3) had few basal tillers in agreement with Muldoon and Pearson (1979a) and Langer (1963) who reported that infrequent defoliation had a negative effect on the total tiller number due to a combined effect of a lower total shoot number and basal shading which inhibited tillering.

The significant variety x frequency interaction effect on the axillary tillers indicate a differential capacity of the varieties tested to withstand severe defoliation. French Cameroon and Clone 13 appear to withstand severe defoliation better than Bana and Hybrid napier. This is mainly due to the former's extensive rhizomes compared to Bana and Hybrid napier which have less extensive rhizomes or none at all, respectively. The significant reduction in the number of terminal shoots after the eight weeks cutting interval is attributed to the infrequent defoliation effect discussed above. The final order of tiller predominance was basals > terminals > axillaries, an indication that basal tillers probably contribute more to the final dry matter yield than any other class of tillers or shoots.

5.1.2 Effect of cutting height on tillering

Regardless of the regrowth phase, there were consistent responses of the various categories of tillers to the cutting height. In all the regrowth phases, there was a significant decrease in basal tiller number with increase in cutting height up to 20 cm. An exception to this was the early post-defoliation phase where the drop in basal tiller number with increase in cutting height from 10 cm to 20 cm was not significant. With the physical removal of all the aerial forage (0 cm cutting height) regrowth inevitably originated from the underground, either in form of terminal shoots previously defoliated above their apical meristems or new basal tillers from the rhizomes. The gradual decline in the number of basal tillers with increase in cutting height was partly attributable to the shading effect of the stubble, thereby inhibiting the development of the basal buds (Mitchell, 1958) and a gradual increase in tiller mortality (Huokuna, 1966).

There was a significant and consistent increase in the number of axillaries with increase in cutting height up to 20 cm in all the regrowth phases. The sharp increase in the number of axillaries from 0 cm to 10 cm cutting height was obvious since no axillaries were recorded at 0 cm cutting height. The 20 cm cutting height must have exposed more axillary buds which later developed into shoots. Jewiss (1972) attributed the activation of dormant axillary buds after defoliation to a hormone-mediated increase in the supply of carbohydrates to the repressed buds. He successfully induced lateral bud activation in intact spring wheat plants with localised application of TIBA (2, 3, 5 - Triiodo-benzoic acid), an auxin inhibitor.

The response of the terminal shoots to the cutting height was not consistent over the three regrowth phases. In the pre-defoliation phase, there was a significant increase in the number of terminals with increase in cutting height up to 10 cm beyond which there was a slight drop. This tiller count was conducted in the middle of the dry season (February) and there was evidence of shoot mortality possibly due to the prevailing soil moisture stress. Early post-defoliation phase indicated no cutting height effect on terminal shoots. This tiller count was conducted two weeks after defoliation and onset of rains (four weeks in the case of F_2) and the stand was probably still recovering from the combined effect of the dry spell and the defoliation. In the late post-defoliation phase the 10 cm cutting height treatment had a higher number of terminal shoots than both 0 cm and 20 cm cutting height treatments. This was in contrast to the findings of Muldoon and Pearson (1977b) who reported that within the first five post-defoliation weeks most apical meristems of Hybrid napier were below the 20 cm cutting height. The difference between the number of terminal shoots at 10 and 20 cm cutting heights was, however, not significant. It is also possible that the more dense stubble in the 20 cm cutting height (relative to the 10 cm cutting height) played an inhibitory role to basal tillering thus reducing the number of the potential terminal shoots (Mitchell, 1958; Huokuna, 1966).

5.1.3 The varietal effect

At all regrowth phases, Hybrid napier had the highest number of basal and terminal shoots while the other three varieties did not differ significantly. French Cameroon and Clone 13 had the highest number of axillaries, significantly higher than Bana and Hybrid napier.

In the absence of literature on tillering in local napier varieties, visual observations would partly explain these differences. Despite the virtual absence of rhizomes in Hybrid napier, it has been observed to be very prolific in basal tillering especially when cut at the ground level (Muldoon and Pearson, 1979c). Up to 200 basal tillers per plant were recorded in this study and this was in agreement with the findings of Muldoon and Pearson (1979c). Many of these tillers, however, never live to contribute to the dry matter yield due to an inherent high tiller mortality. Hybrid napier has characteristically long and slender internodes (and hence few nodes), hence its low number of axillary tillers. The high number of terminals are derived from the basal tillers.

