

PRODUCTIVITY AND NUTRITIVE VALUE OF SIRATRO
AND CENTRO-BASED BRACHIARIA PASTURES

BY

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ABSTRACT

An experiment was conducted at Sokoine University of Agriculture farm, Morogoro, Tanzania, from October, 1987 to June, 1988.

The objective of the study was to evaluate the productivity and nutritive value of *Brachiaria brizantha* receiving fertilizer N at the rates of 0, 100 and 200 kg/ha, and *B.brizantha* in association with either *Macroptilium atropurpureum* (siratro) or *Centrosema pubescens* (centro) at 42 and 70 days of growth.

The study showed that advancing stage of growth caused an increase ($P < 0.001$) in the DM yield (from 3643 to 4686 kg DM/ha), DDM yield (from 2592 to 3087 kg DDM/ha, NDF (from 65 to 68%), and ADF (from 36 to 41%) of *B. brizantha*. However, there was a decline in the CP content (from 8.70 to 6.95%) ash content (from 9.06 to 8.85%) and IVDMD (from 75 to 67%). Similarly, there were declines in the CP content (from 9.106 to 7.61%), ash content (from 9.28 to 8.88%) and IVDMD (from 73.52 to 66.98%) of the grass/legume sward with advancing stage of growth.

The NDF and ADF contents of the grass/legume mixed swards increased by 5 and 18%, respectively, with advancing stage of growth. However, the ADF content of the legume species in the mixed swards was not affected ($P > 0.05$).

Increasing fertilizer N rate caused a highly significant ($P < 0.001$) increase in the yields of DM (113%), DDM (84%) and CP (185%) of *B. brizantha*. Similarly, N application increased the CP content of the grass by 38%, but caused a decrease in the ash content (from 9.02% at 0 to 8.27% at 200 kg N/ha).

Siratro outyielded centro in DM, DDM and CP yields. Siratro, on average, had higher IVDMD than centro (70.62% compared to 54.25%, respectively). The presence of siratro in the mixed sward increased the CP content by 28% and the CP yield by 109% relative to the grass alone without fertilizer N applied. However, centro had no significant ($P > 0.05$) effect on the CP content and yield of the mixed sward.

Siratro contributed N yield equivalent to the grass alone receiving over 120 kg N/ha, while centro contributed N yield equivalent to between 5 and 50 kg N/ha.

DECLARATION

I, VENUSTE GAHUTU RUSHALAZA, do hereby declare that the work presented herein is my own, and has not been submitted for a degree in any other University.

Signature: .....
Date: 2 - 4 - 1991.....

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DEDICATION

To my wife Francisca, my son Mulenzi and my daughter Mutesi.

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ABBREVIATION

Abbreviation	Term
DM	Dry matter
CP	Crude protein
IVDMD	<i>In vitro</i> dry matter digestibility
IVOMD	<i>In vitro</i> organic matter digestibility
OM	Organic matter
CF	Crude fiber
EE	Ether extract
NDF	Neutral - detergent fiber
ADF	Acid - detergent fiber
NFE	Nitrogen - free extract
DDM	Digestible dry matter
NVI	Nutritive value index
VFA	Volatile fatty acid
CWC	Cell wall constituents
DMI	Dry matter intake
P _N	Net photosynthesis
SA	Sulphate of ammonia
AN	Ammonium nitrate
N	Nitrogen
CAN	Calcium ammonium nitrate
kg/ha	kilogrammes per hectare
kg/ha/a	kilogramme per hectare per annum
g	gramme

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$\text{kg}^{0.75}$	Metabolic body weight in kilogrammes
g/m^2	Grammes per square meter
kg DM/kg N	Kilogrammes dry matter per kilogramme nitrogen
%	Percent
$^{\circ}\text{C}$	Degree celsius/centigrade
mm	Millimeter
cm	Centimeter

1. INTRODUCTION

Natural pastures form a major source of feed for ruminant livestock in the tropics. In the case of Tanzania, 99% of the country's ruminant livestock population is found in the traditional livestock sector (Livestock Policy 1983), where the animals depend almost entirely on natural grassland plant species for their feed (French 1957).

The major limitation of natural grassland plant species is their inherently low productivity and nutritive value for at least half of the year in seasonally dry areas (French 1957; Calo 1976; Mwakatundu 1977; Evans 1982; Mannetje 1982). The DM yields are low, ranging from 1 to 2 ton/ha/a in the dry areas of Tanzania (Walker 1969; Wigg, Owen and Mukurasi 1973), and from 2 to over 10 ton/ha/a in humid areas of Tanzania (Anderson 1965; Naveh and Anderson 1966), Kenya (Keya 1974) and Uganda (Olsen 1972; Bredon and Horrell 1963).

The nutritive value of most of the tropical grass species is low, especially during the dry season when it has deteriorated to the minimum (French 1957; Minson and Milford 1966; Butterworth 1967; Karue 1974). Tropical grass species are characterized by fast growth associated with rapid deterioration in quality with advancing stage of growth (Thairu 1972; Reid *et al.* 1973; Kidunda and Lwoga 1985). Climatic and edaphic factors have been identified as the major environmental constraints to improved pasture production in the

tropics (Russell 1966).

In order to improve livestock productivity under such circumstances, efforts should be directed towards improving the productivity and nutritive value of the natural grassland species. There are several strategies which could be used to achieve these objectives. They include :- (i) the introduction of superior pasture species especially legumes into natural pastures (ii) improvement of the soil fertility by application of fertilizers (iii) control of pasture utilization through manipulation of stocking rates and methods of grazing, and (iv) the integration of irrigated, conserved or special purpose pastures into existing production systems (Crowder and Chheda 1982; Evans 1982).

Under many tropical situations, the introduction of legume species into natural grasslands has been observed to be the most feasible strategy (Lwoga 1978; Rukanda and Lwoga 1981; Kusekwa and Lwoga 1985; Haque and Jutzi 1984). The benefits of incorporating pasture legumes into pasture mixtures are two-fold: firstly, there is an improvement in the DM yields of the associated grasses resulting from a higher uptake of nitrogen fixed by the legumes; secondly, the nutritive value of the grass species is improved, particularly, during the dry season when their quality has deteriorated to the minimum (Milford and Haydock 1965; Minson and Milford 1967; Keya 1974; Rukanda and Lwoga 1981).

Tropical forage legumes are superior in terms of quality to tropical grass species. Ostrowski (1978) reported the mean CP contents of tropical legume species under Australian conditions to vary from 10 to 25% of the DM depending on the species and the stage of growth of the plants. Mero and Kabatange (1988) working at Mpwapa, Tanzania, indicated values ranging from 13 to 16% and 8 to 12% of the DM, for tropical legumes and grasses, respectively, when harvested between 123 and 183 days of growth.

The dry matter digestibility (DMD) of tropical legumes also declines at a slower rate than that of grasses (Reid *et al.* 1973; Kidunda 1988) with advancing stage of growth.

The advantages of grazing grass/legume mixed pastures have been reported in many countries of the tropics. Animal production has been increased in both the dry and humid areas of the tropics by incorporation of a legume in the pasture mixture (Stobbs 1969b, h; Shaw and Mannelje 1970; Mellor, Hibberd and Grof 1973).

