EFFECTS OF CUTTING INTERVAL AND NITROGEN FERTILIZER RATE ON THE YIELD AND NUTRITIVE VALUE OF *BRACHIARIA BRIZANTHA* AND *CHLORIS GAYANA*

By

EPHRAIM JOSEPH MTENGETI

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DECLARATION

I, EPHRAIM JOSEPH MTENGETI, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my original work and that it has never been submitted for a degree in any other University.

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ABSTRACT

The effects of three cutting intervals (20, 40 and 60 days) and four levels of N application (0, 100, 200 and 400 kg N/ha) on the dry matter yield, dry matter content, tiller height, CP content, CP yield, N utilization efficiency, *in vitro* dry matter digestibility and *in vitro* digestible dry matter yield were studied in *Chloris gayana* and *Brachiaria brizantha* over a period of 120 days in 1987 in a field experiment at Sokoine University of Agriculture farm in Tanzania.

The dry matter yield of the grasses increased with extension of the cutting interval up to 40 days and then declined thereafter. The dry matter yield of the grasses increased with increasing N rate. The dry matter content increased with increasing cutting interval and decreased with increasing N rate.

The green leaf and stem dry matter yields increased with increasing N rate. Extended period between successive cuts slightly reduced the green leaf dry matter yield and slightly increased the stem dry matter yield. Leaf:stem ratio was not significantly ($P > 0.05$) affected by extension of the cutting interval. Tiller height increased significantly ($P < 0.01$) with increasing N rate and cutting interval.

The CP content of the herbage decreased with extension of the cutting interval. The CP yield increased with increasing N rate and extension of the cutting interval to 40 days and declined thereafter. The recovery of applied N increased with increasing N rate up to 200 kg N/ha then declined thereafter. Dry matter yield response in terms of kg DM per kg of applied N decreased with increasing N rate.

In vitro dry matter digestibility of the grasses increased with increasing N rate and decreased with extension of the cutting interval. *Brachiaria brizantha* had a significantly ($P < 0.01$) higher *in vitro* dry matter digestibility than *Chloris gayana* at all cutting intervals. The *in vitro* digestible dry matter yield of the grasses increased with nitrogen rate. It also increased with extension of the cutting interval up to 40 days and then declined thereafter.

The results of this experiment support the view that, the productivity of grasses can be improved by N fertilization. In this study it has been shown that *B. brizantha* and *C. gayana* should be harvested every 40 days during the period of favourable growth in order to balance the productivity and the quality of the produced herbage.

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ABBREVIATIONS

Abbreviation	Term
DM	Dry matter
CP	Crude protein
CF	Crude fibre
N	Nitrogen
IVDMD	*In vitro* dry matter digestibility
IVDMY	*In vitro* digestible dry matter yield
kg	Kilogramme
ha	Hectare
r	Correlation coefficient
mm	Millimetre
cm	Centimetre
m	Metre
%	Percent
^{o}C	Degrees centigrade
LWG	Liveweight gain
t	Ton
Spp	Species
yr	Year
wt	Weight
L. wt	Liveweight

1. INTRODUCTION

About 99% of the ruminant livestock population in Tanzania derive their feed almost entirely from pastures. Tanzania's natural grasslands, like most of the tropical natural grasslands, are characterized by rapid growth rates during the rainy season, followed by reduced growth and a deterioration in quality in the dry season. This reduction in the quality and quantity of the forage coupled with a genetically low production potential of the indigenous livestock and poor animal husbandry, in turn, severely reduces the productivity of ruminant livestock (Table 1).

Introduction of tropical improved pasture grasses of higher nutritive value which are also more tolerant to drought and heavy grazing than the unimproved native pasture grasses has been encouraged in Tanzania (Madallali, 1974). In central Tanzania Wigg (1973) found that the sown pastures provided over 50% more dry matter yield per hectare and a higher carrying capacity than the natural pastures which were seriously invaded by weeds particularly sodom apple (Solanum incanum). Stobbs (1976) estimated, from published data in the tropics, beef production from natural and sown grassland under monomodal and bimodal rainfall conditions (Table 2). The benefits of sown pastures over natural pastures and the effect of climate were clearly shown.

Table 1 : Productive and reproductive traits of cattle in Tanzania (Min. of Agric. 1984)

Traits	Present estimation	Estimated future goals
Calving rate	50%	75%
Calf mortality	20 - 25%	10%
Adult mortality	10%	3%
Average live wt. at slaughter	200 kg L.wt.	450 kg L.wt.
Average weight	100 kg L.wt.	293 kg L. wt.
Age of offtake for males	5 - 6 yrs	2 - 3 yrs
Offtake	$\leq$ 10% per yr	25 - 30% per yr

Table 2 : Estimated beef production from natural grasslands and sown (improved) grasslands in the tropics (kg LWG/ha/yr) (Stobbs, 1976)

	Monsoonal 5-6 months dry	Humid tropics long growing season
Natural grasslands :		
Improved grazing	10 - 80	60 - 100
Oversown legumes and fertilizer	120 - 170	250 - 450
Cultivated grasslands :		
Grass/legume mixtures with fertilizer	200 - 300	300 - 600
Nitrogen fertilized grass	300 - 500	800 - 1500

One of the factors limiting the growth, yields and nutritive value of tropical grasses is the deficiency in N of tropical soils (Henzel, 1962; Crowder and Chheda, 1982). Henzell (1962) in Queensland (Australia) was uncertain on whether pasture legumes could satisfy the very large N requirements of the most vigorous tropical grasses. Some workers in Nigeria (Haggar, 1971) and in Puerto Rico (Vicente-Chandler et al., 1974) reported that the benefits of nitrogen fertilizer exceeded those of oversown legumes particularly where moisture was abundant and intense management was practised.

This was particularly demonstrated in terms of greater carrying capacity, animal production per hectare and stocking rates at Shika (Nigeria) (Haggar, 1971). In comparing farm yard manure with fertilizer nitrogen as sources of N for the production of Cenchrus ciliaris, Chloris gayana and Cynodon dactylon in Central Tanzania, Wigg et al. (1973) found that manure was inferior to fertilizer N for an immediate reponse in herbage yield.

The merits arising from the use of fertilizer N in a given area depends on the efficiency of animal production. Henzell (1962) noted that, the economy of fertilizer use is influenced by the efficiency with which the fertilized grass can be converted into animal products. The efficiency of animal production in Tanzania is not high, compared to developed countries (Table 1). However,it has been estimated that the dairy herd in Tanzania is growing at an annual rate of a little over 6% (Min. of Agric. 1984) justifying intense research on ways and means of increasing pasture production. For this reason, the use of N to increase grass production in Tanzania cannot be overlooked.

Nitrogen fertilizer trials under cutting management have been carried out with various grass species in Tanzania (Lane and Lwoga, 1978; Fredricksen and Kategile, 1980; Muyoya, 1980). However, Brachiaria brizantha has received little attention in particular with regard to nitrogen fertilization and cutting management. In contrast, relatively much work has been done on Chloris gayana. Brachiaria brizantha is one of the most promising improved grasses that have produced good results under N fertilization and cutting management in other parts of the tropics (Appadurai and Goonewardena, 1974; Appadurai and Arasaratnam, 1969; Silvalingan 1964a, 1964b). In this respect, the objectives of this study were to determine the influence of cutting interval and nitrogen rate on the yield, nutritive value and growth of Chloris gayana and Brachiaria brizantha.

2. LITERATURE REVIEW

2.1 Sources of nitrogen for grass based pastures

The sources of available nitrogen for tropical pastures include : Soil nitrogen, animal excreta, nitrogen from fertilizer N and nitrogen from fixation by the legume Rhizobium symbiosis.

2.1.1 Soil nitrogen

Soil nitrogen is the main source of nitrogen for vast areas of natural pastures. Tropical soil N status is low, thus limiting grassland production and herbage protein content even though in these soils the total amount of nitrogen in the root zone may appear to be high (Whiteman, 1980). The limitation to pasture production is not the total amount of N in the profile but the rate at which this N is mineralized to available forms for uptake by plants (Henzell *et al*., 1968). The rate of release of soil N under old undisturbed grassland in the tropics has been considered to be very slow, usually less than 1% per annum for the whole profile and a little higher for the top soil (Norman, 1963). Studies on pasture production in Zambia (Brockington, 1960) and Queensland in Australia (Norman, 1963) have shown that the quantity of N available for plant growth is usually less than 100 kg/ha/yr and often only 10 to 20 kg/ha/yr. Data on amounts of available soil N for pasture growth is lacking in East Africa.

2.1.2 Animal excreta

The real value of the nutrients in animal manure depends on a number of factors such as soil type, soil fertility status, time of application, rainfall after application and stocking rate (Van Burg et al., 1980). The nutrients originate partly from herbage and partly from other animal feedstuffs.

It has been observed that some quantities of soil N are provided by excreta of grazing animals. Smith (1965) calculated that the urine of cattle grazing Hyprrhenia veld in Zambia (2 - 4 ha/animal) would return 1 to 3 kg N/ha/year. In Zimbabwe, Rhodel (1969) suggested that, provided coprophagous beetles were present to carry the dung into the soil, more than 168.5 kg N/ha would be returned to the soil at a stocking rate of 10 yearling/ha on pasture in a six-month grazing period.

If manure is collected from the night-yarding or housing of animals for sale or for use on cropland, there occurs fertility loss from grassland. Wigg (1973), in Central Tanzania, suggested that 24 hours grazing or having a system of movable night enclosures would spread fertility to the grasslands. Normally animals avoid grazing in the vicinity of the feaces. There is a need, therefore, to ensure distribution of the droppings in order to reduce concentration of grazing and to distribute the nutrients over a wider area.

2.1.3 Fertilizer nitrogen

There are many fertilizer compounds containing nitrogen. The most common N fertilizers are :- Ammonium sulphate (21%N); Urea (46%N); Ammonium nitrate (34%N) and Calcium ammonium nitrate (25%N). The choice of which fertilizer to use depends on the cost and soil reaction of the various compounds.

Various researchers (Henzell, 1971; Figarella et al., 1972; Vicent-Chandler and Figarella, 1962; Burton and Jackson, 1962) have reported that there is very little difference in the utilization of various forms of fertilizer N by grasses. Ammonium sulphate has been found to be the most efficient and urea the least efficient sources of N to the grass pasture (Burton and Jackson, 1962; Figarella et al., 1972). Crowder and Chheda (1982), however, noted from tropical studies that ammonium sulphate has a rapid and deleterious effect on soil pH and causes leaching of bases especially calcium and potassium.

2.1.4 Nitrogen fixation by the legume-Rhizobium symbiosis

Legume - Rhizobium symbiosis can be defined as a relationship in which Rhizobium bacterial infect the legume roots and transform atmospheric nitrogen into a form which is utilized by the legumes and ultimately made available to associated plants, and the bacteria depending on the legume for basic nutrients needed to sustain their life functions. Fixation of nitrogen by legume - bacterial symbiosis depends upon the presence of an efficient strain of Rhizobium that infects the legume - root, availability of soil and plant nutrients, environmental conditions (e.g. pH and temperature), competetion of associated vegetation and intensity of defoliation or grazing (Crowder and Chheda, 1982). The Rhizobium - legume symbiosis is considered to give mutual benefit to both partners, the legume supplying sugars to the Rhizobium in the nodules while the Rhizobium in turn supplies fixed nitrogen to the host (Whiteman, 1980).

Cultivation of leguminous plants provides the most economical means of adding N to the soil - plant - animal system. In the past, tropical legumes were thought by pasture researchers to be less efficient in their capability to fix N than temperate legumes. This belief has, however,been disproved by results obtained from widely dispersed trials of several tropical legumes (Crowder and Chheda, 1982). For example the annual production of 567 kg/ha/yr of N by Leucaena leucocephala was obtained in Queensland (Australia) (Hutton and Bonner, 1960). In their review on the potential of and limitation to the biological contribution from forage legumes in sub-Saharan Africa, Haque and Jutzi (1984) noted that the amounts of N transferred to the soil by forage legumes (in sub-saharan Africa) vary between 62 and 290 kg/ha/ yr.

2.2 Effects of fertilizer nitrogen on grass based pasture

2.2.1 a. Dry matter yield of herbage

Many experiments with a variety of tropical grasses have shown that, given adequate soil moisture, N fertilizer increases herbage DM yield (Chheda and Akinola, 1971a; Funes et al., 1980; Vicente-Chandler et al., 1959, 1972; Appadurai and Arasaratnam, 1969; Appadurai and Goonewardena, 1974; Figarella et al., 1972; Gordon and Burton, 1976 ; Stomayo-Rios et al., 1960; Fredricksen and Kategile, 1980; Lwoga, 1981; Olsen, 1972; Mwakha, 1972). There is little or no response to applied N in the arid and semi-arid regions found in many parts of the tropics and sub-tropics (Crowder and Chheda, 1982). Fig. 1 shows the response of herbage dry matter yield to N fertilizer application from Tanzania and other parts of the tropics.

In Sri-Lanka the DM yield of Brachiaria brizantha increased linearly up to 280 kg N/ha/yr, the N efficiency being 29 kg of DM/kg N (Appadurai and Arasaratnam, 1969). Results from experiments with Chloris gayana conducted for three years at Uyole in the southern highlands of Tanzania (Mean annual rainfall of 900 mm) showed an increase in dry matter yield per hectare with increases in N level (Table 3). The nitrogen efficiency reached a maximum (43 kg DM/kg N) at the rate of 240 kg N/ha/yr while dry matter yield per hectare was still increasing as depicted by Table 3. In another experiment with the same species at Morogoro in Tanzania (Mean annual rainfall about 700 mm),Lwoga (1977) as quoted by Lane and Lwoga (1978) reported an increased dry matter yield with increasing nitrogen levels. The nitrogen levels were 0, 100, 200, kg N/ha and the dry matter yields at three months growth were, respectively, 2.9, 12.2 and 19.8 tons DM/ha. Dry matter yield per hectare was still increasing at 200 kg N/ha implying that much higher levels than 200 kg N/ha could be applied to increase dry matter yield.