French Cameroon and Clone 13 have an elaborate network of rhizomes (Karanja, 1981). This is the basis of their extensive tillering. They grow fast, flower in 10 to 12 weeks after defoliation and when cut above the ground level (but below the apical meristem) they are efficient in axillary tillering due to their early cane formation. The characteristic late flowering (and cane formation) of Bana has been discussed by Karanja (1981). At the normal defoliation frequencies (six to ten weeks interval) the apical meristem is often below the cutting height and hence regrowth is initiated mainly by the terminal shoots followed by the basals (Muldoon and Pearson, 1979b).

It should be noted that the effect of the cutting frequencies on tillering, reported in this study, is not conclusive, firstly because comparisons between the three frequencies, cannot be made directly since they were not cut at the same time and cutting has a major influence on tillering. Secondly, the effect of the defoliation regime on tillering is cummulative (May, 1960) and is unlikely to have manifested itself fully within the establishment year when this data was taken. The effect of cutting height on tillering is also cummulative but there was strong evidence to show its significance even within the first year. While the trend was expected to remain the same, subsequent results were expected to be more dramatic. The varietal differences are noteworthy as they are likely to influence management. Thus, rhizomatous varieties such as French Cameroon and Clone 13 are likely to tolerate low cutting height much better than the non-rhizomatous Hybrid napier. The latter would require a certain amount of stubble to initiate regrowth.

DRY MATTER YIELD

The dry matter yields reported were low compared with those reported in other studies at Embu Research Station under similar conditions. Considering the seven months period of the study, however, the yields were consistent with those reported by Ngare (1978) in the first production year in Embu, higher than the three-years' mean DM yields reported by Boonman (unpublished) in Embu and within the ranges quoted by Goldson (1977) and Muldoon and Pearson (1979c).

The positive linear response of DM yield to defoliation interval was consistent with the findings of Vincente-Chandler *et al.*(1959) and Rivera-Brenes *et al.*(1962) in Puerto Rico, who reported increases in DM yield from 30.26 to 86.08 t/ha and 27.17 to 46.53 t/ha with increase in cutting interval from 40 to 90 days and 60 to 90 days, respectively. Similarly, Oyenuga (1959) and Gomide *et al.*(1969) reported an increase in DM yield from 4.79 to 13.72 t/ha and 12.20 to 43 t/ha with increase in cutting interval from 21 to 84 days and 28 to 252 days, respectively. The steady increase in DM yields with increase in cutting interval was attributed to a gradual increase in the DM content in the fresh herbage.

Under normal farm conditions in Central Kenya, napier grass is defoliated when it has extremely low DM content. Current findings at the Kenya Agricultural Research Institute, Muguga, indicate that herbage DM rather than CP content, is the limiting factor to milk production in the small scale dairy farms of Central Kenya (Potter, personal comm.).

The absence of significant cutting height effect on DM yields was in sharp contrast to the findings of Caro-Costas and Vincente-Chandler (1961), Boonman (unpublished) and Kusewa *et al.*(1977) who reported higher DM yields from ground level cutting; and Watkins and Severen (1951), Oakes (1967) and Tomer *et al.*(1974, cited by Goldson, 1977) who reported yield benefits from stubbles ranging from 20 to 45 cm. The present findings at Embu indicate that so long as sufficient time for regrowth is allowed, cutting height may not be a limiting factor to DM yields (Karanja and Ngare, 1979). Due to poor management, however, most farmers do not give the stand sufficient rest.

Napier grass does not attain its full production potential until the second year (Kusewa et al. 1977). The varietal differences and their response to cutting height are therefore inconclusive because, as in tillering, the effect of cutting height on the herbage DM yield is cummulative*.

CRUDE PROTEIN CONTENT AND YIELD

Hybrid napier maintained superiority in crude protein content throughout the duration of the study. The other three varieties did not differ significantly and in fact maintained a very narrow range of CP content. There was a slight increase in the mean protein content from the first to the third cutting (Table 5.1).