Thus, in view of the advantages of tropical legume species in the improvement of pasture productivity and nutritive value, there is need to develop and maintain grass/legume pastures in Tanzania. In order to achieve this goal, there is a need to select legume species which are compatible with selected grass species so as to produce high yielding and nutritious grass/legume mixed pastures.

The objectives of the present study therefore, were :-

- i. To evaluate the DM yields of the pure *B. brizantha* pasture with and without fertilizer N application, and *Brachiaria*/siratro or *Brachiaria*/centro mixed pastures at 42 and 70 days of growth.
- ii. To evaluate the chemical composition of *B. brizantha* with and without fertilizer N application, and *Brachiaria*/siratro or *Brachiaria*/centro mixed swards at 42 and 70 days of growth.
- iii. To determine the *in vitro* DMD of *B. brizantha* pasture with and without fertilizer N application, *Brachiaria*/siratro or *Brachiaria*/centro mixed swards at 42 and 70 days of growth.
- iv. On the basis of (i) and (ii) above, to estimate the legume N contribution to the productivity and nutritive value of the companion grass and that of the mixture.

2. LITERATURE REVIEW

2.1 The productivity of tropical pasture

2.1.1 Dry matter yield

The DM yield of a pasture is an important parameter determining to a large extent, the carrying capacity of the pasture (Grieve and Osbourn 1965; Mannetje 1982). The DM yields of tropical pasture species vary considerably depending on the genotype, the environment in which they are growing and the agronomic and cultural practices (Bogdan 1977; Whiteman 1980; Crowder and Chheda 1982). Table 1 shows these variations for a few selected grass and legume species under experimental conditions in the tropics.

Crowder and Chheda (1982) in a review of tropical grassland husbandry, noted that the annual DM yields from tropical grasses vary from less than 0.5 tons/ha/a on the arid *Aristida* grassland of the sub-Saharan to more than 100 tons/ha/a on heavily fertilized elephant grass in the humid, lowland tropics. The DM yields of tropical legumes on the other hand, vary from less than 1 to more than 15 tons/ha/a (Bogdan 1977; Skerman 1977). Yields from grass/Legume mixtures usually exceed those from pure grass swards receiving no fertilizer N (Morrison 1966; Whitney and Green 1969; Lugenja 1979) as well as yields from pure legume swards (Tetteh 1972). Table 2 shows the performance of grass alone, legume alone and grass/legume mixtures. It can be seen that the DM yield of Pangola grass in the kaimi/pangola mixtures was 1.3 times that of pangola alone, whereas,

Table 1 : Annual DM yields of selected grass and legume species

Location/author(s)	Species	DM yield (tons/ha)	Applied N (kg/ha)
Puerto Rico (Vicente- Chandler, Silva and Figarrella 1959)	<i>P. purpureum</i> <i>P. maximum</i>	83.4 54.0	2244 1795
Trinidad (Adeniyi and Wilson 1960)	<i>D. decumbens</i>	49.3	269
Nigeria (Ademosum and Chheda 1974)	<i>C. nlemfuensis</i>	25.7	84
Ivory Coast (Cadot 1965)	<i>S. guianensis</i>	17.4	-
Hawaii (Younge, Plucknett and Rotar 1964)	<i>D. intortum</i>	9.9	-

Source : Crowder and Chheda (1982)

Table 2 : Performance of grass alone, legume alone and mixtures of grass and legume (Whitney and Green 1969)

Treatment	<u>DM yields(kg/ha)</u>				<u>CP yields(kg/ha)</u>	
	Grass	Legume	Total	% legume	Grass	Legume
Pangola	3780	-	3780	-	260	-
Pangola/ <i>D. intortum</i>	4940	5870	10810	54	520	1070
Pangola/uninoculated						
kaimi	5080	1760	6840	26	420	340
<i>D. intortum</i>	-	10630	10630	100	-	2070

that of uninoculated kaimi/pangola grass was 1.8 times that of pangola alone. The DM yield of pangola grass in pangola/*D. intortum* mixed sward was 1.3 times, whereas, that of the mixed sward was 2.8 times that of pangola alone.

The DM yields from unfertilized tropical pastures under East African conditions also show considerable variation depending on environmental conditions, especially climate (Lwoga, 1978). The DM yields have been shown to vary from 1 to 2 ton/ha/a in the dry areas of Tanzania (Walker 1969; Wigg, Owen and Mukurasi 1973), to over 10 tons/ha/a in humid areas of Tanzania (Anderson 1965; Naveh and Anderson 1966), Kenya (Keya 1974) and Uganda (Horrell and Bredon 1963).

Bogdan (1977) reported the DM yield of *B. brizantha* (signal grass) to range from 5 to 36 tons/ha/a. Fredericksen and Kategile (1980) and Mtengeti, E.J. (Personal communication, 1988) at Morogoro, Tanzania, reported the mean DM yield of *B. brizantha* (unfertilized) to be less than 3 tons/ha. However, Kidunda (1988) in a study at the same location obtained a mean DM yield of unfertilized *B. brizantha* of 11.5 tons/ha. The difference observed could probably have been caused by the differences in fertilizer levels in soils of the experimental sites. It might as well have been due to differences in the management of the experimental plots.

In Nigeria, Akinola (1977) reported a mean DM yield of 15.5 tons/ha/a for the same species. Studies on the effects of fertilizer N application and frequency of defoliation on the DM yields, chemical composition and nutritive value of *P. purpureum* (elephant grass), *P. maximum* (Guinea grass) and *B. brizantha* (signal grass) undertaken in Sri Lanka by Sivalingam (1965), showed that *B. brizantha* receiving no fertilizer N produced the highest DM yield (11.5 tons/ha/a) when cut every 30 days. Sotomayor-Rios *et al.* (1980) studying the effect of three harvest intervals on the yield and chemical composition of ten *Brachiaria* species at Corozal sub-station in Puerto Rico (humid mountainous region), applied NPK fertilizer at the rate of 3360 kg/ha/a in 6, 8 and 12 equal applications. The authors reported that the mean DM yield of *B. brizantha* was 21, 27.6 and 31.7 tons/ha/a at 30, 45 and 60 days, respectively.

Thus, from the literature, it is evident that there is enormous variation in the DM production of tropical pasture species in response to changes in climatic, edaphic and agronomic conditions.

2.1.1.1 Measurement of DM yield

The DM yield of a pasture can be measured by weighing the herbaceous material produced per unit area per unit time (Brown 1954; McIlory 1972; Humphreys 1978; Crowder and Chheda 1982).

The measurement of pasture DM yield unlike that of cultivated crops, presents difficulties since under a grazing situation, it is continuously harvested by the grazing animal. Thus, its growth cannot be estimated directly except under experimental conditions (Brown 1954).

The methods used for estimating herbage DM yields can be grouped into two main categories :-

a. Agronomic methods

These methods give the actual yield of herbage growth or the gross yield. Herbage yield is determined by (i) cutting and weighing samples of herbage from plots of known dimensions at appropriate time intervals, (ii) indirect estimates based on relationships between selected plant factors and production, and (iii) weight estimates based on visual observations. Method (i) is commonly used in pasture agronomy experiments, and has been used in the present study.

b. Animal production methods

These methods give estimates of the net yield in terms of (i) animal productivity, that is, animal days per hectare, liveweight gain per hectare, milk or wool production per hectare, and (ii) the quantity of feed units required for animal maintenance, weight increase, production of milk or other products.