In Southern Uganda (mean annual rainfall of 1300 mm) Olsen (1972) applied ammonium nitrate to four grasses at six rates ranging from 0 to 2240 kg N/ha/yr. The results for two grasses are summarized in Table 4. Mean annual dry matter yield increased linearly

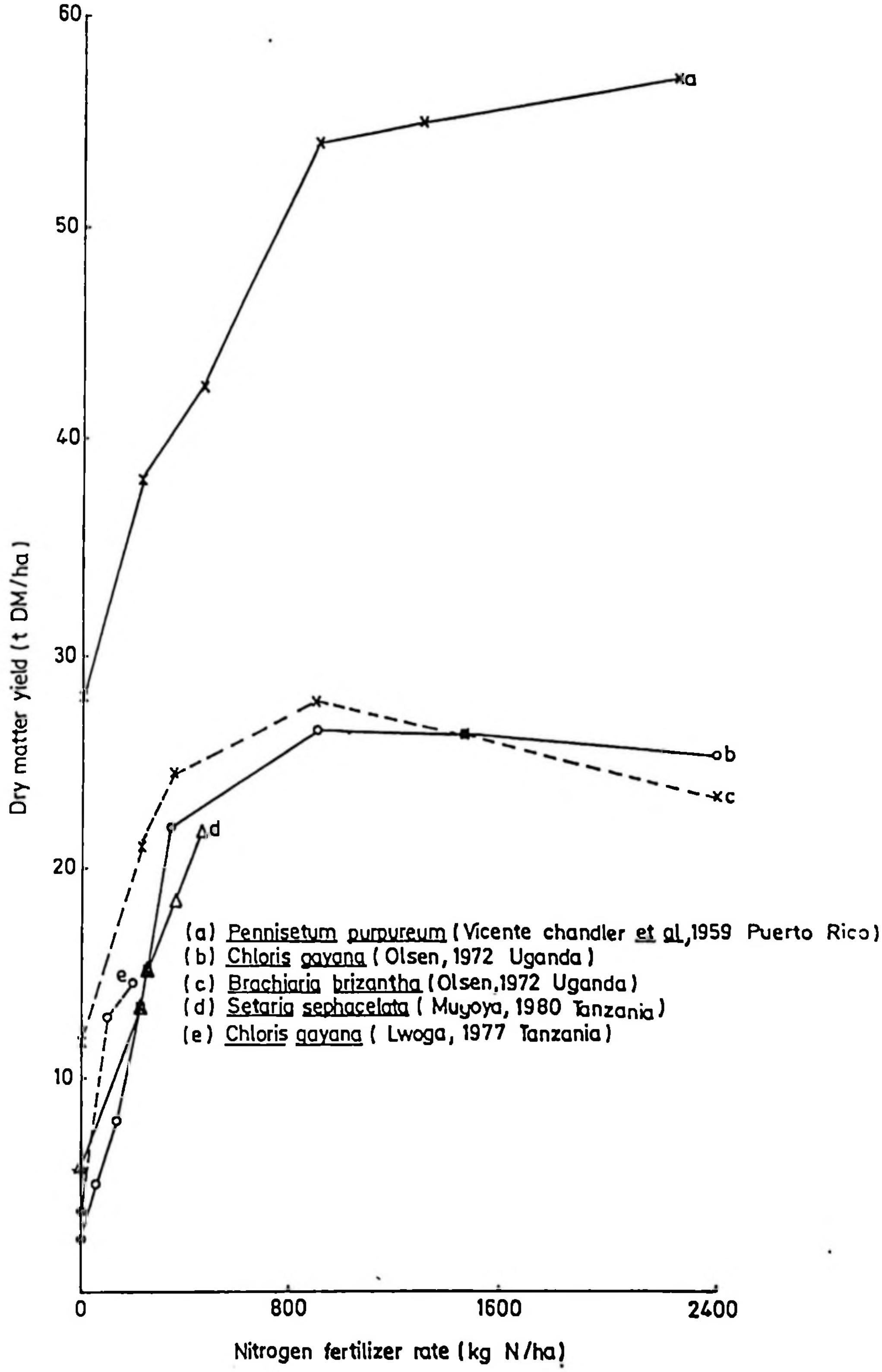

Fig. 1 . Effect of fertilizer N on pasture dry matter yield in the tropics

Table 3 : Dry matter yield kg DM/ha of Chloris gayana and nitrogen efficiency (kg DM/kg N) under six levels of nitrogen (mean of three years) (Uyole Agric. Centre Research Report No. 28, 1980)

Nitrogen kg/ha/yr	Dry matter yield ton DM/ha	Nitrogen efficiency kg DM/kg N
0	3.7	
60	6.0	39
120	8.7	42
240	18.7	43
360	17.9	39
480	21.6	37

Table 4 : Effect of nitrogen fertilizer application on the mean annual dry matter production (t/ha), CP % of DM and yield of CP (t/ha) of *Brachiaria ruziziensis* and *Chloris gayana* (Olsen, 1972)

	Rate of N application (kg/ha/yr					
	0	224	448	896	1568	2240
Brachiaria ruziziensis						
DM yield (t/ha)	6.1	13.9	21.8	26.5	25.9	23.5
CP % of DM	6.7	7.7	10.1	13.9	16.3	16.3
CP yield (t/ha)	0.6	1.2	2.4	3.6	4.1	3.9
Chloris gayana						
DM yield (t/ha)	11.2	20.7	24.5	27.8	26.0	25.4
CP % of DM	8.5	9.3	11.3	14.3	15.7	15.5
CP yield (t/ha)	1.1	1.9	2.8	3.9	3.9	3.9

with increases in N rate up to 448 kg N/ha, levelled off at 896 kg N/ha and fell off when more than 1568 kg N/ha was applied. Similar results were reported in Puerto-Rico by Vicente-Chandler *et al.* (1959).

N affects herbage yield through its influence on various aspects of the morphology and physiology of the grass plant. Generally N fertilizer increases tiller density and tiller weight (Dovrat *et al.*, 1971; Deinum and Dirven, 1972, 1976; Wilman, 1977; Joseph and Waisel, 1977; Lwoga 1977a; Grof, 1969). Wilman (1977) in his review of temperate grasses, reported that, the effect of N on yield can be considered in terms of its effect on the tiller density and on weight per tiller. He further considered that N increases weight per tiller partly because of a greater weight of leaf blade and partly because of heavier sheath and stem.

2.2.1 b. Factors that affect dry matter yield response to applied N

i. Defoliation : Defoliation is the removal of plant shoots by grazing or cutting. According to Humphreys (1978) defoliation can be considered in terms of :

a. Frequency - how often plant shoots are removed;
b. Intensity - how much plant material remains after defoliation, or how much is removed ; and

c. Timing - the stage of plant development and the climatic conditions at the time of defoliation.

Maximum yield response to fertilizer N is likely to be obtained with infrequent defoliation and a low height of cut (Whitehead, 1980). In Puerto-Rico, Vicente-Chandler et al. (1972) obtained the highest yield response of Congo grass (Brachiaria ruziziensis) cut at a height of about 5 cm from the ground at 90 days interval and with 673.8 kg N/ha applied. Optimum frequency and height in practical situations will be influenced by the required quantity and digestibility of herbage and the level of fertilizer N applied. Hunt et al. (1975) working with temperate grasses reported that high yield in rye grass may be obtained by extending the cutting interval at the expense of herbage quality.

ii. Chemical form of fertilizer nitrogen

The most widely used nitrogen fertilizers are disucssed in section 2.1.3. Several studies have shown that all forms of N fertilizer markedly increase dry matter yields of grasses with little difference in total production (Figarella et al., 1972; Henzell, 1971; Burton and Jackson, 1962). Table 5 compares the results of the effects of five sources of nitrogen applied to Pangola grass over a three year period on the dry matter yield, recovery of fertilizer nitrogen and the acidity of the upper 15 cm of a deep red clay soil. It can be seen that response to urea was

Table 5 : Yields of Pangola grass as influenced by forms of N fertilizer in Puerto-Rico, average of 3 years (Figarella *et al.*, 1972)

N source	N rate (kg/ha)	Dry matter t/ha	CP forage (%)	N recovery (%)	Soil pH
Nil	0	5.37	6.4	-	5.5
Urea	628	19.89	7.7	40.6	4.8
Ammonium sulphate	632	20.46	8.6	55.3	4.[illegible]
Ammonium nitrate	617	20.11	8.1	46.4	4.9
Urea + $CaCo_3$	584	20.34	7.3	41.8	5.2
Ammonium nitrate-lime	632	20.91	7.9	44.4	5.5

slightly less than to the other forms of N fertilizer. However, ammonium sulphate gave the lowest soil pH (4.5). Crowder and Chheda (1982) in a review of tropical grassland husbandry noted that with continued application of most forms of N fertilizer there is a general decline of herbage dry matter yield due to unfavourable soil conditions (such as increased soil acidity, phosphorus fixation and decreased exchangeable calcium and magnesium).

iii. The return of animal excreta.

Studies on the chemical composition of animal excreta in East Africa are scarce. In their review on the recycling of nutrients from dung and urine spots of grazing cattle, Crowder and Chheda (1982), noted from temperate zone studies that on the average fresh cattle feaces contain 0.38% N, 0.18% P_2O_5, 0.22% K_2O and fresh urine 1.10% N, 0.01% P_2O_5 and 1.15% K_2O. About 75% of nitrogen and phosphorus and from 80 to 90% of the potassium consumed by grazing cattle normally passes through the animal (Peterson *et al.*, 1956a).

The importance of animal excreta in maintaining soil fertility is well known and many studies on the effects of mechanically applying the various types of animal excreta to the soil as a fertilizer supplement have been reported. In Central Tanzania Wigg *et al.* (1973) compared the effects of manure and nitrogen fertilizer on the production of *Cenchrus ciliaris*, *Chloris gayana* and *Cynodon dactylon* and found that the former gave a small immediate response but had a larger residual effect, with the overall yield increases after four years being similar. In Zimbabwe, Rhodel (1969) applied a high level of nitrogen (448 kg N/ha) to Chloris gayana sward in various dressings during the 1965 - 66 and 1966 - 67 summers. He top-dressed the nitrogen with and without kraal manure, at the rate of 20 tons of DM/ha. Kraal manure increased yields by 4,010 kg DM/ha in the first year and by 3302 kg DM/ha in the second year (Table 6), indicating that on heavily grazed pastures manure is likely to affect herbage production even where very large amounts of nitrogen have been applied in chemical form. Recycling of N, by grazing animals, however, involves large losses and in practice, the influence on herbage production of N returned in excreta is often small. The loss of nutrients occurs from the time of deposition of the excreta through volatilization, leaching, surface run off of water and absorption by plants (Crowder and Chheda, 1982).

iv. Species of the grass

Crowder and Chheda (1982) in a review of tropical grassland husbandry noted that grass species respond differently to applied N. With yields of such species as elephant grass, guinea grass, Cynodon increasing linearly with annual rates of 600 - 800 kg N/ha applied, the curve being less pronounced beyond 1000 to 1200 kg N/ha. In Sri Lanka, Sivalingam (1964a) studying three tropical grasses (Pennisetum purpureum, Panicum maximum, Brachiaria brizantha) under three cutting intervals (30, 60 and 80 days) and four rates of applied

Table 6 : Effect of applying manure, in addition to 448 kg N/ha on the herbage yield (kg DM/ha) of <u>Chloris gayana</u> (Rhodel, 1969)

Treatment	Year	448 kgN/ha	448 kgN/ha + 20 tons Kraal manure	Herbage yield difference kg DM/ha
Mean yield of	1965-66	23,868	27,878	4,101
herbage (kg DM/ha)	1966-67	30,114	33,416	3,302

N (0, 45, 134.7 and 404.2 kg N/ha/yr) obtained a difference in yield response at each N level, but the response tended to be less divergent at the highest N level (Table 7). In Australia, Colman and Lazenby (1970) reported that differences in yield response (at each N level) between species could be related to root yield.

v. Presence or absence of legume in the grass pasture

In the absence of fertilizer N, yields from grass/legume combinations are higher than from all grass swards due to the ability of the legume to fix atmospheric nitrogen (Whitehead, 1970). The application of fertilizer N reduces legume growth and, therefore, N fixation. Responses to fertilizer N (in terms of herbage yield increase per kg N applied) are therefore, lower with grass/legume swards than with pure grass swards alone (Whiteman, 1980).

In the temperate regions of the U.S.S.R. Sau (1970) found that the efficiency of N fertilizer depended mainly on the contribution of legumes to the soil. In his study on efficiency of N fertilizer on cultivated temperate grass and grass/legume swards on various soils of the U.S.S.R. over ten years, he obtained an increase in DM yield per kg N applied (20 - 30 kgDM) on swards deficient in legumes (15%) and soil N. Yield responses to applied N were very low on swards with more than 50% legume content.

Table 7 : Effect of nitrogen rate and cutting interval on the DM yield (t/ha/yr) of Pennisetum purpureum, Panicum maximum and Brachiaria brizantha (Sivalingam, 1964a)

Grass spp	Rate of N (kg N/ha)			
	0	45	134.7	404.2
			30 days	
Pennisetum purpureum	10.4	11.8	13.7	21.9
Panicum maximum	11.5	12.5	15.2	23.1
Brachiaria brizantha	23.7	28.1	30.2	33.6
			60 days	
Pennisetum purpureum	15.6	16.8	22.2	33.5
Panicum maximum	13.4	15.7	18.9	24.7
Brachiaria brizantha	22.1	23.0	27.5	29.0
			90 days	
Pennisetum purpureum	17.4	18.5	23.1	33.4
Panicum maximum	13.5	16.3	22.1	32.7
Brachiaria brizantha	19.6	23.0	27.8	28.3

vi. Moisture supply.

Moisture is necessary to carry the applied N to the plant root zone. Irrigation, thus, increases the response of grass pastures to applied N in dry climates (Whitehead, 1970; Garwood et al., 1980 ; Tiharuhondi et al., 1973). In Lousiana, U.S.A. where the rainfall is about 1522 mm per annum, quite well distributed over the year, Semple (1951) found that the yield of native blue stem (Andropogon spp) pasture was almost doubled and the quantity of the forage was markedly improved by using commercial fertilizers at the rate of 336.9 kg N/ha. Similar results were obtained by Gordon and Burton (1956) with coastal bermuda grass in Georgia, U.S.A. Shortage of moisture supply especially in the top soil, restricts grass response to fertilizer N by reducing the availability of nutrients to plant roots (Whitehead, 1970 ; Tiharuhondi et al., 1973).

vii. Season of the year and length of growing period

The dry matter yield response to applied N fertilizer also depends on the soil moisture supply. In seasonal rainfall areas of the tropics, pastures grow very rapidly during the early part of the rains and quickly reach the flowering and seeding stage. Crowder and Chheda (1982) noted that grass takes N rapidly as growth resumes when rains begin after the dry season and soil moisture is readily available. For this reason, it may be advisable to apply N fertilizer to the grass sward when rains begin so as to obtain good yield responses.

Whitehead (1970), however, suggested that the most efficient use of N is achieved by avoiding the application of large quantities of N in relation to the proposed growth period and also by applying the N for a given growth period immediately after the previous harvest. He also noted that yield responses of the grass sward to the applied N decrease with the length of the growing period. In an experiment with temperate grasses in Scotland, Hunt (1966)as quoted by Whitehead (1970) found that 312 kg N/ha in a single application to the grass sward gave no additional response over the 208 kg N/ha rate during the 57 day period.

Split application of fertilizer N, rather than a single large application for uniform distribution of grass yields has been suggested (Crowder and Chheda, 1982; Rhodel, 1969). In Georgia, United States of America, Burton and Jackson (1962) fertilized Coastal bermudagrass with 6 nitrogen sources (ammonium nitrate, ammonium sulphate, ammonium nitrate solution, anhydrous ammonia, urea-ammonium nitrate solution and urea) at annual rates of 112, 224 and 448 kg N/ha, all in March or half in March and half after second cutting in July for 5 years. They reported that splitting the nitrogen application did not increase yields in years with no heavy leaching rains. However, over the 5 year period, splitting the nitrogen fertilizer application significantly increased the yields from all sources (except anhydrous ammonia) by 1.2 to 2.4 tons per hectare.

2.2.2 Quality of the herbage

The quality of the herbage refers to its chemical composition, level of acceptability to the animal, digestibility, and the efficiency with which digested nutrients are utilized for maintenance and productivity of the animal (Crowder and Chheda, 1982).

i. Chemical composition of herbage dry matter

Various researchers have shown that if soil moisture is not limiting, N fertilizer increases the nitrogen content of the herbage dry matter of the tropical grass pasture (Vicente-Chandler *et al*., 1974; Olsen, 1972; Fredricksen and Kategile, 1980; Henzell, 1962). In his review of N on East African pasture, Lwoga (1981) noted that if the herbage is harvested at short and regular intervals, N content continues to rise with increases in fertilizer N rate beyond levels that give maximum dry matter yields. Olsen (1972) in Southern Uganda working with four grasses (*Brachiaria ruziziensis, Chloris gayana, Panicum maximum* and *Setaria anceps* observed an increase in herbage N content with an increase in fertilizer N rate beyond levels that gave maximum dry matter yield (Table 4).