The significant decline in crude protein content with increase in cutting interval recorded in the second cutting and found in the mean values for the three cuts (Table 5.1) supported, even at such an early

* FOOTNOTE: At the time of writing (Dec. 1982) Hybrid napier had the lowest annual herbage DM yield.

Table 5.1 Effect of variety, cutting frequency and period of defoliation on herbage CP content (%)

Variety	F. Cameroon				Clone 13				Bana				Hybrid			
Cut No.	1	2	3	mean	1	2	3	mean	1	2	3	mean	1	2	3	mean
Cutting interval (weeks)																
6	10.50	15.88	15.80	14.06	11.24	16.97	14.47	14.23	12.22	15.91	13.00	13.71	13.79	17.64	18.27	16.63
8	10.16	9.50	16.63	12.10	12.39	10.30	15.90	12.86	12.38	10.52	15.98	12.96	16.80	10.93	16.25	14.66
10	10.97	8.54	15.41	11.64	11.75	10.28	14.23	12.09	12.04	10.61	14.56	12.40	15.63	10.56	19.13	15.11
Mean	10.54	11.31	15.95	12.60	11.79	12.52	14.87	13.06	12.21	12.35	14.51	13.02	15.46	13.04	17.88	15.47

stage of the napier stand, the commonly accepted inverse relationship between cutting interval and the herbage crude protein content (Paterson, 1933; Oyenuga, 1957; Vincente-Chandler et al., 1959; Gomide et al., 1969). The absence of significant differences in crude protein content in response to the cutting frequency in the first and third cuttings is noteworthy. So is the apparent superiority of the eight-weeks treatment (F_2). The whole of the first cutting was taken during the dry season (except F_3 which was cut four days after the onset of rains) and the lack of response could have been due to the moisture stress, and hence the low crude protein values. The third cutting was taken during a fairly dry period after a very wet six-weeks period and extremely high crude protein values were recorded (range 13.00 - 19.13%). This was consistent with the principle of inverse relationship between rainfall and crude protein content reported by Oyenuga (1957) and Vincente-Chandler et al. (1959). Crude protein values around and above 20% are rare but have been reported in Brunei (Bateman and Decker, 1962) and Brazil (Gomide et al., 1969). The high crude protein content may also have been due to the second dose of nitrogen fertilizer which was applied around this time.

There was no significant cutting height effect on the crude protein content. This was in line with the findings of Watkins and Severen (1951), Caro-Costas and Vincente-Chandler (1961) and some earlier work done at Embu (Ngare, 1978) and tends to underline the lack of response of crude protein content of napier grass to the cutting height.

Crude protein yield is the product of the DM yield and the crude protein content of the dry matter. Consequently, a direct relationship between CP yield and each of the two components is expected. Thus, Hybrid napier, with its superiority in both DM yield and crude protein content also outyielded all the other varieties in crude protein. The response of the crude protein yield to defoliation frequency showed no definite trend (Table 5.2). While DM yields vary directly with cutting interval an inverse relationship generally exists between cutting interval and the herbage crude protein content (Paterson, 1933; Oyenuga, 1958: Vincente-Chandler et al. 1959: Capiel and Ashcroft, 1971). In this case, the response of the crude protein yield to the cutting interval will depend on the relative "strength" of the direct and inverse relationships. The resultant crude protein yield responses are therefore often inconsistent.(Rivera - Brenes et al., 1963, Gomide et al., 1969)

There were no significant cutting height effects on the crude protein yield, in line with the absence of such effects on both the DM yield and crude protein

Table 5.2. Effect of variety, frequency and height of cutting on total herbage crude protein yield (t/ha).