2.2 The nutritive value of tropical pastures

The nutritive value of a forage refers to its chemical composition, digestibility and the nature of digested products (Van Soest 1965; Ekern and Vik-Mo 1972). However, Raymond (1969) classified nutritive value into three general components, namely, feed consumption, digestibility and energetic efficiency. Ulyatt (1973) on the other hand, divided nutritive value into the proportion that is digested or the apparent digestibility and the efficiency with which digested nutrients are utilized for maintenance and production.

Smethan (1977) noted that, the level of digestibility, at least, over the range of 30 to 70% is regarded as the main determinant of forage intake by ruminants. Raymond (1969) concluded that since the variation of gross energy in herbage is small, it is mainly digestibility which determines the nutritive value of the feed to the animal.

Crampton, Donefer and Lloyd (1960) suggested the use of a joint measure of digestibility and intake in assessing the feeding value of a forage. The measure was called the "Nutritive Value Index (NVI)". The index is a product of the relative intake and the percent energy digestibility. Ingalls *et al.* (1961) concluded that intake accounted for 70% of the variation, whereas, differences in digestibility accounted for 30% of the variation in the production potential between forages. The nutritive value index attempts to estimate the intake of the digestible nutrients (Van Soest 1982).

2.2.1 Chemical composition

The chemical composition of a forage refers to the content of protein, carbohydrates (non-structural and structural) and minerals (Norton 1982; Crowder and Chheda 1982). Chemical composition is often used as an index of forage quality. High quality forages provide protein, minerals and energy in direct proportion to the animal's requirement (Norton 1982).

Forages differ considerably in their chemical composition depending upon their genotype, stage of growth, soil and climatic conditions (McIlory 1972; Barnes 1973; Mwakatundu 1977).

The methods used to estimate the chemical composition of forages attempt to identify specific chemical entities or groups of related substances (Barnes 1973; Crowder and Chheda 1982). The Weende proximate analytical scheme analyses a feedstuff into proximate constituents of CP, CF, Ash, fat or ether extract (EE) and nitrogen free extractives (NFE). The scheme generally involves the use of strong acids or solvents at high temperatures. The scheme is based on the assumption that the entire CF fraction represents the indigestible part of the forage, and the NFE constituents, the digestible portion of the carbohydrates. Thus, forages with high NFE content were considered to be high in nutritive value and *vice versa* (Van Soest 1965; Crowder and Chheda 1982).

However, it was later realized that part of the CF was more digestible than the NFE (Van Soest 1982). This finding led to the use of the more recent analytical method which characterizes the forage DM into an available portion (cell contents), partially available portion (hemicellulose, cellulose, fiber-bound protein) and an unavailable portion (lignin, cutin, indigestible nitrogen and silica).

The method employs the stepwise use of detergent solutions in partitioning the forage fractions (Van Soest 1967).

Crude protein content

Tropical grass species have lower CP contents than tropical legume species. Also, their CP content declines at a faster rate with advancing stage of growth (Butterworth 1967a; Gohl 1975; Minson 1967; Ostrowski 1978; Mero and Kabatange 1988) than that of legumes.

Butterworth (1967a) reported the mean CP content of tropical grass species as $7.5 \pm 3.5\%$. However, Gohl (1975) reported an average CP value of 670 samples of tropical grass species as $9.9 \pm 5.8\%$.

Ostrowski (1978) working in Australia, reported that tropical legume species had CP contents ranging from 10 to 25% depending on the species and stage of growth. Marnettje and Ebersohn (1980) reported mean CP values of 12.2 and 21.2% in tropical grass and legume species, respectively. The authors also observed that it took longer for the

legume protein content to fall, thus, prolonging the period during which the forage value remained high.

However, recent studies undertaken in Tanzania by Mero and Kabatange (1988) reported mean CP content of tropical grasses and legumes cut at 112 and 177 days of growth to be 7.3 and 12.7%, respectively. The grass species studied included *C. gayana* cv. Samford, *C. ciliaris* cv. Gayndah, *B. insculpta* cv. Hatch, *P. coloratum* cv. Bambatsi, *C. ciliaris* cv. Biloele and *C. gayana* cv. Mpwapwa, while the legume species were *S. hamata* cv. Verano, *N. wightii* cv. Tinaroo, *M. axillare* cv. Archer, *S. scabra* cv. seca, *N. wightii* cv. Mpwapwa and *M. atropurpureum* cv. siratro. Kidunda and Lwoga (1985) at Sokoine University of Agriculture, Morogoro, reported mean CP value of 5.89 and 15.09% for grasses and legumes, respectively, cut between 2 and 4 months of regrowth. Kayongo-Male *et al.* (1976) in Puerto Rico, reported CP values of 101 tropical grass species cut at 30 days of growth to range from 9.8 to 23.8%.

Cell wall constituents (CWS)

The nature and concentration of structural carbohydrates in plant cell walls are major determinants of forage quality (Van Soest 1965, 1982). The CWC comprises lignin, cellulose, hemicellulose, pectin, fiber-bound protein, lignified N, waxes, cutin and insoluble mineral components (Van Soest 1982; Crowder and Chheda 1982). Hemicellulose and cellulose are valuable nutritionally in ruminants; their fermentation products, the volatile fatty acids (VFA), microbial

proteins and lipids are utilized by the host animal to perform body building and maintenance functions (Van Soest 1968). Tropical legume species contain higher lignin-hemicellulose ratios than grasses (Johnson and Pezo 1965; Van Soest 1982).

Mero and Kabatange (1988) at Mpwapwa, reported mean CWC of legumes to be 49% and that of grasses to be 73%. The samples were taken at 123 and 112 days for the legumes and grasses, respectively. In studies by Johnson and Pezo (1965) in Peru, the mean CWC of tropical grasses and legumes harvested between 28 and 42 days were 62 and 45% of the DM, respectively. The study by Kayongo-Male *et al.* (1976) indicated the mean ADF and NDF contents of tropical grasses cut at 30 days, to range from 31 to 45% and 46% to 79%, respectively.

Mineral content

The balance, concentration and nature of minerals, in herbage vary with plant species, stage of growth and mineral availability in the soil (Norton 1982). Fertilizers may increase plant growth rate and mineral content, but differences between species are evident when optimal fertilizer requirements are provided (Dougall 1960; Gomide *et al.* 1969).

Norton (1982) noted that, where nutrient availability is limiting, fertilizer application increases the plant mineral content, as it stimulates the growth of young digestible leaf and stem. Sivalingam (1965) in Sri Lanka, reported that the total ash content

was highest in Napier grass (12.71%) and lowest in Signal grass (8.32%) at 0 kg N/ha and cut at 60 days. Tropical legume species are generally richer sources of most mineral elements than tropical grasses (McDowell *et al.* 1974).

Table 3 shows the mean value for mineral contents in the DM of tropical grasses and legumes. It can be seen that though the legumes had three times more calcium than grasses, the grasses had four times more sodium compared with the legumes.