Heavy N-dressing to the grass pasture, however, increases non-protein nitrogen (NPN), like amino acid and nitrate, and decreases the true protein in percentage crude protein. In Brazil, Queitoz *et al*. (1982) working with tropical and sub tropical perenial grass species found that increasing N level from 200 to 400 kg N/ha increased the N-NO_3 content significantly. *Brachiaria ruziziensis* and

Brachiaria radicans showed maximum (1818 and 1609 ppm, respectively) N-NO_3 contents, while *Setaria sphacelata* cv Kazungula showed the lowest (500 ppm) N-NO_3 content. Nitrates can be toxic to livestock, since they are often reduced to nitrite which is toxic to the animals (Crowder and Chheda, 1982; Simon, 1984). The increase in crude protein content and decrease of carbohydrate content due to heavy nitrogen dressing affects the quality of silage because of the formation of large quantities of butyric acid that leads to rotting and losses of N through NH_3 (Raymond *et al*., 1978).

Fertilizer N application often exerts a major influence on the mineral composition of forages. Vicente-Chandler *et al*. (1959) , working with three tropical grasses (*Pennisetum purpureum*, *Panicum purpurascens* and *Panicum maximum*) in Puerto-Rico, found that fertilization with N had no apparent effect on the Ca, K or Mg contents of the *Panicum purpurascens* but decreased P and K, and did not affect the Mg and Ca contents of *Pennisetum purpureum*. In another experiment with *Brachiaria ruziziensis*, Vicente-Chandler *et al*.(1972) found that N fertilizer decreased the phosphorus content but did not affect the Ca, Mg or K contents of the forage. Increased length of harvest interval reduced the mineral contents of the forage. The effect of fertilizer N on the mineral composition of forages has, however, received little attention because minerals are easily supplemented to the grazing animals as compared to protein and energy.

ii. Digestibility of herbage dry matter

Nitrogen fertilizer does not greatly influence digestibility of the herbage (Minson, 1967, 1973), but may increase the nitrogen content of herbage above the critical level of 1.2% N below which feed intake is normally depressed (Minson, 1971). Milford and Minson (1966) in Australia reported that when crude protein in the herbage exceeds 7% digestibility does not appear to be affected by additional N supply. If herbage with a crude protein content below 7% is fed to animals, however, microbial activity in the rumen is depressed by deficiency of nitrogen. This causes an incomplete utilization of the structural carbohydrates in the ingested forage and a slow rate of passage of the digesta and thus both forage digestibility and voluntary intake are significantly reduced (Crowder and Chheda, 1982). According to Van Soest (1983) N dressings to a grass pasture reduce the cell wall content but increase the lignin content which can be reponsible for low digestibility. However, due to the higher rate of dry matter production, the herbage is cut or grazed at a younger stage when lignin concentration is low.

2.2.3 The efficiency of N fertilization of grasses

Efficiency of N fertilization has been defined as the response in dry matter yield of the herbage per kg fertilizer N applied. The efficiency of N fertilization of grasses provides an important check on the extent to which applied N is being converted into protein for animal production (Henzell, 1962).

The use of fertilizer N by pasture grass has been considered to be relatively inefficient (Blue, 1970). Reasons for this inefficient use of N fertilizer by pasture grass include immobilization of N in grass roots, volatilization and denitrification (Henzell, 1962). Henzell et al. (1970) reported results of a field experiment with N fertilized Rhodes grass under mowing in Southern Queensland which showed that a signficant proportion of the added N was lost from the system and that the loss increased with increasing fertilizer rate. About 30% of the added N was lost from the plots receiving 448 kg N/ha/year. In another experiment with the same grass species an analysis of N removed in the herbage and that found in the stubble and roots to a 30 cm depth showed that 15% or more of applied N was not recovered (Henzell, 1971).

The efficiency of N fertilization of grasses can be estimated in two ways, namely :-

a. Dry matter produced per kg of each increment of nitrogen (kg DM/kg N applied).

b. Amount of applied nitrogen recovered in harvested forage (% N recovered).

Dry matter produced per kg of each increment of nitrogen (kg DM/ kg N applied) depends on the amount of N used and frequency of cutting i.e. stage of growth at harvest time (Vicente-Chandler 1959; Henzell, 1971). Crowder and Chheda (1982) in their review of tropical pasture husbandry, suggested that for the first 400 kg N/ha applied on an annual basis, from 50 to 65 kg of DM per kg of N would be obtained with a cutting interval of about 45 days and adequate soil moisture to assure continued regrowth. Above this level of applied N the efficiency would decline sharply.

The amount of applied nitrogen recovered in harvested forage depends on the amount of N applied, time of application, soil-moisture level, source of N, production of forage, N content of the herbage and varietal or species differences (Crowder and Chheda, 1982). According to Henzell (1962) percentage nitrogen recovery can be computed as follows :

$$\% \text{ N recovery} = \frac{100\ (\ (N_F\ \%\ \times \text{DM kg/ha}_F) - (N_0\ \%\ \times \text{DM kg/ha}_0)\ )}{\text{Applied N kg/ha}}$$

where :

F = N fertilized plots and

0 = unfertilized plots

Fluctuations in percentage N recovery have been observed in various N fertilizer experiments (Fredricksen and Kategile, 1980; Appadurai and Arasaratnam, 1969; Vicente-Chandler et al., 1959, 1972; Colman and Lazenby, 1970; Henzell et al., 1970). Table 8 shows the fluctuation of N recovery figures obtained from various tropical species. Most commonly obtained N recovery percentages range between 30 and 65%. The data in the Table 8 shows that N recovery increases

Table 8 : The effect of nitrogen rate and cutting interval on the percentage of N recovered from some tropical grass species (from literature)

Grass species	Cutting interval (days)	Nitrogen rate kg N/ha/yr										Reference
		112	224	336	449.2	672	898.4	1008	1348	1797	2246	
Pennisetum purpureum	40		44.5		48.2		48.4		52.2		31.6	Vicente-Chandler et al. (1959) in Puerto-Rico
	60		63.8		76.4		66.9		61.0		43.6	
	90		35.4		56.2		71.4		58.7		45.8	
Panicum purpurascens	40		45.2		47.7		47.6			34.3		
	60		49.5		48.8		47.8			34.5		
	90		29.0		38.7		39.8			28.4		
Panicum maximum	40		39.8		57.1		46.9			32.1		
	60		47.6		54.7		49.5			35.7		
	90		72.5		56.3		51.0			41.3		
Cynodon dactylon	14	69.5 (39.3)*		72.5 (51.8)		68.2 (35.3)		57.0 (25.2)				Gordon and Burton (1956) in Georgia U.S.A
	21	99.2 (5.05)		77.7 (5.77)		65.9 (36.0)		52.6 (24.3)				
	28	102.2 (45.7)		97.5 (54.6)		68.6 (36.0)		58.2 (27.1)				
	42	79.4 (52.8)		85.2 (60.1)		71.2 (34.0)		57.2 (30.8)				
	56	91.8 (55.7)		77.2 (49.1)		60.4 (37.3)		46.9 (32.5)				

* Figures in bracket were obtained during the dry season of 1954.

at low N rates but falls at high N rates. In order to get optimum N recovery percentages soil moisture should be adequate as shown with Cynodon dactylon in Table 8. However, there is limited information on the effect of N rate and cutting interval on N recovery in East Africa.

2.2.4 Influence of N fertilizer on the botanical composition of grass based pastures

Various research workers have shown that continued use of N fertilizer causes a rapid decline in the legume component of tropical grass-legume combinations (Whiteman, 1980; Hymphreys, 1978; Jones, 1967; Henzell et al., 1968). Jones (1967) in Queensland (Australia) found that low amounts of N at 75 and 225 kg N/ha reduced the legume fraction in a grass-siratro pasture (Table 9).

In a grass-legume mixture, the grass is a stronger competitor for available nitrogen, and takes up most of the applied N (Lenehan and Lowe, 1960, Henzell et al., 1968). This leads to an increased rate of growth, leaf expansion and tillering in the grasses often leading to suppression of the legume owing to shading of the latter. Table 10, illustrates the sensitivity of the competitive capacity of Pennisetum clandestinum to N supply.

Akinola et al. (1971a) working with Cynodon dactylon strains in Ibadan (Nigeria), reported that, provided moisture is not limiting,

Table 9 : Effect of rate of application of N on yield of Siratro in a Siratro-Rhodes grass pasture (Jones, 1967)

Nitrogen level kg N/ha	Dry matter yield kg DM/ha			% Reduction in legume
	Siratro	Other spp	Total	
0	3700	6000	9700	
75	3120	7600	10700	16
225	2500	9400	11900	33

Table 10 : Nitrogen supply and botanical composition of mixed swards (Gatner, 1966 as quoted by Humphreys, 1978)

Rate of nitrogen application (kg N/ha)	Pennisetum clandestinum (%)	Paspalum dilatatum (%)	Axonopus affins (%)
0	3	10	87
55	10	21	69
112	12	33	55
224	44	46	11
448	76	23	1

increased N level influences positively all the components of growth (tiller density, tiller height, leaf area index and specific leaf area).

2.3 Effect of cutting interval on grass based pastures

2.3.1 Dry matter yield of herbage

The cutting interval (that is, the period between successive cuts) greatly influences pasture production. Generally increasing the length of the cutting interval results in increased dry matter yield (Crowder and Chheda, 1982). Increased dry matter yield with extended cutting interval is a consequence of additional tiller and leaf formation, leaf elongation and stem development (Akinola et al, 1971a; Dovrat et al, 1971). Short cutting intervals reduce total forage dry matter yields as they cause depletion of carbohydrate reserves, a decline in root development, and adversely affect regrowth potential (Chheda and Akinola, 1971b; Akinola et al., 1971b).

The effect of cutting interval on the dry matter yield is influenced by the grass species, soil moisture and fertility and the cutting height of the grass plants (Haggar, 1970; Van Voorthuizen, 1971). Lack of moisture supply reduces the rate of regrowth of the grass, so that intervals between cuts normally need to be longer in the dry season, in order to get optimum yield, than during the wet season. At Mlingano in Northern Tanzania (Mean annual rainfall 1060 mm)

Van Voorthuizen (1971) subjected four grass species to three cutting intervals (4, 6 and 8 weeks) and three cutting heights (5, 10 and 50 cm above ground level) for one year and found the variation of dry matter yield as shown below.

Species	Largest annual DM yield	Smallest annual DM yield
Panicum maximum	5 cm cutting height + 8 week interval	10 cm cutting height + 4 week interval
Cenchrus ciliaris	10 cm cutting height + 4 and 6 week interval	5 cm cutting height + 6 week interval
Hyperrhenia rufa	10 and 20 cm cutting height + 6 week interval	5 cm cutting height + 6 week interval
Panicum trichocladum	20 cm cutting height + 6 and 8 week interval	5 cm cutting height + 4 week interval

From the above results Van Voorthuizen (1971) concluded that natural pastures containing a large percentage of a particular species must be managed with a grazing system that would allow for a maximum growth response.

The combination of cutting interval and N rate has a considerable effect on the yield performance of the grass pasture. The effect of nitrogen is to accelerate the growth of plants so that a given yield will be reached more rapidly (Van Burg et al., 1980). This suggests that with an increase in N supply the harvesting interval could be shortened to give the required yield. For example in Tanzania Lwoga (1977a) as quoted by Lane and Lwoga (1978), obtained 2.7 tons DM/ha from Chloris gayana in a period of 6 weeks without N fertilization and obtained the same herbage yield (2.7 tons DM/ha) in a period of 4 weeks with 200 kg N/ha applied. In Sri Lanka, Sivalingam (1964a) working with Panicum maximum reduced the time of obtaining 15.2 tons DM/ha of the herbage from 60 days to 30 days by increasing fertilizer rate from 45 to 134.7 kg N/ha. Thus, provided moisture is not limiting the length of the cutting interval can be reduced by increasing N fertilizer rate so as to meet the required herbage dry matter yield.

2.3.2 Quality of the herbage

Generally with extended cutting intervals, there is an increase in dry matter yield and in the content of structural components (CF, lignin and cell wall percentage) but the desirable components such as green leaf proportion, crude protein and mineral contents decline (Funes et al.,1980; Crowder and Chheda, 1982; Appadurai and Goonewardena, 1974; Veitia and Marquez, 1973). In Cuba, Veitia and Marquez (1973) carried out two experiments to determine the effects of cutting frequency on the digestibility and voluntary intake of fresh pangola grass (cut every 20, 40 and 60 days) and Rhodes grass hay (cut at 42 63 and 84 days). They found that DM intake for both species was progressively reduced with increasing interval between cuts. The N digestibility of Pangola grass cut every 20 days was higher than for

40 to 60 days. Rhodes grass hay cut at 84 days had the lowest DM intake and digestibility values. They however, pointed out that although the highest digestibility and intake values were obtained with the 20 days cutting of pangola grass, it seemed difficult to establish such a practice without affecting the regrowths. Under Morogoro conditions in Tanzania, Lane and Lwoga (1978) suggested an optimum growth period of 3 to 6 weeks but due to changes in nutritive value the optimum growth period would also depend on the required productivity per animal.

2.3.3 Growth and botanical composition of grass based pastures

Cutting frequently encourages weed invasion as it causes depletion of carbohydrate reserves, a decline in root development and adversely affects regrowth potential (Chheda and Akinola, 1971b; Akinola et al., 1971b; Jones, 1973; Perez and Lucas, 1974).

Both in tropical and temperate conditions it has been observed that, increasing the length of the cutting intervals increases stem length, leaf length, plant height, internode number, tiller density and tiller weight but reduces leaf percentage (Gordon and Burton, 1956; Holiday and Wilman, 1965; Akinola et al., 1971a). Akinola et al.(1971a) in Ibadan (Nigeria) noted that the reduction in tillering due to increased cutting intervals can be accounted for by reduced light intensity that arises from profuse leaf production, increased shoot size resulting in increasing dry matter production rate, initiation of reproductive growth and closer spacing of tillers resulting in competition for light. For this reason the longer cutting interval and high N rate produce lower tiller densities than unfertilized plots and shorter cutting interval. Lwoga (1981) reviewed various tropical experimental results and noted that N application reduces the proportion of green leaf and increases that of stem in the herbage. Gordon and Burton (1956) in Georgia (U.S.A.), found that increased nitrogen rate and a long cutting interval reduce the proportion of green leaf. Since stem is less digestible than green leaf (Laredo and Minson, 1973) factors that increase the proportion of green leaf, and reduce that of stem would be favoured by pasture producers. Pasture management aimed at high leaf production, however, has a good chance of success when the moisture supply is adequate, fertility levels are high, and when species capable of exploiting improved environmental conditions are grown.

3. MATERIALS AND METHODS

3.1 Site description

The experiment was conducted at the Sokoine University of Agriculture farm at Morogoro in Tanzania. The University is situated at 37° 39'E and 06° 50'S and is about 500 m above sea level.

The University is situated within an area which experiences a bimodal rainfall regime with short rains between November and January and the long rains during March to May (Table 11). Annual rainfall ranges from less than 600 to over 1000 mm, with a mean of about 860 mm. Normally, April receives the highest rainfall.