Variety	Cutting Interval (weeks)				Cutting Height (cm)			
	6	8	10	mean	0	10	20	mean
F.Cameroon	0.968	1.012	1.043	1.008a	1.078	0.931	1.014	1.008a
Clone 13	0.853	0.843	1.076	0.924a	0.867	0.902	1.004	0.924a
Bana	1.070	0.947	1.183	1.067a	1.001	1.120	1.080	1.067a
Hybrid	1.491	1.141	1.390	1.341b	1.365	1.415	1.242	1.341b
Mean	1.096	0.986	1.173		1.078	1.092	1.084	
Cutting Ht. (cm)								
0	1.088	1.035	1.110	1.078				
10	1.143	0.925	1.209	1.092				
20	1.055	0.998	1.200	1.084				
Mean	1.096	0.986	1.173					

S.E. Variety means $\pm$ 0.054

S.E. Height and Frequency means $\pm$ 0.047

S.E. V x H and V x F means $\pm$ 0.094

S.E. H x F means $\pm$ 0.082

C.V. (%) = 26.05

Varietal means followed by a common letter do not differ significantly at p = 0.05 level according to Duncan's New Multiple Range Test (DMRT).

content. In Kenya, the napier cutting height is quite variable but generally inclines towards the ground level. In the absence of significant responses of herbage DM yields, crude protein content and yield to the cutting height, the choice of the cutting height should be mainly based on its expected long term effect on the productive life of the stand. Severe and frequent defoliations have been reported to shorten the life of napier stands remarkably (Paterson, 1933; Wilsie *et al.*, 1940).

5.4 IN VITRO DIGESTIBILITY

The varietal differences in D-value recorded over the duration of this study is noteworthy. Apart from Hybrid napier, the other three varieties generally did not differ significantly. The overall mean D-value for French Cameroon, Clone 13 and Bana were 56.99, 56.96 and 57.05%, respectively, compared to 53.77% in Hybrid napier (Table 5.3). The narrow range of D-value indicated that D-value alone was not a sufficient criterion for choice of any of the four varieties. The lower D-value in Hybrid napier did, however, reduce its digestible dry matter yield (DDM) shifting it from the first position in dry matter yield to a third position (Table 5.4). This is important from the utilization point of view.

The effect of defoliation frequency on D-value was inconsistent over the duration of the study. The absence

Table 5.3. Effect of variety, cutting frequency and the period of defoliation on herbage D-value (%)

Variety	F. Cameroon				Clone 13				Bana				Hybrid			
Cut No.	1	2	3	mean	1	2	3	mean	1	2	3	mean	1	2	3	mean
Cutting Interval (weeks)																
6	58.57	55.36	55.36	56.43	61.32	54.14	55.42	56.96	60.16	54.82	57.03	57.34	55.98	51.86	54.73	54.19
8	62.71	54.07	57.31	58.03	59.68	52.83	60.68	57.73	61.19	54.43	59.92	58.18	54.52	50.40	56.32	53.75
10	61.27	52.31	55.96	56.51	59.11	53.32	56.12	56.18	58.77	50.50	57.63	55.63	55.59	50.07	54.46	53.37
Mean	60.85	53.91	56.21	56.99	60.04	53.43	57.41	56.96	60.04	52.92	58.19	57.05	55.36	50.78	55.17	53.77

Table 5.4. Effect of variety on digestible dry matter (DDM) yield (t/ha).

Variety	DM yield (t/ha)	mean D-value (%)	digestible DM yield (t/ha)
F.Cameroon	9.1	56.99	5.19
Clone 13	7.4	56.96	4.22
Bana	8.9	57.05	5.08
Hybrid	9.4	53.77	5.05
Mean	8.7	56.19	4.89

of significant differences in the first cutting was probably due to the prevailing dry spell and the apparent dormant state of the napier stand.

In the second cutting, a negative linear response was obtained, with a steady decline in D-value with increase in cutting interval. This was attributed to gradual lignification which has been reported to start as early as the fourth week of the napier regrowth (Oyenuga, 1958; Gomide *et al.*, 1969). Lignin is largely indigestible and has been found to reduce the digestibility of associated cell wall components (van Soest, 1973). The linear trend was consistent with that estimated by Reid, Postamy, Olsen and Mugerwa (1973) at Makerere University, Uganda, in their regression equation, D-value = 78.69 - 0.20X, where X is the number of days of regrowth. The napier variety used was, however, not specified. Although the D-values obtained in this study were much lower than those reported by Reid *et al.* (1973), they were consistent with values for napier grass (variety French Cameroon) reported by Sheldrick and Thairu (1975) in Kitale, Kenya. They reported a mean organic matter digestibility (OMD) of 59.50% when napier grass was defoliated every four weeks.