2.2.2 Digestibility

The digestibility of a forage is defined as the difference in value between the feed eaten and the materials voided by animals, expressed as a percentage of the feed eaten. This is referred to as the "Apparent Digestibility" of the feed. True digestibility, on the other hand, refers to the balance between the diet and the feed residues in the faeces exclusive of metabolic products (Van Soest 1982). Thus, the overall digestibility of a forage by ruminants is defined as the summation of the digestibility of the component tissues as affected by the anatomy, morphology and chemical composition of the forage (Norton 1982). Digestibility is an important measure of the nutritive value of forages (Crowder and Chheda 1982).

Table 3 : Mean values for mineral content in the DM of tropical grasses and legumes (McDowell *et al.* 1974)

Mineral element	Tropical	
	Grass (%)	Legume (%)
Phosphorus	0.22	0.26
Calcium	0.40	1.21
Magnesium	0.36	0.40
Sodium	0.26	0.07

The digestibility of forages varies considerably and is related to changes in the chemical composition particularly fiber, lignin and silica contents and the protein content of the forage. The changes in chemical composition arise as a result of differences in species, stage of growth, environmental conditions and management practices (Bogdan 1977; Minson 1977; Whiteman 1980).

2.2.2.1 Measurement of digestibility

Forage digestibility can be measured using several methods.

a. *In vivo* (Direct) method

The method involves feeding experiments with cattle, sheep or goats. It involves the determination of forage DM, OM or chemical constituents eaten by animals confined in metabolism cages, and the respective amounts voided in the faeces (Raymond 1969; Barnes 1973).

However, these methods are laboreous, time consuming and expensive.

b. Indirect estimation methods

These methods comprise of chemical (Barnes 1973), *in vitro* rumen techniques (Tilley and Terry 1963), nylon or dacron - bag technique (Kempton 1980; Ørskov, Hovell and Mould 1980), and physical methods (Chenost 1966; Troelsen and Bigsby 1964).

i. Chemical methods

The results of laboratory chemical analysis of forages are obtained, and are related by regression equations to the results of *in vivo* digestion trials (Barnes 1973). The data obtained are used to predict the digestibility of forages.

Bredon, Harker and Marshall (1963a, b) computed regression equations based on digestion trials undertaken in Uganda with zebu cattle. They reported highly significant correlation coefficients between digestibility and chemical components such as CF ($r = -0.721$) and CP ($r = 0.9362$). Ademosun (1974) in Nigeria, studied the relationship between DMD and several chemical constituents including ADF and CF.

He observed that the ADF and CF contents of improved tropical forages were highly negatively correlated with the DMD. The correlation coefficient between DMD and ADF was -0.87 while that between DMD and CF was -0.71 .

Crowder and Chheda (1982) suggested that, with improved methods available to separate the various nutritional components and with the greater understanding about their availability to animals, it is possible to predict digestibility more accurately.

In vitro rumen fermentation techniques

These techniques attempt to approximate digestion in an artificial environment where rumen conditions are simulated in a test-tube (Tilley and Terry 1963; Barnes 1973; Goering and Van Soest 1978).

The techniques do not require extensive laboratory facilities, and many samples can be analyzed simultaneously. The *in vitro* technique uses either a "one - stage" or a "two - stage" digestion procedure.

The "one-stage" technique involves anaerobic fermentation of a forage sample inoculated with rumen micro-organisms in a buffered nutrient medium under controlled conditions of temperature (39°C) and pH (6.7 - 6.9). The DMD or OMD, after a specified period of incubation, is expressed as a percentage. The digestibility coefficient obtained is related to *in vivo* parameters by means of prediction equations. This technique attempts to measure the fibrous fraction of the forage (Barnes 1973; Goering and Van Soest 1978).

The "two-stage" technique attempts to measure both the fibrous fraction and the digestible soluble fraction (Tilley and Terry 1963; Barnes 1973)

The first stage as outlined in the "one-stage" technique is followed by a second stage, which involves the solubilization of the

DM residue of the first stage by acid-pepsin for 48 hours (Tilley and Terry 1963). The use of standard herbage samples of known *in vitro* digestibilities in each *in vitro* run is essential to avoid arriving at erroneous conclusions.

The nylon-or dacron-bag techniques

The technique has been described in detail by Kempton (1980) and Ørskov, Hovell and Mould (1980).

It involves the placement of samples of dried forage in bags of an indigestible material such as nylon, dacron or silk within the rumen. The rate and extent of digestion is measured by loss of DM or nutrient content from the sample after a specified incubation period.

ii. Physical methods

The artificial mastication procedure has been proposed for the prediction of voluntary intake of herbage for ruminants by Troelsen and Bigsby (1964) and Chenost (1966). The method involves measurement of the rate of breakdown of herbage tissue to particle sizes fine enough to pass through a 100 - mesh size.

Histological methods have also been used to study the lignification patterns in plants and their resistance to digestibility (Drapala, Raymond and Crampton 1947).

However, these methods have not been put into routine forage evaluation due to the fact that they are difficult to standardize and they require considerable skill (Barnes 1973).

2.2.3 Voluntary intake

Voluntary intake is defined as the amount of forage ruminants will ingest when an excess of 15 to 20% is offered (Van Soest 1982). Milford and Minson (1966) in their study of the intake of tropical pasture species concluded that the daily intake of DM is the most important single factor controlling the nutritional value of tropical pastures.

The standard method for estimating the voluntary intake of a forage is by feeding a known amount of fresh, dried or frozen forage to individual animals, usually 8 to 10, in pens and then measuring the refusals. The forage is usually offered to the animal at least twice daily.

The intake has been related to the metabolic body weight on the assumption that it is a function of the metabolic requirements of the animal. Thus, it is expressed as $\text{g/d/kg}^{0.75}$.

The voluntary intake of a forage is influenced to a large extent, by the stage of growth, digestibility and the genotype of the forage (Crowder and Chheda 1982; Van Soest 1982).

2.3 Factors influencing dry matter yield and nutritive value of tropical pasture species

The productivity and nutritive value of tropical pasture species vary considerably. They are mainly a function of the plant species and the stage of growth of the pasture plants at the time of harvesting (Mwakatundu 1977; Whiteman 1980).

The species and stage of growth effects are modified by climatic factors during growth, soil factors which affect nitrogen and other mineral status and management factors which affect pasture growth rate, sward structure and the botanical composition (Alberda 1965; Deinum 1966; Wilson 1984).

2.3.1 Species

The DM yield potential and the nutritive value of pasture plants vary between families, genera, species and even varieties or cultivars. Tropical grass species are C_4 plants. They have a more efficient biochemical pathway (the "Hatch and Slack pathway") compared to that of tropical legumes and temperate species (grasses and legumes). These are C_3 plants and they utilize the "Calvin pathway" (Whiteman 1980; Crowder and Chheda 1982). Thus, tropical grass species grow faster and accumulate more DM compared to tropical legume species. However, tropical legume species have higher nutritive value than grasses when harvested at the same stage of growth (Minson 1976; Kidunda 1988; Mero and Kabatange 1988).