The minimum and maximum temperatures are $15^\circ C$ and $33^\circ C$, respectively. The hottest period is between October and January and the coolest months are June and July (Table 11). The rainfall and temperature figures during the experimental period are presented in Table 11. The site experienced an abnormal weather conditions during the experimental period. The rainfall received during June and July 1987 was 0.0 and 4.0 mm. respectively against the expected rainfall of 18.6 and 11.4 mm respectively (Table 11).

The most common natural plant species on the site included *Hyparrhenia rufa*, *Pennisetum purpureum*, *Panicum maximum*, *Cynodon dactylon*, *Glycine wightii*, *Brachiaria brizantha*, *Chloris gayana* and

Table 11 : Mean monthly rainfall and temperature for 13 years (1974 - 1986) including the experimental period (1987) at Sokoine University of Agriculture Meteorological Station

Month	Rainfall (mm)		Temperature (^oC)			
	13 years mean	Experimental period (1987)	13 years mean		Experimental period (1987)	
			Max.	Min.	Max.	Min.
January	98.2	108.7	27.3	18.0	30.0	20.9
February	76.1	74.9	32.5	20.6	32.1	21.1
March	133.4	65.7	31.5	20.8	32.3	21.6
April	171.5	108.2	30.2	20.2	30.5	21.0
May	55.3	132.7	28.3	18.5	20.9	19.2
June	18.6	0.0	27.7	15.5	28.4	15.3
July	11.4	4.0	27.5	14.7	28.1	15.7
August	6.5	8.5	28.3	15.3	28.8	17.2
September	8.7	0.0	29.7	16.4	30.5	17.7
October	34.0		31.0	18.0		
November	76.5		32.0	19.4		
December	110.0		31.6	19.8		

Sporobolus spp.

3.2 Establishment of the grass species

The land was prepared in October, 1986 using a disc plough and a harrow mounted to a tractor. It was then demarcated into seventy two plots of 4 m x 4 m each (Appendix II).

The grasses were established in November, 1986, during the short rains. The two grass species established were *Brachiaria brizantha* and *Chloris gayana* and are described in detail in Appendix I. Both the two grasses were planted vegetatively using stocks. The space between plants was 25 cm and between the rows 40 cm. No fertilizer was applied at planting. During the period of establishment the plots were kept clean from weeds by using a hand hoe.

3.3 Experimental design

The two grasses were planted in a total of 72 plots in a 2 x 3 x 4 factorial design with three replications. Appendix II shows the field plan of the experiment. Analysis of variance of all the data collected was done by using the methods outlined by Snedecor and Cochran (1980) for the factorial design.

3.4 Treatments

The grass plots were subjected to three cutting intervals of 20, 40 and 60 days. The cutting dates for each cutting interval are shown below :

Cutting intervals (days)	Cutting dates
20.	9/4/87, 29/4/87, 19/5/87, 8/6/87, 28/6/87, 18/7/87
40	29/4/87, 8/6/87, 18/7/87
60	19/5/87, 18/7/87

Four N fertilizer rates, 0, 100, 200 and 400 kg N/ha in the form of calcium ammonium nitrate (27.5% N) were applied to the grasses during March to May 1987 as shown below in Table 12. The N fertilizer was split into uneven lots (instead of 6, 4 and 2 lots; 4, 2 and 2 lots were used as indicated in Table 12) due to expected shortage of moisture in the second half of the experimental period, i.e. the month of June and July as shown in the Table 11.

The lots of N fertilizer were applied immediately after the grasses were mown. Phosphorus was applied as Triple superphosphate (20% P) at the uniform rate of 40 kg P/ha to all plots at the beginning of the experimental period (21/3/87).

Table 12 : Nitrogen fertilizer treatment

Plot cut every	Number of N fertilizer lots	Lot weight per plot (16 m^2)	Equivalent N rate	Dates of fertilizer application
		0.04125 kg N/plot	100 kg N/ha	21/3/87,
20 days	4	0.07975 kg N/plot	200 kg N/ha	9/4/87, 29/4/87
		0.16019 kg N/plot	400 kg N/ha	19/5/87
		0.0825 kg N/plot	100 kg N/ha	
40 days	2	0.1595 kg N/plot	200 kg N/ha	21/3/87
		0.3204 kg N/plot	400 kg N/ha	29/4/87
		0.0825 kg N/plot	100 kg N/ha	
60 days	2	0.1595 kg N/plot	200 kg N/ha	21/3/87
		0.3204 kg N/plot	400 kg N/ha	19/5/87

3.5 Sampling and field data collection

From each plot an area of 2 m^2 was harvested by using a reciprocating mower. A one metre square quadrat was used as the sampling unit. Before harvesting each plot, plant height from the ground level to the apical meristematic point was measured using a long graduated rule. Five readings were taken by locating the rule in five locations within each plot and the average of these five readings gave the average height of the grass plants on the plot.

The harvested grass from each plot (an area of 2 m^2) formed a bulk sample which was weighed to obtain the fresh herbage yield per harvested area and then subsampled to give two subsamples, each weighing about 1 kg. One subsample was taken for estimation of the proportion of stem and green leaf, while the second subsample was placed in a plastic bag and then taken to the analytical laboratory for the determination of dry matter content which was used to calculate the dry matter yield per hectare. The leaf and stem proportion were separated manually by hand. Only leaf blades were taken and leaf sheath remained attached to the stem

3.6 Sample preparation and chemical analysis

The sub-samples taken to the laboratory were weighed when fresh so as to get fresh herbage weight. They were then dried in the oven at 74°C for 48 hours to obtain constant weight and then weighed to get the dry herbage weight. The dry herbage weight from each sub-sample taken to the laboratory was used to calculate dry matter yield per harvested area and the dry matter yield per hectare. The dried sub-sample was ground in a small hammer mill through a 1 mm diameter sieve. The ground materials were then stored in glass sample bottles for analysis of N content and *in vitro* digestibility.

i. Crude protein of the herbage was determined by Kjeldahl process (AOAC, 1975). The percentage nitrogen was multiplied by 6.25 to obtain the percentage protein content of the herbage.

ii. *In vitro* dry matter digestibility was determined in accordance with the method described by Tilley and Terry (1963)

4. RESULTS

4.1 Effects of nitrogen rate and cutting interval on the dry matter yields of Brachiaria brizantha and Chloris gayana

Dry matter yields of Brachiaria brizantha and Chloris gayana at different nitrogen rates and cutting intervals are shown in Table 13. The forage dry matter yield increased with increasing nitrogen rate (Fig. 2). Increasing the rate from 0 to 400 kg N/ha increased the mean dry matter yield of B. brizantha by 268% (1591 to 5861 kg DM/ha) and that of Chloris gayana by 112% (2313 to 4901 kg DM/ha). At 40 days cutting interval, B. brizantha produced 2133, 3527, 5565 and 7605 kg DM/ha and C. gayana 2291, 4420, 5703 and 7340 kg DM/ha with 0, 100, 200 and 400 kg N/ha applied, respectively.

The mean dry matter yield of both grasses (B. brizantha and C. gayana) increased with increasing cutting intervals up to 40 days and then declined thereafter (Fig. 5 and 6). Although at 20 days cutting interval B. brizantha had a higher mean dry matter yield (3688 kg DM/ha) than C. gayana (3321 kg DM/ha)the former grass had lower mean dry matter yields (4707 and 3813 kg DM/ha) than the latter grass (4939 and 4088 kg DM/ha) at 40 and 60 days cutting intervals.

Table 13 : Effects of nitrogen rate and cutting interval on dry matter yield of Brachiaria brizantha and Chloris gayana (kg DM/ha)

Grass species	Fertilizer rate kg N/ha	Cutting interval			Mean
		20 days	40 days	60 days	
	0	1331a*	2133a	1309a	1591a+
	100	2978a	3527a	3190a	3232a
Brachiaria brizantha	200	5382b	5561b	5832b	5592b
	400	5059b	7605c	4919b	5861b
	MEAN	3688a+	4707b	3813a	4069
	0	1301a	2291a	3346a	2313a
	100	4094a	4420b	2860a	3791a
Chloris gayana	200	5133b	5703c	5535b	5457b
	400	2754a	7340d	4611b	4901b
	MEAN	3321a	4939b	4088a	4116

Overall effect of nitrogen rate and cutting interval on dry matter yield of the herbage regardless of grass species.

	0	1316a	2212a	2328a	1952a
	100	3536b	3973a	3025a	3512b
	200	5258c	5632b	5684b	5525c
	400	3906b	7473c	4765b	5381c
	MEAN	3504a	4823b	3951a	4093

* Within each column, cutting interval and grass species means followed by the same letter(s) do not differ significantly at P = 0.05 according to Duncan's multiple range test.

\+ Means of cutting interval and nitrogen rate followed by the same letter(s) do not differ significantly at P = 0.05 according to Duncan's Multiple range test.

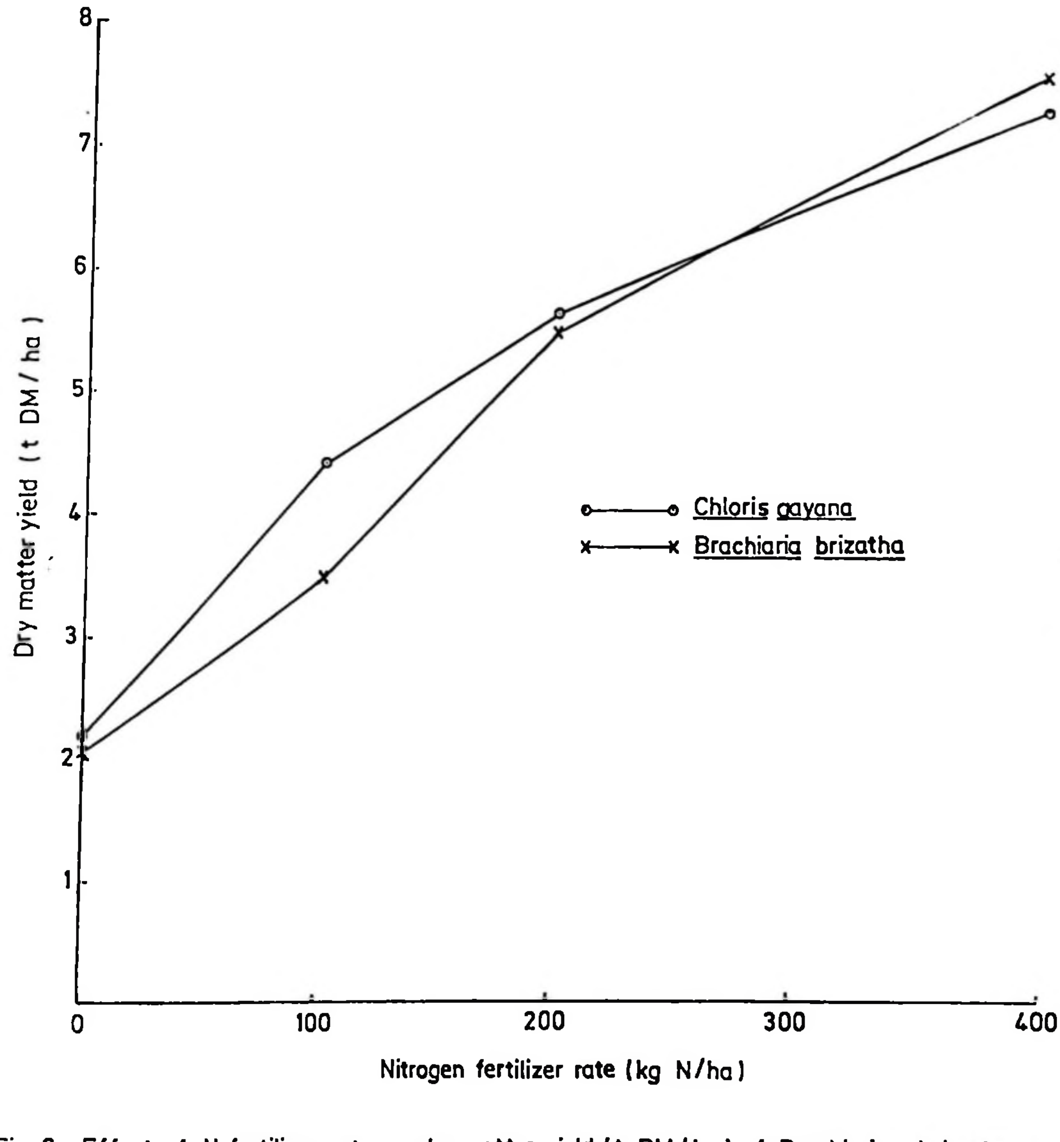

Fig. 2. Effect of N fertilizer rate on dry matter yield (t DM/ha) of Brachiaria brizatha and Chloris gayana at 40 days cutting interval.

4.2 Effects of nitrogen rate and cutting interval on the dry matter content of *Brachiaria brizantha* and *Chloris gayana*

Table 14 shows that there was a general decrease in the dry matter content of the herbage with increasing N rate. The mean dry matter content of *B. brizantha* decreased from 22.9 to 18.9 and of *C. gayana* from 23.3 to 19.2% with 0 to 400 kg N/ha applied, respectively.

The dry matter content of the grasses increased with increasing cutting interval. The difference between grass species in dry matter content response to nitrogen fertilization and increasing cutting interval was non-significant ($P > 0.05$). The decrease in dry matter content with increases in nitrogen rate declined significantly ($P < 0.01$) as cutting interval was extended.

4.3 Effects of nitrogen rate and cutting interval on the green leaf and stem dry matter yields of *B. brizantha* and *C. gayana*

The green leaf and stem dry matter yields at different N rates and cutting intervals are shown in Tables 15a and 15b. The green leaf and stem dry matter yield of both grasses increased with increasing nitrogen rate. The overall mean leaf and stem dry matter yields increased by 4 and 3 times from 0 to 400 kg N/ha application, respectively. However, the mean green leaf and stem dry matter yields of *B. brizantha* were still increasing at N rate of 400 kg N/ha while those of *C. gayana* started to decline after 200 kg N/ha rate (Fig. 3).