There was a quadratic response in the third cutting with a peak D-value at eight weeks cutting interval. This peak coincided with a peak crude protein content and was partly attributed to the effect of the second dose of nitrogen fertilizer.

Literature on _in vitro_ dry matter digestibility of napier grass, especially in response to defoliation frequency is limited. The values obtained in this study were, however, consistent with the _in vivo_ digestibility values reported by Marshall and Bredon (1964), Butterworth (1966), Gupta _et al_. (1967) and Ranjhan and Talapatra (1967), converted into _in vitro_ D-values as proposed by Long (1967).

Although the effect of cutting height on D-value was not significant, the gradual decline in D-value with increase in cutting height was probably due to the inclusion of some old herbage (leaves and stem) in the 10 and 20 cm cutting heights. Apart from the ground level, the maintenance of a particular cutting height is often difficult, much like the maintenance of a plucking table in a tea bush which finally necessitates cutting back. Efforts to maintain the required stubble height results in a certain amount of old herbage being defoliated (Sheldrick and Thairu, 1975). This phenomena has been discussed in details by Boonman (unpublished).

From the foregoing discussion, it can be said that the duration of the study was inadequate for firm conclusions on the effect of defoliation frequency on D-value. Although the highest D-value recorded in this study was 62.71%, most values were below 60%. Muldoon and Pearson (1977) reported that Hybrid napier herbage with less than 60% D-value was unlikely to supply metabolizable energy beyond the maintenance requirements of dairy cattle and hence was only suitable for beef cattle.

CONCLUSION

Most of the results discussed in this study are not conclusive, firstly because they are derived from the first seven months' life of a napier stand expected to last four to five years. Secondly, the effects of the two factors tested (frequency and height of cutting) are cummulative.

These preliminary results however indicate that at the ranges of cutting frequency (6 - 10 weeks) and height (0 - 20 cm) tested, regrowth of Bana and Hybrid napier is dominated by basal and terminal shoots while that of French Cameroon and Clone 13 is dominated by basal and axillary shoots. Good management should therefore ensure this dominance. Hybrid napier maintained the highest number of basals, terminals and total tiller number but this does not seem to be directly related to the final DM yields.

Within the cutting interval limits tested (6 - 10 weeks) there was a direct relationship between the cutting interval and herbage DM yields but an inverse relationship with the herbage crude protein content and *in vitro* DM digestibility. At this early stage of the napier stand the cutting height seems to have very limited influence on both the herbage DM yield as well as the herbage quality.

SUGGESTION FOR FUTURE RESEARCH

Studies on tillering under field conditions are difficult - yet this is the most appropriate place to conduct them. The spacing of 100 cm by 50 cm adopted in this study was too close and limited tiller counting to the first year only, due to an overlap of stools in French Cameroon and Clone 13 plots. Thus,

(a) there is need to study the tillering pattern in a simple trial, preferably a 3 x 3 factorial with three varieties and three cutting heights or frequencies.

(b) a comprehensive study of the *in vivo* and *in vitro* digestibility of napier grass is appropriate. Derivation of appropriate regression equations to convert *in vitro* D-value to *in vivo* values would be a vital tool in nutritive value determinations.

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Appendix I: The general analysis of variance table

Source	DF	SS	MS	F
Replicates	2			
Treatments	35			
Variety	3			
Height	2			
Frequency	2			
V x H	6			
V x F	6			
H x F	4			
V x H x F	12			
Error	70			
Total	107			

Appendix II: Frequency and intensity of defoliation of napier grass trial

Cutting Schedule

F_1 (6 weeks)	F_2 (8 weeks)	F_3 (10 weeks)
1. 20th Feb.	1. 4th March	1. 20th March
2x. 20th March	2x. 2nd April	2. 26th May
2. 4th May	2. 26th May	3. 4th August
3. 19th June	3. 22nd July	
4. 29th July		

Please note:

(a) Cut numbers 2x (F_1) and 2x (F_2) were erroneously cut 4 weeks after their previous cuts (cut 1).

(b) The project covers the period 5th January to 4th August 1981, a period of exactly 30 weeks.

(c) F_1 therefore had a total of 5 cuts (including the 20th March cut), F_2 had 4 cuts (including the 2nd April cut) and F_3 had only 3 cuts.