Kidunda (1988) reported the mean DM yields of four tropical grass and four legume species to be 18.5 and 3.1 t/ha, respectively. Among the grass species evaluated, *P. purpureum* produced the highest DM yield (29.2 t/ha) whereas *C. gayana* gave the lowest DM yield (10.8 t/ha). Similarly, *C. mucunoides* (Calopo) outyielded the other legume species (3.4 t/ha).

The results of this study showed that the legume species had higher CP content and DMD but lower NDF and ADF contents than grasses cut between 2 and 4 months of growth. The legume species had a mean CP, DMD, NDF and ADF values of 15.1, 54.5, 60.7 and 45.2% compared to the mean for grass species of 5.9, 39.5, 77.7 and 50.7%, respectively.

The study by Mero and Kabatange (1988) showed the pattern depicted in Table 4. The mean DM yield of the grasses studied was higher (5.5 t/ha) than that of the legume species (4.2 t/ha). The chemical composition and OMD were also different between and within species.

The studies by Kayongo-Male *et al.* (1976) in Puerto Rico, Johnson and Pezo (1965) in Peru and Reid *et al.* (1973) in Uganda, all showed similar patterns, except that the values differed between locations, most likely because of varying environmental influences and stages of growth.

Table 4 : The influence of plant age on chemical composition (% of DM) and IVOMD (%) of 6 grasses and 6 legumes at Mpwapwa, Tanzania (Mero and Kabatange 1988)

Species	Plant age (days)									
	112 days			177 days			202 days			
	DM(%)	CP(%)	CMC(%)	OMD(%)	DM(%)	CP(%)	CMC(%)	OMD(%)	DM(%)	CP(%)
<u>C. gayana</u> cv. Sanford	25.9	12.0	73.1	76.9	34.6	7.7	73.8	65.3	63.8	5.7
<u>C. ciliaris</u> cv. Gayndah	31.6	7.8	71.5	70.1	48.3	7.6	72.3	64.9	68.5	5.9
<u>B. insculpta</u> cv. Hatch	33.7	8.4	74.5	70.9	54.7	4.8	74.7	67.4	70.5	4.7
<u>P. coloratum</u> cv. Bambatsi	29.2	11.0	70.5	72.5	43.0	7.5	71.6	66.9	64.3	6.6
<u>C. ciliaris</u> cv. Biloela	29.0	9.4	72.7	67.6	38.0	7.1	73.2	64.2	69.4	5.3
<u>C. gayana</u> cv. Mpwapwa	29.5	9.5	76.3	76.8	48.1	5.6	77.4	-	63.9	5.4
<u>Legumes</u>										
<u>S. hamata</u> cv. Verano	35.6	13.9	49.5	75.8	47.6	13.5	55.1	72.2	71.9	12.3
<u>N. wightii</u> cv. Tinaroo	28.3	16.1	45.0	72.8	51.0	11.9	54.2	69.6	71.7	9.2
<u>M. axillare</u> cv Archer	23.7	13.4	47.5	76.8	45.8	12.5	51.5	75.7	59.4	10.2
<u>S. scabra</u> cv. seca	33.5	13.6	54.1	70.0	58.1	13.2	56.1	68.9	71.9	11.5
<u>N. wightii</u> cv. Mpwapwa	31.8	15.2	47.0	74.4	46.1	12.9	50.5	73.2	59.8	10.9
<u>M. atropurpureum</u> cv Siratro	24.9	14.4	51.3	69.9	52.9	12.9	55.7	67.8	61.9	11.3
<u>297 days</u>										

Minson (1971) demonstrated differences in the proportion of leaf, DMD, N content and voluntary intake between varieties of *Panicum* species.

As shown in Table 5, *in vivo* DMD of coloniao was the highest (54.8%) among the *Panicum* varieties while that of green panic was the lowest (51.0%). Kabulabula variety on the other hand, had the highest N content (2.20%) compared with the rest of the varieties.

It is clear from the above results that there are variations between families, genera, species and even varieties in the DM yield and nutritive value. Thus, screening work for pasture species and varieties with ability to produce high DM yields of reasonably good quality is necessary before giving recommendations for pasture establishment.

2.3.2 Stage of growth

It has been observed by several workers that advancing stage of growth of pasture plants is associated with increase in DM yield and decrease in the nutritive value. However, the rates of increase and decrease vary between and within pasture plant species (Johnson and Pezo 1965; Minson 1971; Ogwang and Mugerwa 1976; Kidunda 1988).

Butterworth (1967a) observed increase in the mean DM content and decrease in the mean CP and DMD values of tropical grass species with advancing stage of growth. He observed that the CP content of B.

Table 5 : Comparison of mean leaf percentage, DMD, N content and voluntary intake of varieties of *Panicum* (Minson 1971)

Parameter	Kabulabula	Burnett	CPI 13372	Coloniao	Green	Humi1
Proportion of						
leaf (%)	24.0	34.0	26.0	54.0	25.0	47.0
N content (%)	2.2	2.01	1.88	2.09	1.9	1.02
DMD (<i>in vivo</i> %)	53.2	54.6	51.0	54.8	51.0	52.4
DMI(g/kg ^{0.75})	45.2	53.5	50.0	60.8	51.3	62.8

brizantha declined from 6.1% at 50 days to 4.6% at 80 days, whereas, the DM content increased slightly from 21 to 23% during the same period.

The study on the yield and nutritive value of some tropical grasses (*B. brizantha*, *C. gayana*, *P. purpureum* and *T. laxum*) and legumes (*C. ternatea*, *M. atropurpureum*, *C. mucunoides* and *C. pubescens*) by Kidunda (1988) at Morogoro, showed a significant increase in the DM yield of both the grasses and legumes with advancing stage of growth.

The DM yield of grasses increased from 4.5 t/ha at two months to 24.8 t/ha at four months of growth. The corresponding DM yield of the legume species were 2.9 t/ha and 3.3 t/ha, respectively.. Similarly, the NDF content of the grass and legume species increased from 73.86 to 81.69% and from 56.65 to 64.77%, respectively.

The author reported decrease in the CP content, ADF and DMD percentage of both grasses and legumes. The DMD of grass and legume species declined from 45.6 to 33.2% and 57.7 to 51.3%, respectively. The rates of decline in the DMD were 0.3 and 0.15% per day for grasses and legumes, respectively.

Similarly, the study by Mero and Kabatange (1988) at Mpwapwa, showed decreases in CP and OMD with advancing stage of growth, as shown in Table 4.

Johnson and Pezo (1965) reported increase in the ADF contents of both the grass and legume species studied in Peru. The ADF content of *B. decumbens* increased from 38% at 42 days to 46% at 70 days, whereas, that of siratro increased from 32 to 39%, respectively.

Thus, from the above results, the appropriate time to harvest grass for hay, is just before inflorescence emergence. However, legumes could be harvested at a later stage as they have the ability to maintain growth and high nutritive value over a longer time.

2.3.3 Climate

2.3.3.1 Temperature

Several studies have indicated increased DM yield in tropical grasses with increasing environmental temperature through its effects on the net photosynthetic rate (P_n) (Terharne *et al.* 1971). Tropical grasses have a higher net photosynthetic rate than either tropical legumes or temperate grasses and legumes (Whiteman 1980).