Table 14 : Effects of nitrogen fertilizer rate and cutting interval on dry matter content (%) of the Brachiaria brizantha and Chloris gayana

Grass species	Fertilizer rate kg N/ha	Cutting interval			Mean
		20 days	40 days	60 days	
	0	23.2b*	21.8b	23.7b	22.9b+
	100	18.2a	19.2b	18.5a	18.3a
Brachiaria brizantha	200	17.2a	18.8a	18.9a	18.7a
	400	14.9a	16.4a	25.3b	18.9a
	MEAN	18.4a+	19.1ab	21.6b	19.7
	0	20.2a	21.8a	25.1b	22.3b
	100	17.4a	23.7b	21.6a	20.9ab
Chloris gayana	200	18.2a	23.9b	21.5a	21.2a
	400	17.3a	18.9b	21.3a	19.2a
	MEAN	18.3a	22.1b	22.4b	20.9
Overall effects of nitrogen fertilizer rate and cutting interval on dry matter content (%) of the herbage regardless of grass species					
	0	21.7b*	21.8b	24.4b	22.6b
	100	17.3a	21.4b	20.0a	19.6a
	200	18.2a	21.4b	20.2a	19.9a
	400	16.1a	17.7a	23.3b	19.0a
	MEAN	18.3a	20.6b	22.0b	20.3

* Within each column, cutting interval and grass species means in column followed by the same letter(s) do not differ significantly at P = 0.05 according to Duncan's Multiple range test

+ Means of cutting interval and nitrogen rate followed by same letter(s) do not differ significantly at P = 0.05 according to Duncan's Multiple range test

Table 15a : Effects of nitrogen fertilizer rate and cutting interval on the green leaf dry matter yield (kg DM/ha) of B. brizantha and C. gayana

Grass species	Fertilizer rate (kg N/ ha)	Cutting interval			Mean
		20 days	40 days	60 days	
	0	424.1a*	918.9a	601.2a	648.1a+
	100	2189.1b	1556.2b	960.4a	1568.5b
Brachiaria brizantha	200	3089.4c	2461.2c	1556.7a	2369.1c
	400	3923.9d	4545.7d	1724.6a	3398.1d
	MEAN	2406.6b+	2370.5b	1210.7a	1996.0
	0	778.9a	409.9a	1089.9a	759.6a
	100	1230.9a	1937.9b	1114.3a	1427.7b
Chloris gayana	200	1782.2b	2521.7c	2014.2b	2106.2c
	400	2823.5c	1705.6b	2330.3b	2286.5c
	MEAN	1653.9a	1643.8a	1637.2a	1645.0

Overall effects of nitrogen fertilizer rate and cutting interval on the green leaf dry matter yield regardless of grass species

	Fertilizer rate (kg N/ ha)	20 days	40 days	60 days	Mean
	0	601.5a	664.4a	845.6a	703.8a
	100	1709.9b	1747.0b	1037.3a	1498.1b
	200	2435.8bc	2491.4b	1785.5b	2237.6c
	400	3373.7c	3125.7c	2027.5b	2842.3c
	MEAN	2030.2b	2007.1b	1424.0a	1820.4

* Within each column, cutting interval and grass species means followed by the same letter(s) do not differ significantly at P = 0.05 according to Duncan's multiple range test.

\+ Means of cutting interval and nitrogen rate followed by same letter(s) do not differ significantly at P = 0.05 according to Duncan's Multiple range test.

Table 15b : Effects of nitrogen fertilizer rate and cutting interval on the stem dry matter yield (kg DM/ha) of B. brizantha and C. gayana

Grass species	Nitrogen fertilizer rate kg N/ha	Cutting interval			Mean
		20 days	40 days	60 days	
Brachiaria brizantha	0	774.5a*	969.3a	1234.2a	992.7a+
	100	1276.4a	1713.3b	1233.3a	1407.7a
	200	1994.1b	2058.2c	3200.4b	2417.6b
	400	2028.6b	3284.1a	3250.4b	2854.4b
	MEAN	1518.4a+	2006.2b	2229.6b	1918.1
Chloris gayana	0	540.0a	1039.7a	1431.3a	1003.7a
	100	2526.4c	1377.1a	1967.9a	1890.5b
	200	2784.9c	2898.4b	3616.2c	3099.8c
	400	1938.3b	2326.3b	2986.5b	2417.1b
	MEAN	1947.4a	1910.4a	2500.5b	2102.8
Overall effect of nitrogen fertilizer rate and cutting interval on the stem dry matter yield of the herbage regardless of grass species					
	0	657.2a*	1004.5a	1332.8a	998.2a
	100	1910.4b	1545.2b	1500.6a	1649.1b
	200	2389.5b	2478.3c	3408.3b	2758.7c
	400	1983.5b	2805.2c	3118.5b	2635.7c
	MEAN	1732.9a	1958.3a	2340.1b	2010.4

* Within each column, cutting interval and grass species means followed by the same letter(s) do not differ significantly at P = 0.05 according to Duncan's multiple range test.

\+ Means of cutting interval and nitrogen rate followed by same letter(s) do not differ significantly at P = 0.05 according to Duncan's Multiple range test.

There was a slight decrease in mean green leaf dry matter yield and a slight increase in mean stem dry matter yield with extended cutting interval.

The positive effect of nitrogen fertilizer on the green leaf dry matter yield was reduced by extending the cutting interval. This reduction was significantly ($P < 0.01$) higher in B. brizantha than C. gayana.

4.4 Effects of nitrogen fertilizer rate and cutting interval on leaf: stem ratio of Brachiaria brizantha and Chloris gayana

The results of the effects of nitrogen fertilizer rate and cutting interval on the leaf:stem ratio (by dry weight) of B. brizantha and C. gayana are shown in Table 16. The leaf:stem ratio was not significantly ($P > 0.05$) affected by either nitrogen fertilizer rate or grass species. However the leaf:stem ratio decreased with extension of the cutting interval.

4.5 Effects of nitrogen fertilizer rate and cutting interval on tiller height of B. brizantha and C. gayana

The tiller height of the B. brizantha and C. gayana at different nitrogen rates and cutting intervals are shown in Table 17. Nitrogen fertilizer rate increased significantly ($P < 0.01$) the tiller height. At all nitrogen rates, C. gayana had a higher mean tiller height than B.

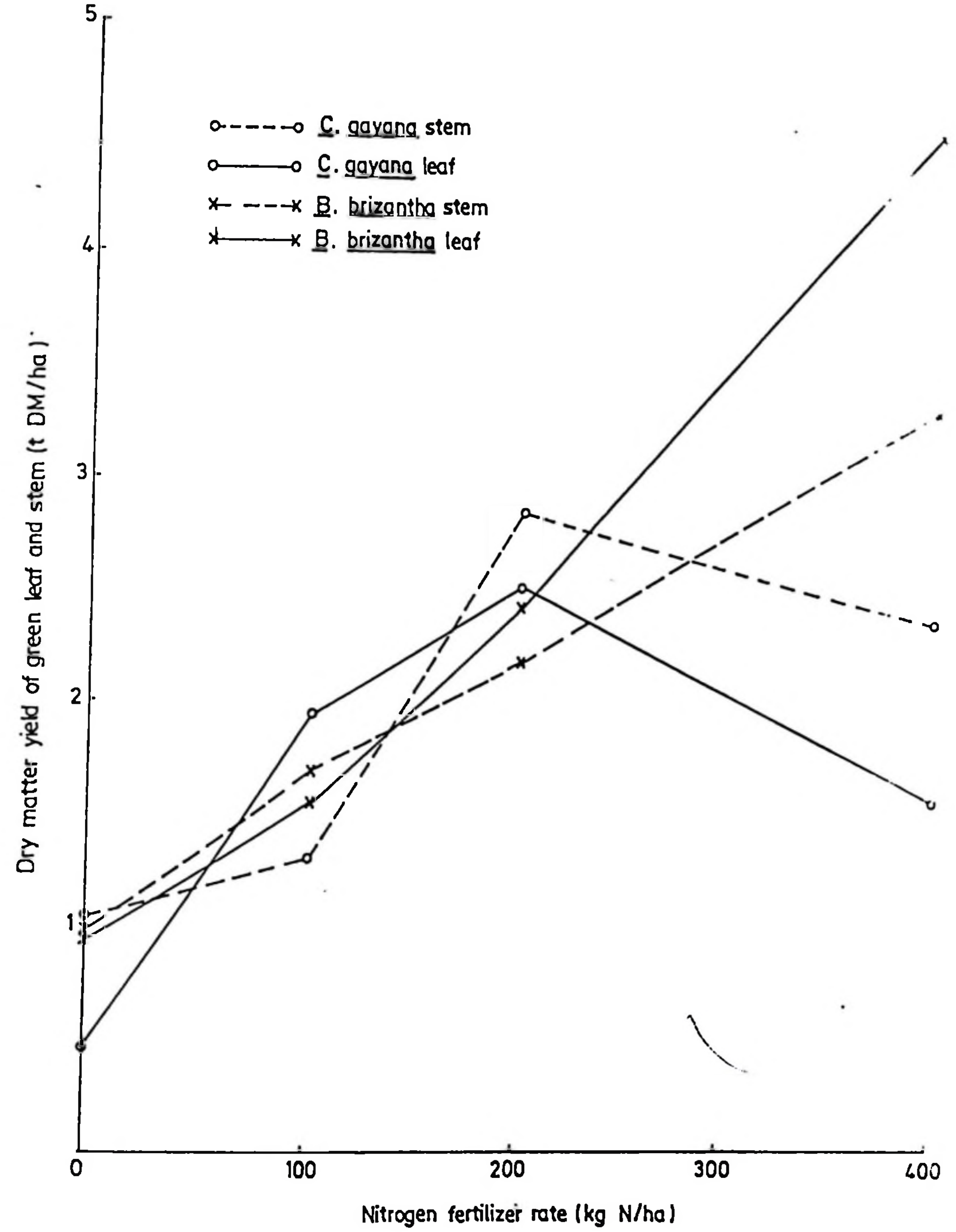

Fig. 3. Effect of nitrogen fertilizer rate on the dry matter yield of green leaf and stem of *Brachiaria brizatha* and *Chloris gayana* at 40 day cutting interval.

Table 16 : Effects of nitrogen fertilizer rate and cutting interval on the leaf:stem ratio (by dry weight) of *Brachiaria brizantha* and *Chloris gayana*

Grass species	Fertilizer rate kg N/ha	Cutting interval			Mean
		20 days	40 days	60 days	
	0	0.3a*	1.1a	0.6a	0.6a+
	100	5.9b	1.0a	0.3a	2.4c
B. brizantha	200	3.8b	1.3a	0.5a	1.8b
	400	4.9b	1.2a	0.5a	2.2c
	MEAN	3.7c+	1.2b	0.5a	1.8
	0	1.4a	0.9a	0.7a	1.0a
	100	1.5a	1.5a	0.5a	1.2a
C. gayana	200	1.4a	0.7a	0.6a	0.9a
	400	1.6a	1.2a	0.5a	1.1a
	MEAN	1.5b	1.1b	0.6a	1.1

Overall effects of nitrogen fertilizer rate and cutting interval on the leaf:stem ratio (by dry weight) of the herbage regardless of grass species.

	0	0.9a*	1.0a	0.6a	0.8a
	100	3.7b	1.2a	0.4a	1.8b
	200	2.6b	1.0a	0.6a	1.0a
	400	3.3b	1.2a	0.5a	1.7b
	MEAN	2.6c	1.1b	0.5a	1.3

* Within each column, cutting interval and grass species means followed by the same letter(s) do not differ significantly at P = 0.05 according at Duncan's Multiple range test.

+ Means of cutting interval and nitrogen rate followed by same letter(s) do not differ significantly at P = 0.05 according to Duncan's Multiple range test.

Table 17 : Effects of nitrogen fertilizer rate and cutting interval on the tiller height (cm) of Brachiaria brizantha and Chloris gayana

Grass species	Fertilizer rate kg N/ha	Cutting interval			Mean
		20 days	40 days	60 days	
B. brizantha	0	22a*	45a	60a	42.3a+
	100	19a	46a	110c	61.7b
	200	32bc	64bc	80b	58.7b
	400	39c	74c	70a	61.[illegible]
	MEAN	30.5a+	57.5b	80.0c	56.0
C. gayana	0	37a	58a	112a	69.0a
	100	52b	92b	97a	80.0b
	200	52b	99b	105a	85.3b
	400	53b	104b	93a	83.3b
	MEAN	48.5a	88.3b	101.8c	79.4

Overall effects of nitrogen fertilizer rate and cutting interval on the tiller height (cm) of the grasses regardless of grass species

	Fertilizer rate kg N/ha	20 days	40 days	60 days	Mean
	0	29.5a*	51.5a	86.0b	55.7a
	100	40.5b	69.0a	103.5b	71.0c
	200	42.0b	81.5b	92.5b	72.0c
	400	46.0b	89.0b	57.5a	64.2b
	MEAN	39.5a	72.8b	84.9c	65.7

* Within each column, cutting interval and grass species means followed by the same letter(s) do not differ significantly at P = 0.05 according to Duncan's Multiple range test.

+ Means of cutting interval and nitrogen rate followed by the same letter(s) do not differ significantly at P = 0.05 according to Duncan's Multiple range test.

brizantha. The mean tiller height of B. brizantha and C.gayana were 42.3, 61.7, 56.7, 61 and 69, 80, 85.3, 83.3 with 0, 100, 200 and 400 kg N/ha application respectively.

The tiller height increased significantly ($P < 0.01$) with increasing cutting interval. The overall increase in tiller height with nitrogen rate was enhanced by extending the cutting interval. There was a significant ($P < 0.01$) difference between the tiller height of the two grasses at every cutting interval. The mean tiller height of the grasses cut every 20, 40, 60 days were 48.5, 88.3 and 101.8 cm for C. gayana and 30.5, 57.3 and 80 cm for B. brizantha.

4.6 Effects of nitrogen rate and cutting interval on the crude protein content and yield of Brachiaria brizantha and Chloris gayana

The crude protein content of both grasses increased significantly ($P < 0.01$) with nitrogen rate up to the highest rate tested as shown in Table 18. The mean crude protein content of B. brizantha was increased by 87% (from 6.9 to 12.9%) and that of C. gayana by 72% (from 7.1 to 12.2%) comparing 400 kg N/ha applied with 0 kg N/ha.

The crude protein content of the grasses decreased significantly ($P < 0.01$) with extension of the cutting interval. The mean crude protein contents of B. brizantha and C. gayana cut every 20, 40 and 60 days were 11.5,9.9,8.5% and 11.7, 9.4, 7.9%, respectively. The crude protein yield of the herbage was significantly ($P < 0.01$) increased by nitrogen

Table 18 : Effects of nitrogen fertilizer rate and cutting interval on the crude protein content and crude protein yield (kg DM/ha) of *Brachiaria brizantha* and *Chloris gayana*

Grass species	Fertilizer rate kg N/ha	Cutting interval						Mean	
		20 days		40 days		60 days			
		CP %	CP yield	CP %	CP yield	CP %	CP yield	CP %	CP yield
	0	8.4a	108.9a	6.4a	136.8a	6.1a	95.0a	6.9a	113.6a
	100	10.8b	322.3b	8.7b	306.1b	7.7a	229.4b	9.1b	286.0b
B. brizantha	200	12.5c	659.5c	10.8c	608.8bc	9.4b	552.3c	10.9b	606.8c
	400	14.3c	725.1c	13.7d	1044.6d	10.6b	534.3c	12.9c	768.0d
	MEAN	11.5b+	451.0a	9.9ab	524.1a	8.5a	352.8a	10.0	443.6
	0	8.3a	110.3a	6.9a	162.1a	6.1a	193.0a	7.1a	155.1a
	100	10.5b	429.7b	8.4b	363.0b	7.1a	243.5a	8.7a	345.4b
C. gayana	200	13.4c	689.4c	10.1c	571.2c	8.4b	464.6a	10.6b	575.1c
	400	14.6c	400.8b	12.1d	881.5d	10.0c	488.9a	12.2c	590.4c
	MEAN	11.7b	407.6a	9.4ab	494.5a	7.9a	347.5a	9.7	416.5

Overall effect of nitrogen fertilizer rate and cutting interval on the crude protein content and crude protein yield (kg/ha) of the forage regardless of grass species.

Fertilizer rate kg N/ha	20 days CP %	20 days CP yield	40 days CP %	40 days CP yield	60 days CP %	60 days CP yield	Mean CP %	Mean CP yield
0	8.4a*	109.6a	6.7a	149.5a	6.1a	144.0a	7.0a	134.4a
100	10.7b	376.0b	8.6b	334.6b	7.4ab	236.5b	8.9b	315.7b
200	12.8c	674.5c	10.5b	590.0c	8.9b	508.5c	10.8c	590.9c
400	14.4c	562.9c	12.9c	963.1d	10.3c	511.6c	12.6d	679.2c
MEAN	11.6b	430.8a	9.7ab	509.3a	8.2a	350.a	9.8	430.1

* Within each column, cutting interval and grass species means followed by the same letter(s) do not differ significantly at P = 0.05 according to Duncan's Multiple range test.

+ Means of cutting interval and nitrogen rate followed by same letter(s) do not differ significantly at P = 0.05 according to Duncan's Multiple range test.

fertilizer rate. The mean crude protein yield was 134.4, 315.7, 590.9 and 679.2 kg/ha with 0, 100, 200 and 400 kg N/ha applied, respectively. The crude protein yield of both grasses increased with extension of the cutting interval up to 40 days and then decline thereafter. The grass species were not significantly different in terms of both crude protein content and yield, with extension of the cutting interval.

4.7 Effects of nitrogen fertilizer rate and cutting interval on the efficiency of nitrogen utilization by Brachiaria brizantha and Chloris gayana

Table 19 demonstrates the effects of nitrogen fertilization and cutting interval on nitrogen recovery and forage dry matter produced per kg of applied N. The forage dry matter produced per kg of applied nitrogen decreased ($P < 0.01$) with increasing nitrogen rate.

There was no significant ($P > 0.05$) difference between the two grass species both in terms of nitrogen recovery percentage and dry matter produced per kg of applied N (Appendix III).

Forage dry matter produced per kg applied nitrogen increased slightly with increasing length between cuts to 40 days and then declined sharply thereafter with increasing cutting interval. The same pattern was depicted by both grass species.

Table 19 : Effects of nitrogen fertilizer rate and cutting interval on nitrogen utilization efficiency (Kg DM/kg N) and percentage nitrogen recovery from *B. brizantha* and *C. gayana*

Grass species	Fertilizer rate kgN/ha	Cutting interval						Mean	
		20 days		40 days		60 days			
		KgDM/kgN	%N recovery	KgDM/kgN	%N recovery	KgDM/kgN	%N recovery	KgDM/kgN	%N recovery
	0								
	100	29.8	34.1	35.3	27.1	17.4	21.5	27.5	27.6
B. brizantha	200	25.3	44.0	27.8	37.8	24.6	25.9	25.9	39.4
	400	12.6	24.7	19.0	38.2	10.9	17.6	14.2	26.8
	MEAN	22.6	34.3	27.4	34.4	17.6	25.2	22.5	31.3
	0								
	100	40.9	51.2	44.2	32.2	28.6	18.1	37.9	33.8
C. gayana	200	25.7	46.2	28.5	32.7	27.2	21.7	27.1	33.6
	400	6.9	11.6	18.4	28.8	8.8	11.8	11.3	17.4
	MEAN	24.5	36.3	30.4	31.3	21.5	17.2	25.4	28.2
Overall effect of nitrogen fertilizer rate and cutting interval on nitrogen efficiency (kg DM/kg N) and nitrogen recovery of the herbage regardless of grass spp.									
	0								
	100	35.4	42.6	39.7	29.6	23.0	49.8	32.7	30.7
	200	25.5	45.1	28.2	35.2	25.9	29.2	26.5	35.5
	400	9.8	18.1	18.7	33.5	9.8	14.7	12.8	22.1
	MEAN	23.6	35.3	28.9	32.8	19.6	21.2	24.0	29.8

4.8 Effects of nitrogen fertilizer rate and cutting interval on the *in vitro* dry matter digestibility of *Brachiaria brizantha* and *Chloris gayana*

In vitro dry matter digestibility of *B. brizantha* and *C. gayana* at different nitrogen levels and cutting intervals are shown in Table 20. The *in vitro* dry matter digestibility increased with nitrogen rate (Fig. 4) and decreased with increasing the cutting interval (Fig. 5 and 6) for both grasses.

In the absence of applied N, the highest *in vitro* dry matter digestibility was 50.5% obtained at 20 days cutting interval with *Brachiaria brizantha*. Nitrogen application at 400 kg N/ha maintained the digestibilities of both grasses above 50% at 60 days cutting interval.

Regarding grass species differences, *Brachiaria brizantha* on average had higher dry matter digestibility than *Chloris gayana* at all levels of applied N. However, the mean *in vitro* digestibility differences between the two grasses narrowed with increases in the cutting interval. The difference was 1.8% units at 20 days cutting interval as compared to 0.3% units at 60 days cutting interval.

The *in vitro* dry matter digestibility was highly related to crude protein percentage but poorly related to leaf:stem ratio as shown below.

Table 20 : Effects of nitrogen rate and cutting interval on the *in vitro* dry matter digestibility (IVDMD) and *in vitro* digestible dry matter yield(IVDMY) of *Brachiaria brizantha* and *Chloris gayana*

Grass species	Fertilizer rate kgN/ha	Cutting interval						Mean	
		20 days		40 days		60 days			
		IVDMD (%)	IVDMY (kg/ha)	IVDMD (%)	IVDMY (kg/ha)	IVDMD (%)	IVDMY (kg/ha)	IVDMD (%)	IVDMY (kg/ha)
B. brizantha	0	50.5a*	673a	48.2a	1028a	43.7a	573a	47.5a+	7582
	100	52.9ac	1575b	51.8a	1828a	45.7a	1459b	50.1a	1621b
	200	55.8bc	3001c	54.3ab	3019b	48.0ab	2800c	52.7a	2940c
	400	58.2b	2943c	57.5b	4374c	52.6c	2589c	56.1b	3302c
	MEAN	54.4b+	2048b	53.0b	2562c	47.5a	1855a	51.6	2155
C. gayana	0	47.3a	616a	45.7a	1046a	42.7a	1430a	45.2a	1031a
	100	51.2a	2097bc	47.0a	1077b	46.4a	1326s	48.2a	1833b
	200	54.3a	2786c	50.4ab	1872c	48.7a	2695b	51.1ab	2784c
	400	57.3b	1577b	52.3c	3837c	50.2a	2314b	53.2 b	2576c
	MEAN	52.5b	1769a	48.9ab	2458a	47.0a	1941a	49.4	2056
Overall effect of nitrogen rate and cutting interval on the *in vitro* dry matter digestibility and *in vitro* digestible dry matter yield of the forage regardless of grass spp.									
	0	48.9a	645a	46.9a	2074a	43.2a	1002a	46.4a	1240a
	100	52.1a	1836b	49.4a	1953a	46.0ab	1393a	49.2a	1727a
	200	55.0b	2894c	52.3ab	2946b	48.4b	2748b	51.9a	2863b
	400	55.7b	2865c	54.9b	4106c	51.4b	2452b	54.8b	3141b
	MEAN	52.9b	2060b	50.9ab	2770c	47.3a	1899a	50.6	2243

* Within each column, cutting interval and grass species means followd by the same letter(s) do not differ significantly at P = 0.05 according to Duncan's Multiple range test.

\+ Means of cutting interval and nitrogen rate followed by the same letter(s) do not differ significantly at P = 0.05 according to Duncan's Multiple range test.

i. The relationship between *in vitro* dry matter digestibility (Y) and crude protein percentage (X).

Brachiaria brizantha : Y = 35.8 + 1.6 X (r = 0.93; P < 0.01)

Chloris gayana : Y = 35.6 + 1.5 X (r = 0.99; P < 0.01)

ii. The relationship between *in vitro* dry matter digestibility (Y) and leaf:stem ration (X).

Brachiaria brizantha : Y = 49.3 + 1.3 X (r = 0.57; P < 0.05)

Chloris gayana: Y = 45.0 + 4.4 X (r = 0.51; P > 0.05)

4.9 Effects of nitrogen fertilizer rate and cutting interval on *in vitro* digestible dry matter yield of *Brachiaria brizantha* and *Chloris gayana*

In vitro digestible dry matter yields of the two grass species (*B. brizantha* and *C. gayana*) at different nitrogen levels and cutting intervals are shown in Table 20. The mean IVDMY of both grasses increased with extension of interval between cuts to 40 days cutting interval and then declined. The mean IVDMY of *B. brizantha* increased with increased N rate while that for *C. gayana* increased up to 200 kg N and then declined.

In the absence of applied N, the highest *in vitro* digestible dry matter yield was 1430 kg/ha, obtained at 60 days cutting interval with *Chloris gayana*. Grass species differences in terms of *in vitro* digestible dry matter yield were not significant (P > 0.05) (Appendix III).

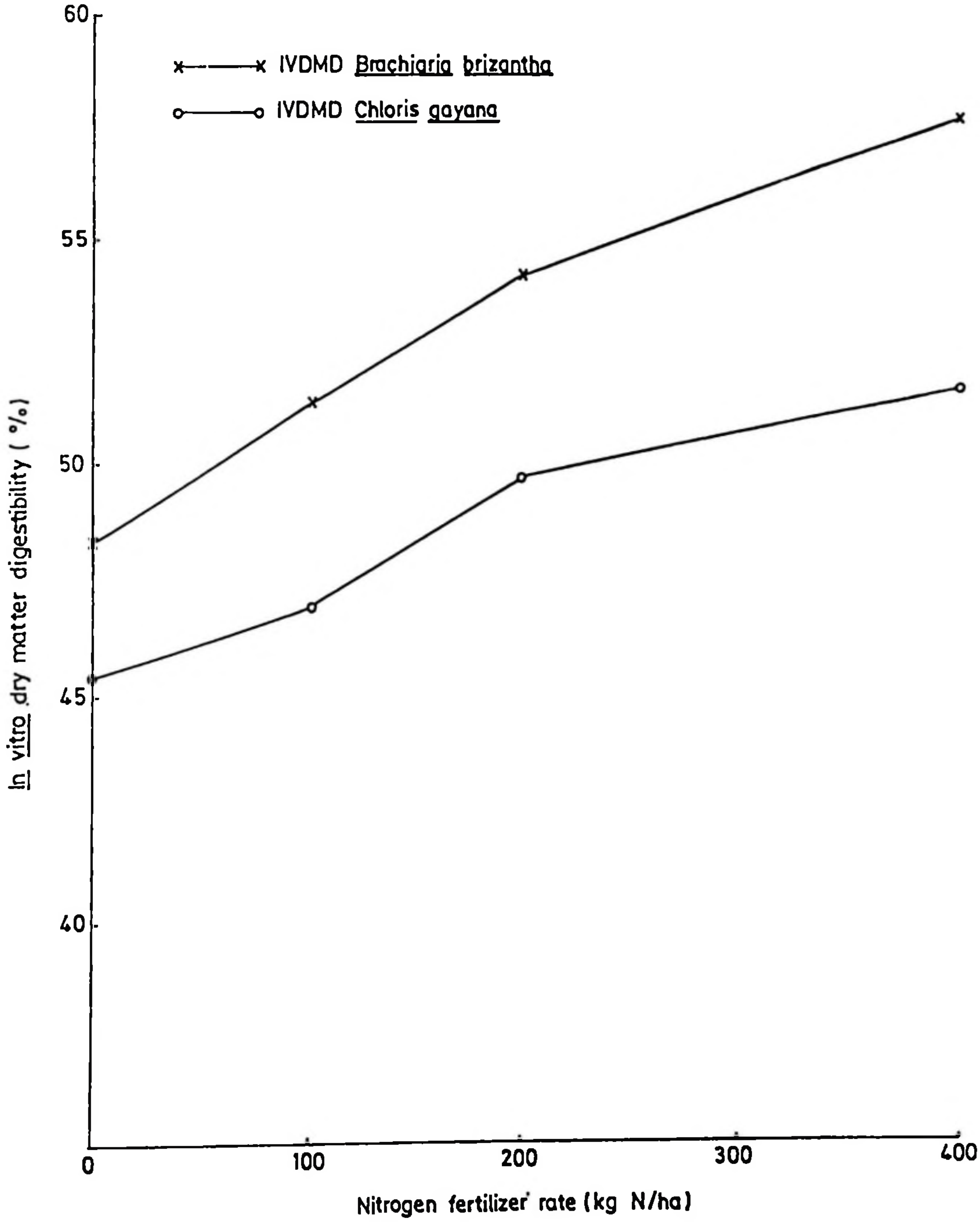

Fig. 4 . Effect of nitrogen fertilizer rate on the *in vitro* dry matter digestibility (%)(IVDMD) of *B. brizantha* and *C. gayana* at 40 days cutting interval.

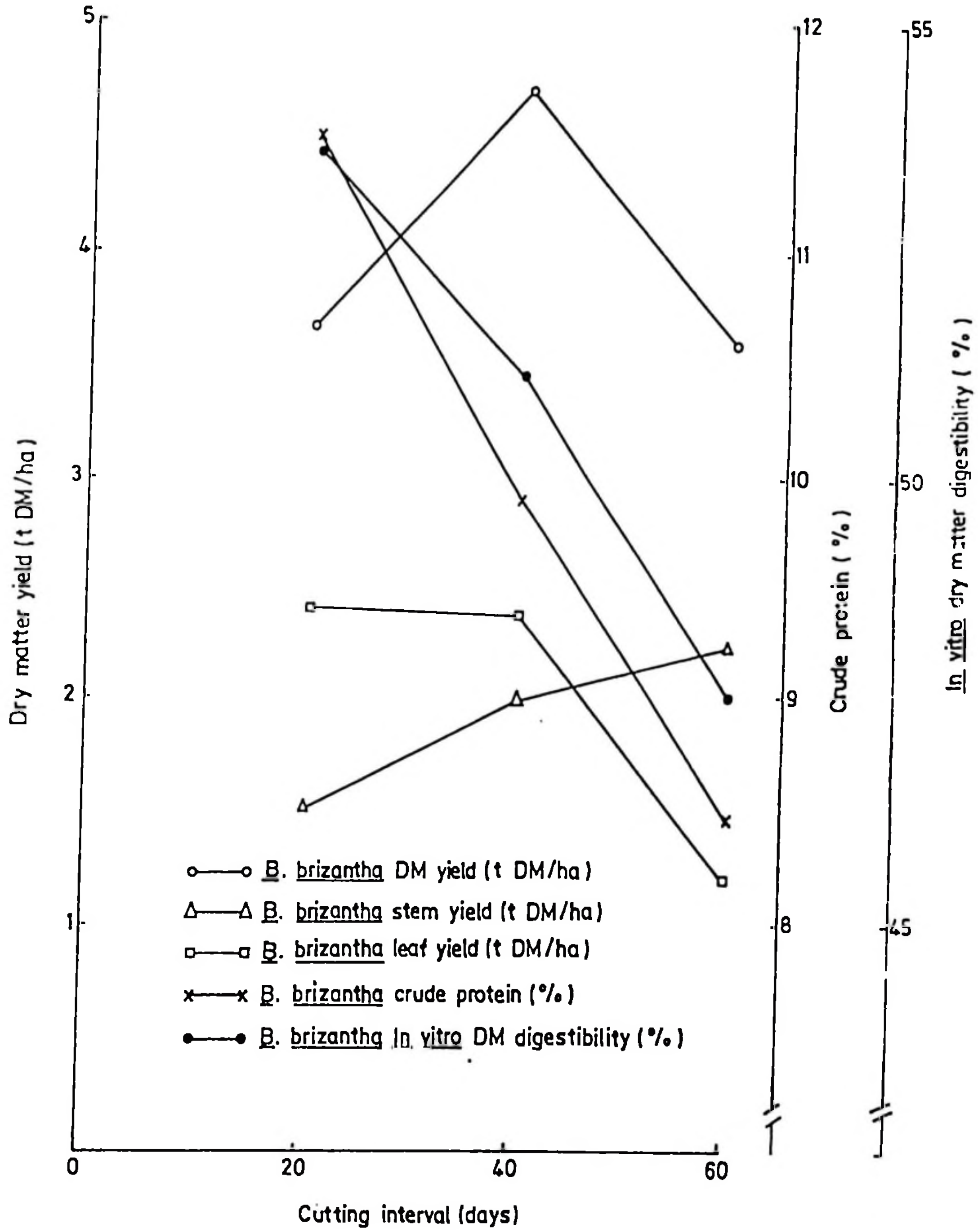

Fig. 5 . Effect of cutting interval on the yield and nutritive value of *Brachiaria brizantha*.