Increased temperature in *Paspalum dilatatum* (Mitchell 1956) and *P. maximum* (Ivory 1975) increased the rate of tiller production, leaf area and development of the whole plant.

Deinum and Dirven (1975) in a trial conducted in temperature greenhouses, observed that an increase in temperature, stimulated development in *B. ruziziensis* and *S. sphacelata*.

High environmental temperature stimulates an earlier onset of lignification (Dirven and Deinum 1977; Wilson 1984; Deinum and Dirven 1972). Deinum and Dirven (1972) planted *B. ruziziensis* in plastic pots in a greenhouse, and subjected them to variable temperatures of 24/19, 28/24.5 and 33/35°C. They observed increase in the DM yield and CF, while the DMD decreased with increasing temperature.

Minson and McLeod (1970) reviewed data of 1000 DMD determinations of tropical and temperate grasses. They reported a mean decrease in the DMD of 1% units per 1°C rise in temperature.

2.3.3.2 Rainfall and its seasonal distribution

Rainfall is the most important climatic element in the tropics since temperature and light are less likely to be limiting to pasture productivity (Crowder and Chheda 1982).

Herbage DM yields of tropical pasture species follow the cyclic pattern of rainfall (French 1957; Mannelje 1982). During the rainy season, the soil moisture content is adequate, thus encouraging high growth rates of pasture plants. This leads to the production of surplus herbage (Burt *et al.* 1983). During the dry season, however, there is soil moisture stress which leads to reduced pasture growth through reduced P_N and later reducing the rate of leaf development (Whiteman 1980). Prolonged periods of soil moisture deficit lead to the death of the whole plant. It is during the dry season when most ruminant livestock lose condition and may even die of starvation

depending on the severity and duration of the dry season.

The nutritive value of tropical pasture species fluctuates with changes in seasons (Karue 1974; Wilson 1984). At the beginning of the wet season, there occurs a rapid growth of the plants which were dormant in the previous dry season. These young immature plants are of high nutritive value. At this time, the CP is above 10% in the DM, and the DMD is above 75%. However, they mature and decline in nutritive value fast, because of increased growth of stems compared to leaves which are usually higher in quality.

Increased growth of stems is associated with increased lignification and decreased cell contents.

Milford (1960) concluded that due to the seasonality of rainfall and the short growth period in tropical herbages, the CP content of the grasses becomes so low that the animals maintained on these pastures experience a negative nitrogen balance during the dry season.

2.3.4 Soil fertility

The ability of the soil to supply nutrients to plants is an important factor in forage production (Henzell 1977; Wilson 1984). It has been observed by many workers that healthy and high quality forage species thrive only on soils well supplied with N, P, Ca, Mg and K (Henzell 1977).

Most tropical soils are highly weathered, leached and deficient in mineral nutrients. Soil N deficiency has been singled out as the nutrient most frequently limiting grassland productivity in the tropics (Russell 1966; Lwoga 1978; Haque and Jutzi 1984; Tothill 1985). Thus, the application of fertilizer N with or without P and K increase the productivity and nutritive value of tropical pasture species provided that there is adequate moisture (Rivera-Brenes, Torres-Mass and Arroyo 1961; Sallete 1970).

The favourable response to fertilizer N application in terms of increased DM yield and nutritive value of the herbage are well documented (Crowder and Chheda 1982). However, the application of fertilizer N in tropical pasture production has found limited use in most tropical countries due to the high costs of N fertilizers in relation to the monetary value of livestock products such as milk or meat (Wigg, Olsen and Mukurasi 1973; Lwoga 1978; Haque and Jutzi 1984).

Most fertilizer N experiments conducted in tropical environments where moisture supply is not limiting, have shown linear increases in the DM yield, CP content and CP yield with increasing fertilizer N rates. In East Africa, there are only few experiments where high rates of fertilizer N have been used.

In Western Kenya (mean annual rainfall, above 1000 mm), Keya (1974) conducted experiments with *S. anceps* pastures at three sites. He used 0, 100, 200, 400 and 800 kg N/ha/a in the form of sulphate of

ammonia (SA). The highest mean response was obtained at the 200 kg N/ha/a rate (18 kg DM/kg N) while the lowest 10 kg DM/kg N) was obtained at 800 kg N/ha/a.

Olsen (1972), working in Southern Uganda (mean annual rainfall, 1200 mm), applied ammonium nitrate (AN) to *B. ruziziensis*, *C. gayana*, *P. maximum* and *S. anceps* at rates equivalent to 0, 224, 448, 896, 1586 and 2240 kg N/ha/a over 2 years. There was a progressive increase in DM yield with fertilizer N increase up to 448 kg N/ha/a, then the DM yield levelled off at 896 kg N/ha/a rate and finally DM production declined at rates exceeding 1568 kg N/ha/a. However, the CP content increased progressively from 7.9 to 16.5% at 0 and 2240 kg N/ha/a, respectively while the CP yield increased linearly from 0.8 t/ha at 0 to 3.9 t/ha at 1568 kg N/ha/a, then declined slightly to 3.7 t/ha at 2240 kg N/ha/a.

A similar pattern of response has been reported in Puerto Rico (Vicente-Chandler, Silva and Figarrella 1959).

The decline in DM yield with high rates of fertilizer N rates was attributed to the burning effect of the fertilizer, which resulted in a decrease in plant population.

In Tanzania, several workers have reported similar responses. At Morogoro, Fredericksen and Kategile (1980) working with *B. brizantha* obtained DM yields of 2.8, 5.8, 8.9 and 9.8 t/ha in 1973, with

fertilizer N rates of 0, 62.5, 125 and 187.5 kg N/ha, respectively. They reported steady increases in the CP content and CP yield of the grass species. The CP content increased from 5.9 to 7.6% and CP yield from 162 to 745 kg/ha, respectively, at 0 to 187.5 kg N/ha.

It is therefore evident that increasing the N content of the soil through the application of N fertilizers, boosts the DM yields and nutritive value (CP content and CP yield) of tropical pasture grasses. However, adequate soil moisture is a prerequisite for maximum responses to applied N.

2.3.5 Frequency and intensity of defoliation

The DM yield and nutritive value of pasture species are influenced by the frequency and intensity of defoliation (Vicente-Chandler, Silva and Figarrella 1959; Sivalingam 1965; Appadurai and Goonewardena 1974; Mshana 1977; Mutz and Drawe 1983).

The study by Mshana (1977) at Morogoro, showed that the total DM yield of *C. gayana* over a 12 - week period increased by 36% when intervals between harvests increased from three to six weeks. However, the DM yield of siratro did not show a significant increase with extended cutting interval (from 158 to 176 g/m²), probably because of *Rhizoctonia* leaf-rot and other disease attacks.

In Puerto-Rico, Vicente-Chandler, Silva and Figarrella (1959) studied the effect of frequency of defoliation on the DM yield and chemical composition of Guinea grass. They observed increase in the

DM yield and DM content of the grass species, and a decline in the CP content with extended cutting intervals at all levels of fertilizer N application. At 896 kg N/ha/a rate, Guinea grass produced 30 860, 36 660 and 48 840 kg DM/ha/a when cut at 40 -, 60 -, and 90 - day intervals, respectively. The corresponding DM percentage were 20.2, 23.5 and 30.4%, respectively. However, the CP content declined with extended cutting intervals. The CP values were 11.1, 9.6 and 7.3 at 40 -, 60 -, and 90 - day cutting intervals, respectively.