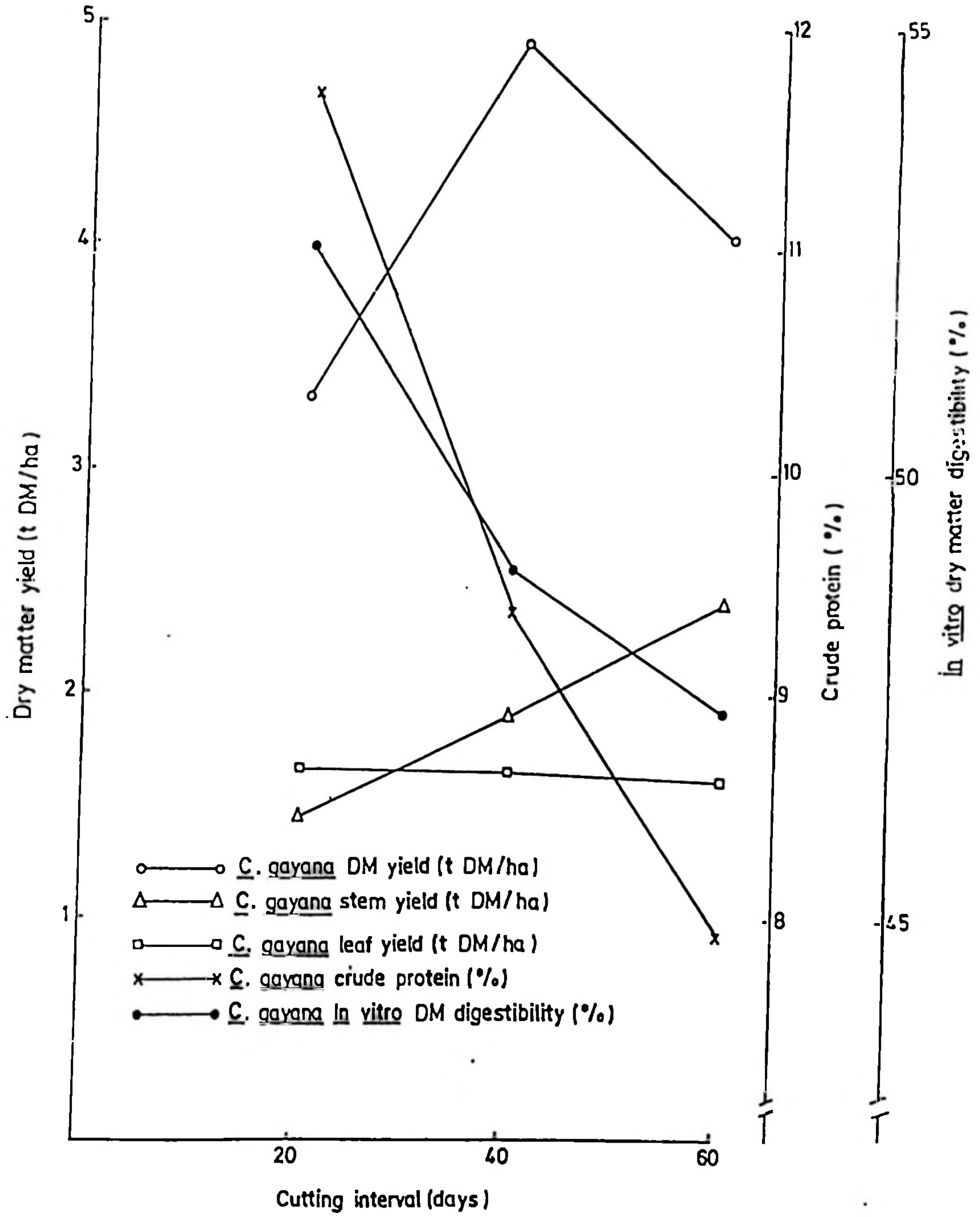

Fig. 5 Effect of cutting interval on the yield and nutritive value of Chloris gayana

4.10 Experimental site soil analysis before and after the experiment

The results of the soil analysis of the experimental site before and after the experiment are given in Table 21.

The data obtained just before the beginning of the experiment and from the plots that received no nitrogen indicated that after the experimental period, there was an increase in soil nitrogen and organic matter. Also there was a decrease in exchangeable bases like Na^+, Mg^{2+} and Ca^{2+} but K^+ increased slightly. However, no statistical analysis was done in this case, since only four soil samples were taken at the end of the experiment and one soil sample was taken at the beginning of the experiment.

The pH (in water) was highest (5.6) with 400 kg N/ha and lowest (5.2) with 100 kg N/ha. The phosphorus content of the soil increased with nitrogen rate from 0 to 200 kg N/ha and then declined (4.9, 8.4, 14.7 and 5.6 ppm) with 0, 100, 200 and 400 kg N/ha, respectively. The carbon:nitrogen ratio increased with increasing nitrogen rate.

Table 21 : Experimental site soil analysis (the top 15 cm of the soil) before and after the experiment

	pH in H_2O	pH in $CaCl_2$	ppm P	% O.C.	% N	C/N	Me/100 Na^+	Me/100 Mg^{2+}	Me/100 Ca^{2+}	Me/100 k^+
Soil analysis before the expt.	5.4	5.4	4.9	0.96	0.11	9.15	0.74	4.19	6.09	0.97
Nitrogen rate (kgN/ha)										
0	5.4	4.9	4.9	1.47	0.25	6.08	0.43	3.38	2.71	1.02
100	5.2	4.7	8.4	1.29	0.25	5.70	0.33	3.38	2.92	1.09
200	5.5	5.2	14.7	1.42	0.21	6.80	0.27	3.13	2.71	1.02
400	5.6	4.6	5.6	1.42	0.14	10.10	0.33	3.50	2.71	1.09
MEAN	5.4	4.9	8.4	1.40	0.21	7.14	0.34	3.34	5.52	1.06

O.C.= Organic carbon

Me/100 = milliequivalents per 100 grams of soil

5. DISCUSSION

5.1 Dry matter yield of forages

The herbage dry matter increased with increasing nitrogen rate. The same pattern of response has been observed by various researchers elsewhere (Fig. 1). Increasing the N rate from 0 to 400 kg N/ha increased the mean dry matter yield of B. brizantha by 268% (1591 to 5861 kg DM/ha) and that of C. gayana by 112% (2313 to 4901 kg DM/ha). The calculated mean growth rates of B. brizantha and C. gayana were 184.4, 117.7, 60.6 and 166.1, 123.5, 68.1 kg DM/ha/day with 20, 40 and 60 days cutting intervals, respectively. The mean yields and growth rates were smaller than those reported at Morogoro in Tanzania by Lwoga (1977a) as quoted by Lane and Lwoga (1978) who obtained 2233, 10,067 and 11,400 kg DM/ha from Chloris gayana at the rate of 0, 100 and 200 kg N/ha. He obtained mean growth rates equal to 257.1, 201.6 and 138.5 kg DM/ha/day with 14, 42 and 84 days cutting intervals, respectively.

The low yields observed in this experiment as compared to those quoted above could be due to the low growth rates of the grasses (in this study) caused by shortage of rainfall during the study period as indicated in Table 11. The dry season in the year 1987 started early in Mid-May instead of late June. The rainfall received in June, July and August, 1987 was 0.0, 4.0 and 8.5 mm, respectively, against the expected rainfall of 18.6, 11.5 and 6.5 mm, respectively (Table 11). Consequently, the second harvest at the 60 days cutting interval (19/5 -

18/7/1987), produced little dry matter yield. The dry matter yields of B. brizantha and C. gayana produced at the second harvest of the 60 days interval (18/7/87) were 314 and 877 kg DM/ha compared with 3146 and 3231 kg DM/ha, respectively, at the first harvest (19/5/1987). The reduction in dry matter yield during the dry season has long been recognised for tropical pastures (Milford, 1960). This reduction in dry matter yield when moisture is inadequate has been attributed to the reduced uptake of nitrogen and other nutrients from the sub soil (Garwood and Williams, 1967) and to the death of tillers or diminution in tiller size or number (Chheda and Akinola, 1971b). The results of this study, however, supported the view that with N application, large quantities of herbage could be harvested earlier than without N applied. For instance, instead of harvesting 1331 and 1301 kg DM/ha of Brachiaria brizantha and Chloris gayana, respectively, at 20 days with 0 kg N/ha, 2978 and 4094 kg DM/ha respectively were harvested at the same cutting interval with 100 kg N/ha applied. Farmers who keep ruminant livestock of high production potential can,therefore, use N fertilizer to produce large quantities of grass herbage to feed their animals under favourable weather conditions.

Although the dry matter yield increased with extension of the cutting interval, the highest dry matter yield was obtained with the 40 days rather than the 60 days cutting interval. This was probably due to the shortage of rainfall in the second half of the experimental period (Table 11). The decline in dry matter yield above the 40 days cutting interval could also be accounted for by the decline in dry matter production after the grass sward had been left (without harvest) beyond the optimum leaf area index (Brown and Blaser, 1968; Holiday and Wilman, 1965). In their review on leaf area index in pasture growth, Brown and Blaser (1968) noted that in an extended cutting interval, leaves in deep shade near the soil are likely to be inefficient in photosynthesis and thus reduce the dry matter production.

The lack of an interaction between nitrogen rate and cutting interval, nitrogen rate and grass species, cutting interval and grass species, nitrogen rate and cutting interval and grass species could also be due to the shortage of soil moisture during the experimental period. These results are in agreement with those of Chheda and Akinola (1971b) in Ibadan (Nigeria), who found no significant interaction between cutting interval and grass strains, cutting interval and nitrogen rate, grass strains and nitrogen rate, cutting interval and grass strains and nitrogen rate in an experiment with three strains of Cynodon during the relatively dry period of the year.

The dry matter content of the grasses decreased with increasing nitrogen rate and increased with increasing cutting interval. These results were contrary to those reported by Horrell and Bredon (1963) in Uganda and Walker (1973) in Tanzania which showed that the dry matter content of herbage increased with increasing nitrogen rate. However, in both cases forage was harvested at a mature stage of growth. The results reported in this experiment were, however, in accord with those reported by Vicente-Chandler *et al* (1972) who found that cutting *Brachiaria ruziziensis* every 30 and 60 days reduced the dry matter content from 26.4 and 28.2% at 0 kg N/ha to 21.8 and 22.1% at 896 kg N/ha, respectively. Where forage is conserved as unwilted silage the increase in water content (i.e. decrease in dry matter content) in herbage with increasing nitrogen level is likely to present problems of effluent disposal and result in greater losses of nutrients by leaching. Where forage is conserved as hay, an increased water content in the crop would probably mean longer field drying, thereby,increasing the risks of large losses in the feeding value of the product, in the event of rain.

The returns as herbage dry matter per kg of nitrogen applied decreased with increasing nitrogen rate. The mean dry matter yield response per kg fertilizer nitrogen was 27.5, 25.9 and 14.2 kg DM/kgN for *B. brizantha* and 37.9, 27.1 and 11.3 kg DM/ kg N for *C. gayana* with 100, 200 and 400 kg N/ha application respectively. These results were in accord with those reported by Keya (1974) in Western Kenya who obtained the largest mean dry matter yield response of *Setaria anceps* (18 kg DM/kg N) at the 200 kg N/ha rate and smallest (10 kg DM/kg N) at the 800 kg N/ha level. These results support the view that small quantities of nitrogen are utilized more efficiently by the grass than large quantities.

The mean dry matter yield response per kg of nitrogen applied increased with extension of the cutting interval from 20 to 40 days

(23.6 and 28.9 kg DM/kg N, respectively) and then declined with 60 days cutting interval (19.6 kg DM/kg N). The decrease in nitrogen efficiency (kg DM/kg N) above the 40 days cutting interval can be accounted for by the shortage of rainfall (Crowder and Chheda, 1982) and probably the decline in growth rate after the grass sward had been left (without harvest) beyond the optimum leaf-area index (Brown and Blaser, 1968). Though leaf area index was not determined in this study, Holiday and Wilman (1965) working with temperate grasses, noted that if the grass sward is left to stand beyond the maximum leaf area index the rate of growth declines and may become negative and the advantage of higher level of N application gets lost.

5.2 Leaf, stem dry matter yields and ratio

The dry matter yields of both green leaf and stem increased with increasing nitrogen rate. The results obtained in this experiment were in agreement with those of Ogwang and Mugerwa (1976) at Kabanyolo in Uganda (annual rainfall of 1300 mm), who applied nitrogen to elephant grass at rates of 0, 75, 150 and 300 kg N/ha and obtained mean leaf yields of 3158, 5110, 5914 and 7193 kg DM/ha.

Extending the interval between cuts increased the stem dry matter yield and reduced the green leaf dry matter yields. The overall mean dry matter yields of stem and green leaf were 1732.9, 1958.3, 2340.1 and 2030.2, 2007.1 and 1424 kg DM/ha with 20, 40 and 60 days cutting interval, respectively. Since green leaf dry matter yield decreases and stem dry matter yield increases with extended cutting interval, the advantage of N fertilizer application on the grass leaf production is due to large grass herbage quantities produced in a short time (Van Burg et al., 1980) before the stems are highly lignified.

The leaf:stem ratio was not significantly ($P > 0.05$) affect by nitrogen rate. The leaf:stem ratio declined with increasing intervals between successive cuts owing to a much greater increase in the quantity of stem than of leaf. Since stem is less nutritious than green leaf (Laredo and Minson, 1973), the two grasses (B. brizantha and C.gayana should, under Morogoro conditions, be harvested every 30 - 45 days so as to compromise between green leaf and stem yields (Fig. 5 and 6): Information on the effect of cutting interval on leaf:stem ratio in East Africa is rather scarce. However, the results from this experiment are in agreement to those observed elsewhere in the tropics. In Sri Lanka Appadurai and Arasaratnam (1969) working with Brachiaria brizantha sward reported that nitrogen levels (56.1, 113.3, 168.4, 224.6 and 280.7 kg/ha, respectively had no significant effect ($P = 0.05$) on the mean leaf:stem ratio (1.04, 0.98, 1.08, 1.09 and 1.02). Sivalingam (1964b) also in Sri Lanka studied changes in the leaf:stem ratio of six tropical grasses and found that with 30, 60 and 90 days cutting intervals the mean leaf:stem ratios were 4.0, 2.0 and 1.2 with 67.4 kg N/ha, and 3.7, 1.9 and 0.9 with 202.14 kg N/ha, respectively. The results from this experiment are in agreement with those quoted above that the leaf:stem ratio is influenced more by cutting interval than by nitrogen levels.

5.3 Crude protein content and yields and nitrogen recovery

The crude protein content in herbage and crude protein yield of the herbage increased with increasing nitrogen rate. The overall mean crude protein content and crude protein yield of the forage were 7.0 8.9, 10.8, 12.6% and 134.4, 315.7, 590.9 and 679.2 kg DM/ha, respectively, with 0, 100, 200, 400 kg N/ha applied. Increasing the cutting interval reduced the protein content, but had little influence on the crude protein yield.

These results are in agreement with the results reported by other workers. Fredreicksen and Kategile (1980) at Morogoro, Tanzania applied 0, 62.5, 125 and 187.5 kg N/ha to a B. brizantha sward at the beginning of the long rains for two consecutive years and obtained 5.9, 4.6, 5.4, 7.6 and 5.5, 5.4, 7.4, 6.1 mean crude protein percentages for the first and second years of study, respectively. Their results were relatively lower than the results obtained in this experiment probably due to the small nitrogen rates they applied in single doses as compared to higher nitrogen rates in split doses applied in this study. Ogwang and Mugerwa (1976) at Kabanyolo in Uganda working with elephant grass (*Pennisetum purpureum*) reported an increasing crude protein content of 11.2, 14.9, 16.1 and 18.1 with increasing nitrogen rates of 0 ,75, 150 and 300 kg N/ha, respectively. The results of this experiment support the view that increasing levels of nitrogen and frequent cutting interval result in herbage with a high crude protein content. It is, therefore, important to balance the cutting interval with nitrogen application so as to maintain both the grass productivity and quality.

The overall mean percentage nitrogen recovery was highest (36.5%) at 200 kg N/ha and lowest (22.1%) at 400 kg N/ha. These results are in agreement with those of Fredricksen and Kategile (1980) who observed the highest mean nitrogen recovery (55%) at 187.5 kg N/ha with a *B. brizantha* sward. In the humid tropical region of Southern Uganda, Olsen (1972) obtained the highest mean nitrogen recovery (64%) at 224 kg N/ha and the lowest mean nitrogen recovery (21%) at 2240 kg N/ha applied. These results again support the view that small quantities of nitrogen are utilized more efficiently for grass growth than large quantities of nitrogen fertilizer.

The highest and lowest nitrogen recovery percentage in this experiment were 51.2 and 8.1 obtained from *Chloris gayana* cut every 20 and 60 days and receiving nitrogen at the rate of 100 kg N/ha. The variation in the nitrogen recovery obtained in this study was higher than that reported by Fredricksen and Kategile (1980) (that is, 38 - 55%) from a *B. brizantha* sward at Morogoro, Tanzania. They, however, used an old *B. brizantha* (6 - 7 year old) sward, harvested the forage once a week (at advancing stages of growth) over a period of eight weeks and applied low nitrogen rates (0 to 187.5 kg N/ha). These factors possibly resulted into a higher uptake of the applied nitrogen. Wide fluctuation in nitrogen recovery (< 10 to 88%) for the tropical grasses has also been noted by Henzell (1962) and Crowder and Chheda (1982) in their reviews of literature on nitrogen recovery from tropical grasses.

5.4 In vitro dry matter digestibility and digestible dry matter yield

Increasing the level of nitrogen fertilizer increased the mean in vitro dry matter digestibility and digestible dry matter yield. Minson (1973) in Queensland observed the same effect of applied nitrogen on the in vivo dry matter digestibility of Chloris gayana, Digitaria decumbens and Pennisetum clandestinum. Ogwang and Mugerwa (1976) at Kabanyolo in Uganda reported a similar pattern of results with Pennisetum purpureum. They obtained increases in the mean in vitro dry matter digestibility (63.8, 65.3, 67.3 and 68.2% respectively) with increasing the nitrogen rate (0, 75, 150 and 300 kg N/ha). They also reported (without data) that, the mean in vitro dry matter digestibility declined with stage of grass maturity.

In this study the overall mean response of in vitro dry matter digestibility at 400 kg N/ha as compared with 0 kg N/ha application was 8.4% units. The high response of in vitro dry matter digestibility to N fertilizer application could be accounted for by increased green leaf yield with N rate (Deinum and Dirven 1976), increased crude protein content with N rate and delayed maturity of the fertilized herbage as compared to the unfertilized herbage (Raymond 1969). The response of *in vitro* dry matter digestibility to N fertilizer reported in this experiment was, however, closely in accord with that reported by Smith (1962) in Zambia. He applied 88 kg N/ha to the grass sward dominated by Hyperrhenia species and found that the dry matter digestibility of the late cut hay increased from 51.7 to 59.5 percent.

The mean *in vitro* dry matter digestibility of the two grasses (*B. brizantha* and *C. gayana*) decreased with increasing cutting interval. The mean digestible dry matter yield, however, increased with increasing cutting interval and declined beyond the 40 days cutting interval. There was no difference in digestibility between the two grasses at 60 days cutting interval (47.5 and 47.0%, respectively). However, *B. brizantha* had a higher mean *in vitro* dry matter digestibility than *C. gayana* at 20 and 40 days cutting interval. The superiority of *B. brizantha* in digestibility over *C. gayana* has been noted by Marshall *et al.* (1969) in Uganda and Kayongo-Male *et al.* (1976) in Puerto-Rico. Soneji *et al.* (1971) in Uganda found that *B. ruziziensis* had a higher dry matter digestibility than *C. gayana* and related this superiority to the higher leaf:stem ratio of *B. ruziziensis*. In this study *B. brizantha* had a higher leaf:stem ratio (3.7 and 1.2 at the 20 and 40 days cutting interval respectively) than *C. gayana* (1.5 and 1.1 respectively).

5.5 Relationships between yield and quality parameters

Sward height and density have been used to estimate relative dry matter yield on different types of grassland ('t Mannetje, 1978). A poor correlation coefficient ($r = 0.31, 0.57$) between *B. brizantha* and *C. gayana* dry matter yield and their tiller heights was observed in this experiment. Plant height is subject to change with wind and lodging, which reduce the measurement accuracy. Unfortunately, wind and lodging effects on the tiller height were not measured in this experiment. The semi-erect growth habit of *B. brizantha* probably accounted for the lower correlation coeffiient ($r = 0.31$) (between its dry matter yield and tiller height) as compared with that of the erect growing *C. gayana* ($r = 0.57$).

Further investigation on plant height and density as a non-destructive technique for estimating dry matter yield of the two grasses sward under the same environment could probably be enhanced by using a better apparatus than a scaled ruler (used in this experiment) for measuring sward height (as explained by 't Mannetje, 1978).

The *in vitro* dry matter digestibility of *B. brizantha* and *C. gayana* was positively correlated ($r = 0.93, 0.99, P < 0.01$) with the crude protein content of the herbage. Crowder and Chheda (1982) reported a strong relationship ($r = 0.91, P < 0.01$) between cell wall constituents digestibility and crude protein content of the tropical grass herbage. Glover and Dougall (1960) reported a marked decline in total carbohydrate digestibility when crude protein content in the forage fell below 6%. Minson (1971) related this drop of digestibility to the suppression of microbial activity in the rumen at crude protein content below 6%. It is, therefore, important to maintain crude protein percentage level of the animals feeds above 7% for maintanance and production. In this experiment the lowest crude protein content was 6.1% at 0 kg N/ha and 60 days cutting interval. Nitrogen fertilization of grass pastures, grass legume mixtures and high-protein feed supplementation are some of the ways by which digestibility of a low-protein forage can be improved considerably.

In this experiment in vitro dry matter digestibilities of the two grasses (B. brizantha and C. gayana) were positively correlated ($r = 0.57$ and 0.51; $P < 0.05$ and $P < 0.05$ respectively) with leaf:stem ratio. Soneji et al (1971) in Uganda associated a higher digestibility of B. ruziziensis (compared with C. gayana) with a higher leaf:stem ratio of the former. They gave no data on that relationship. Higher digestibility of B. brizantha as compared with C. gayana in this study could also be associated with its high leaf:stem ratio.

6. CONCLUSIONS AND RECOMMENDATIONS

The results obtained in this experiment have shown that cutting both *Brachiaria brizantha* and *Chloris gayana* every 40 days during the period of favourable growth will be a beneficial management system for these two grasses in balancing dry matter production and quality of the herbage (Fig. 5 and 6). The same cutting interval has been recommended under the same conditions by Lane and Lwoga (1978).

There was no significant ($P < 0.01$) difference between the two grasses (*B.brizantha* and *C.gayana*) in terms of dry matter yield. The grasses utilized nitrogen fertilizer efficiently at the 100 - 200 kg N/ha rate with the 20 and 40 - day cutting intervals. Almost the same N rate has been found to be efficiently utilized by *B. brizantha* under the same conditions (Fredricksen and Kategile , 1980).

The quality of the grass (both in terms of crude protein content and *in vitro* dry matter digestibility) increased with increasing N rate. This finding supported the view that N fertilization of grasses is important to improve their quality and productivity.

Brachiaria brizantha was more nutritious than *Chloris gayana* at short cutting intervals. *B. brizantha* had a relatively higher leaf:stem ratio, crude protein content and *in vitro* dry matter digestibility than *C. gayana*. This difference in nutritive value between the two grasses was, however, not observed at 60 days cutting interval. These results have shown the need to improve the *B. brizantha* in Tanzania's cultivated grasslands. However, further investigation on simpler methods for its establishment (e.g. by seeds) rather than by the laborious vegetative method is necessary before it could be popularly accepted by the livestock farmers in this country.

Tiller height was poorly correlated with forage dry matter yield while crude protein content was highly correlated with *in vitro* dry matter digestibility. Leaf:stem ratio was moderately correlated with forage *in vitro* dry matter digestibility. However, the number of observations was not large to give a good conclusion on this relationship.

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8. APPENDIX I

DESCRIPTION OF THE GRASS SPECIES USED IN THE EXPERIMENT

Chloris gayana Kunth (Rhodes grass)

Rhodes grass (*Chloris gayana*) is a perennial grass native to Africa (Bogdan, 1955). It has a wide range of ecological tolerance (Joseph and Waisel, 1977) and grows well on various soil types whenever they are well drained. It is relatively drought resistant and can grow under annual rainfall of about 600 mm but not much below this level. *Chloris gayana* occurs naturally in most tropical and sub tropical areas of Africa up to 2000m altitude.

Rhodes grass is stoloniferous, creeping or occassionally tufted. It can be established from pieces of rooting stolons, but propagation by seed is the normal practice. It's herbage yield ranges from 1.5 to 25 t DM/ha depending on soil fertility and fertilizers applied, frequency of cutting or grazing, rainfall and other factors (Bogdan, 1977). Grazing or cutting for hay can begin when the grass reaches some 50 cm high. It mixes well with various legumes e.g.*Centrosema pubescens*, *Clitoria ternatea*, *Desmodium uncinatum*, *Glycine wightii* etc. The productive life usually lasts about 3 years unless heavily fertilized and then it extends to five or more years (Bogdan, 1977). *Chloris gayana* responds well to nitrogen fertilizer and irrigation (Henzell, 1962 and Bogdan, 1977).

Brachiaria brizantha Stapf (Signal grass).

Brachiaria brizantha (Signal grass) occurs naturally throughout tropical Africa from sea level up to 2400 m above sea level, under annual rainfall of about 800 mm mainly in grasslands with scattered bush (Bogdan, 1977). It has been found to be aggressive, competing effectively with other species and resistant to drought (Stomayo-Rios *et al*., 1960). Signal grass grows well under the shade and it has been proposed for planting under coconut trees and in the dry forests (Anker-Lagefoged, 1955). In East Africa, Bogdan (1955) reported that *B. brizantha* (Signal grass) is very variable and several varieties show striking differences in habit, morphology and seed-setting capacity Due to poor seed setting, propogation is normally done by stem cutting (springs) and stocks (Sivalingam, 1964a). It grows better and yields higher when established on acid than on alkaline soils (Stomayor-Rios *et al*., 1960).

A range of 5 to 35 tons DM/ha/year have been obtained from *Brachiaria brizantha* (Bogdan, 1977) depending on soil fertility, fertilizer application, moisture and cutting management. It mixes well with various legumes like *Centrosema pubescens* and *Stylosanthes humilis*. (Bogdan, 1977).

Appendix II. Experimental layout.

N ↑

1st half Rep A	1st half Rep B	1st half Rep C	2nd half Rep A	2nd half Rep B	2nd half Rep C
CN_0I_1	CN_0I_1	BN_4I_2	BN_0I_2	BN_1I_3	BN_0I_3
CN_4I_2	CN_4I_1	CN_0I_2	CN_4I_1	BN_0I_3	CN_2I_1
CN_0I_2	BN_2I_3	CN_1I_1	BN_0I_1	CN_0I_3	BN_1I_1
BN_2I_1	CN_2I_3	CN_1I_1	BN_4I_2	CN_0I_2	BN_0I_1
BN_1I_1	CN_4I_2	CN_4I_2	BN_2I_3	CN_4I_2	CN_4I_1
CN_1I_2	BN_1I_1	CN_1I_3	BN_4I_3	CN_1I_3	BN_4I_1
BN_0I_3	CN_2I_2	BN_2I_2	BN_4I_2	CN_2I_3	CN_2I_2
CN_1I_1	BN_4I_2	CN_1I_2	CN_1I_3	BN_0I_1	BN_4I_3
BN_1I_2	BN_4I_3	CN_0I_1	BN_1I_3	BN_1I_2	BN_1I_2
BN_2I_2	BN_2I_1	CN_1I_3	CN_2I_1	CN_2I_1	BN_2I_3
CN_2I_2	CN_1I_1	BN_1I_3	CN_4I_3	BN_4I_1	CN_0I_3
CN_2I_3	BN_0I_2	BN_2I_1	CN_0I_3	BN_2I_2	BN_0I_2

Continue on the 2nd half.

KEY

- B = *Brachiaria brizantha*
- C = *Chloris gayana*
- I_1 = 20 days cutting interval
- I_2 = 40 days cutting interval
- I_3 = 60 days cutting interval
- N_0 = 0 kg N/ha level
- N_1 = 100 kg N/ha level
- N_2 = 200 kg N/ha level
- N_4 = 400 kg N/ha level
- Rep = Replication
- Space between replication = 3 m
- Space between plots = 1 m
- Each plot has an area of 16 m^2 (i.e. 4 m x 4 m)

APPENDIX III

(a) Overall mean of forage yield and tiller height of Brachiaria brizantha and Chloris gayana regardless of nitrogen rate and cutting interval.

Grass species	Forage DM yield (kg DM/ha)	Forage DM %	Green leaf DM yield(kg DM/ha)	Stem DM yield (kg DM/ha)	Leaf:stem ratio	Tiller height (cm)
B. brizantha	4069 a*	19.7a	1996.0 b	1918.1 a	1.8 b	56.0 a
C. gayana	4116 a	20.9 a	1645.0 a	2102.8 a	1.1 a	79.4 b
MEAN	4093	20.3	1820.4	2010.4	1.3	65.7

(b) Overall mean of forage crude protein content, efficiency of nitrogen utilization and digestibility of Brachiaria brizantha and Chloris ganaya regardless of nitrogen rate and cutting interval

Grass species	CP %	CP yield (kg/ha)	Nitrogen efficiency (kgDM/kg N)	Nitrogen recovery %	IVDMD %	IVDMY (kg/ha)
B.brizantha	10.0a*	443.6a	22.5a	31.3b	51.6b	2155a
C. gayana	9.7a	416.5a	25.4b	28.0a	49.4a	2056a
MEAN	9.8	430.1	24.0	29.8	50.6	2243

* Within each column means followed by the same letter(s) do not differ significantly at P = 0.05 according to Duncan's Multiple range test.