At Samford, Australia, Jones (1967) studied the effect of close cutting and fertilizer N application on the DM yield of siratro pasture. The plots were cut to 3.81 cm stubble height at 4 -, 8 -, and 12 - week intervals. It was observed that the DM yield of siratro was greatly increased by increasing the cutting intervals. The mean DM yield of siratro was 1594, 2380 and 5378 kg/ha at 4 -, 8 - and 12 - week cutting intervals. The contribution of siratro to the total DM yield increased from 19 to 66% with increasing cutting interval from 4 to 16 weeks.

Moore (1962) in Nigeria, observed that the DM yield of *Centro/C. plectostachyus* pasture was highest with the 8 - week cutting regime compared with the 2 - or 4-week regimes.

From the above review, it can be concluded that, in order to optimise both DM yield and nutritive value of tropical pasture species, an appropriate balance of pasture factors (species and stage

of growth), environmental factors (climate and soils) and management factors (fertilization, and cutting or defoliation), should be maintained.

2.4 The importance of legumes in tropical pasture production

The importance of legumes in alleviating N deficiency in tropical soils is well known and documented (Moore 1962; Bruce 1967; Haque and Jutzi 1984). Haque and Jutzi (1984) observed that a more effective and cheaper way of raising the N status of the soil is to exploit the ability of forage legumes to fix appreciable quantities of atmospheric N. The N fixed by the leguminous plants accumulates in the soil and is slowly released to become available to non - leguminous plant species.

2.4.1 The role of the legume in atmospheric N fixation

The role of legumes in atmospheric N fixation in the tropics is well recognized (Reynolds 1982; Haque and Jutzi 1984; Tothill 1985). The forage legumes with the help of the nodule bacteria (*Rhizobium* spp.) are capable of fixing N from the atmosphere. Tropical legumes in sub-Saharan Africa, have been reported to fix more than 300 kg N/ha (Haque and Jutzi 1984).

The fixed N is used by the legumes themselves but up to 90% (Whiteman 1980) is transferred to the companion grass (in grass/legume mixture) by way of leaf fall, root and nodule decomposition and through urine and dung from the grazing animal. Bruce (1967) in

Queensland, indicated that in the elephant grass alone plots, the percentage N content in the top-soil (0 - 15 cm) was 0.272%, whereas, in the elephant grass/centro mixture plots, it was 0.346%. The increase in soil N content was, therefore, 27%.

In experiments conducted at Samford, *Leucaena leucocephala* fixed 560 kg N/ha/a (Hutton and Bonner 1960). This was the highest estimated N fixed by a tropical legume species during that period, while the highest N fixation rate for a temperate legume recorded at Palmerston North, Newzealand, was 645 kg N/ha/a. These results provided evidence that tropical legume species equalled temperate legume in their ability to fix atmospheric N. Thomas (1974), Keya (1977) and Ayanaba (1980), further confirmed these results when they concluded that given good management conditions, tropical and temperate forage legume species have a similar potential for N fixation.

There is considerable variation in the ability of tropical forage legumes to fix atmospheric N. Martin (1960) noted that the quantity of N fixed by legumes in the field was greatly affected by environmental factors operating on the nodule bacteria, the host plant or on both. Work done on N fixation in sub-Saharan Africa has been reviewed by Haque and Jutzi (1984) and is summarized in Table 6.

It can be seen from the table that different legume species under different environments have different N fixation capacities. It can

Table 6 : Nitrogen fixation rates (kg/ha) by forage legumes in sub-Saharan Africa (Haque and Jutzi 1984)

Legume	Average N fixation	Location	Source
<u>C. pubescens</u>	259	Nigeria	Moore(1962) Odu <u>et al.</u> (1971) Adegbola and Fayeni (1972)
<u>C. pubescens</u>	280	Nigeria	Moore (1962)
<u>Centrosema and</u>	84		
<u>S. guianensis</u>	161	Uganda	Herrell and Newhouse (1966)
<u>D. uncinatum</u>	178	Kenya	Anon. (1969)
<u>G. javanica</u>	73 (first 5 years)		
(<u>G. wightii</u>)	45 (last 4 years)	Kenya	Jones (1942)
Lucerne	56 (120 days)	Kenya	de Souza (1969)
Leucaena	110	Tanzania	Hogberg and Kwamstorm (1982)
Leucaena	287 (6 months)	Nigeria	Sanginga <u>et al.</u> (1984)
<u>Lotonosis bainesii</u>	62	Zimbabwe	Clatworthy (1970)
<u>Stylosanthes</u> spp.	124	Nigeria	Odu <u>et al.</u> (1971)
<u>S. ginanensis and D. intortum</u>	94	Malawi	Anon. (1961)
<u>T. repens</u> (cv. Louisiana)	224 -- 336	Kenya	Morrison (1966a)
<u>T. semipilosum</u>	80	Zimbabwe	Clatworthy (1970)

also be seen that centro had a higher N fixation rate in Nigeria than in Uganda.

A great improvement in animal production from pastures can be achieved in the tropics, through exploiting the unique role of forage legumes of fixing atmospheric N.

2.4.2 The effects of the legume on herbage DM yield

Inclusion of a legume in a grass-based pasture improves the DM yield of the associate grass and that of the grass/legume mixture (Horrell 1964; Horrell and Newhouse 1966; Whitney and Green 1969; Balachandran and Whiteman 1975; Lugenja 1979; Myoya 1980; Rukanda and Lwoga 1981).

The grass growing in association with the legume, makes use of the N fixed by the legume after the decay of the legume plant parts (roots, nodules, stubbles and leaves), and by return through urine and faeces of the grazing animal and soil fauna (Whiteman 1980).

Many studies conducted in the tropics have indicated the superiority, in terms of DM yield, of the grass component in the grass/legume mixtures compared to grass alone pastures (Moore 1962; Horrell and Court 1965; Morrison 1966; Naveh and Anderson 1967; Keya, Olsen and Holliday 1971; Tetteh 1972; Akinola 1977).

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A great improvement in animal production from pastures can be achieved in the tropics, through exploiting the unique role of forage legumes of fixing atmospheric N.

2.4.2 The effects of the legume on herbage DM yield

Inclusion of a legume in a grass-based pasture improves the DM yield of the associate grass and that of the grass/legume mixture (Horrell 1964; Horrell and Newhouse 1966; Whitney and Green 1969; Balachandran and Whiteman 1975; Lugenja 1979; Myoya 1980; Rukanda and Lwoga 1981).

The grass growing in association with the legume, makes use of the N fixed by the legume after the decay of the legume plant parts (roots, nodules, stubbles and leaves), and by return through urine and faeces of the grazing animal and soil fauna (Whiteman 1980).

Many studies conducted in the tropics have indicated the superiority, in terms of DM yield, of the grass component in the grass/legume mixtures compared to grass alone pastures (Moore 1962; Horrell and Court 1965; Morrison 1966; Naveh and Anderson 1967; Keya, Olsen and Holliday 1971; Tetteh 1972; Akinola 1977).

In Tanzania, Myoya (1980) reported the DM yield of Nandi Setaria/Silver-leaf desmodium to be 6.8 t/ha compared to Nandi Setaria alone which gave 4.5 t/ha.

Studies by Rukanda and Lwoga (1981) at Morogoro (mean annual rainfall, 865 mm) showed a 30% increase in the DM yield when siratro and *S. guianensis* were oversown in a *Themeda* - *Heperrhaenia* dominated pasture.

In Kenya, Thairu (1972) reported that the DM yield of a *D. uncinatum*/Setaria sward was twice that of Setaria alone after a four year period. Similarly, Horrell (1964) working in Uganda, showed that a mixed sward of *C. gayana*/*S. gracilis* gave twice the DM yield of the pure grass sward.

Tetteh (1972) at Pokoase, Ghana, compared the DM yield of grass/legume mixed swards and their pure stands. The author observed that, the pure stand of *A. gayanus* was outyielded by its mixed stand with *Desmodium* from the third to the fifth harvest. The pure stands of *D. decumbens*, *C. pubescens* and *D. leiocarpum* were outyielded by their mixed stand (Table 7).

The studies undertaken in Hawaii by Whitney and Green (1969) showed that the DM yields of *D. canum*/pangola and *D. intortum*/pangola nearly doubled and tripled those of pangola alone swards, respectively, as shown in Table 2.

Table 7 : Mean DM yields per harvest, total yields and average total
DM yields of pure and mixed stands of grasses and legume
(Tetteh 1972)

Pure or mixed swards	DM yields (tons/ha)						Total	Mean
	1*	2	3	4	5			
<i>A. gayanus</i>	10.3	9.7	8.2	3.9	5.3		37	7.5
<i>D. decumbens</i>	5.2	4.1	2.9	1.7	2.7		17	3.3
<i>C. pubescens</i>	3.8	2.4	0.6	0.5	0.4		8	1.5
<i>D. leiocarpum</i>	1.2	1.1	1.0	1.0	0.6		5	1.0
<i>Andropogon/centro</i>	6.3	8.8	6.9	3.5	4.9		30	6.1
<i>Andropogon/Desmodium</i>	7.3	7.8	8.8	4.1	6.4		34	6.9
<i>Digitaria/centro</i>	9.5	6.2	5.0	3.2	4.0		38	5.6
<i>Digitaria/Desmodium</i>	6.4	4.7	3.8	2.1	3.1		20	4.5

* Harvest dates:

1 = 12/3/1970

2 = 12/5/1970

3 = 14/7/1970

4 = 15/9/1970

5 = 16/11/1970

The study by Balachandran and Whiteman (1975) in Australia, demonstrated that the DM yield of the setaria component in a setaria/*D. intortum* mixed sward was 1.4 times that of *S. anceps* alone. Also, the DM yield of the mixed sward was 3.7 times that of *S. anceps* alone.

Thus, from the above review, it is evident that given favourable conditions for plant growth, incorporating a legume in a grass-based pasture improves both the grass DM yield and that of the pasture mixture.

2.4.3 The effects of a legume on herbage quality

The outstanding feature of a grass/legume sward is the increased N content and the slow rate of decline of N with advancing stage of growth, found in the legume component of the mixed sward (Milford and Haydock 1965; Minson and Milford 1967; Mannerje and Ebersohn 1980; Tothill 1985). This characteristic is true in both tropical and temperate legumes, but it is more important in tropical pastures where the quality of grass-based pastures declines rapidly with advancing stage of plant growth.

Milford and Haydock (1965) demonstrated the characteristic when they compared the effect of age of four tropical grass species (*P. clandestinum*, *S. alnum*, *C. ciliaris* and *D. decumbens*) with the legume siratro on the CP content. The CP content of the young immature plants were above 15%, but declined at varying rates with advancing

stage of growth. The CP content of grasses declined faster than that of siratro.

The CP content of tropical legumes has been reported to range from 5.6 to 35.8% (Hutton and Bonner 1960). Butterworth (1967) reported an average CP content of grasses to be 7.5% for samples cut between 3 and 22 weeks of growth. However, Göhl (1975) reported a slightly higher CP content of tropical grasses of $9.9 \pm 5.8\%$.

The digestibility of both tropical grass and legume species has been observed to be high at young and immature stages of growth. Reid *et al.* (1973) have reported *in vitro* DMD above 80% for some improved tropical grasses and legumes at one week of growth. However, with advancing stage of growth, the digestibility of tropical grasses declines at a faster rate than that of tropical legumes (Reid *et al.* 1973; Kidunda and Lwoga 1985; Mero and Kabatange 1988).

Reid *et al.* (1973) reported a decline of 0.3% units per day in the DMD of *B. ruziziensis* and 0.1% units per day in that of *C. pubescens*.

The inclusion of a legume in pasture mixture has been observed to make an important contribution in maintaining adequate protein levels in pasture (Bryan 1962; Moore 1962; Akinola 1981; Rukanda and Lwoga 1981). Rukanda and Lwoga (1981) at Morogoro, reported a 50% increase in the CP content of the pasture when siratro and stylo were oversown

in a *Themeda-Hyperrhaenia* dominated pasture. Moore (1962) at Ibadan, Nigeria, showed that establishing centro in association with *C. plectostachyus*, raised the CP content of the grass by over 30%.

Thus, the advantages of incorporating a legume in pasture mixtures in terms of improved pasture quality are worth exploiting if improvement in animal production from animals grazing tropical pastures is to be achieved.

3. MATERIALS AND METHODS

The experiment was conducted at Sokoine University of Agriculture farm, Morogoro, Tanzania, from October, 1987 to June, 1988.

The University is located between 6 and 7°S and between 37 and 38°E, at an altitude of about 500 meters above sea level. The area receives a mean annual rainfall of 854 millimeters (17 - year mean, 1971 - 1987, Sokoine University of Agriculture Meteorological Station) (Table 9).

The experimental site was part of an area which had remained uncultivated for the past five years.

The experimental treatments comprised *B. brizantha* receiving 0, 100 and 200 kg N/ha, *B. brizantha*/*M. atropurpureum* and *B. brizantha*/*C. pubescens*. The pasture plots were harvested at two stages of growth, namely, 42 and 70 days after the date of mowing. There were a total of 10 treatment combinations, namely :-

- i. *B. brizantha*, 0 kg N/ha, early harvest
- ii. *B. brizantha*, 0 kg N/ha, late harvest
- iii. *B. brizantha*, 100 kg N/ha early harvest
- iv. *B. brizantha*, 100 kg N/ha, late harvest
- v. *B. brizantha*, 200 kg N/ha, early harvest
- vi. *B. brizantha*, 200 kg N/ha, late harvest

- vii. *B. brizantha*/siratro, early harvest
- viii. *B. brizantha*/siratro, late harvest
- ix. *B. brizantha*/centro, early harvest
- x. *B. brizantha*/centro, late harvest

The DM, DDM and CP yields, chemical composition and *in vitro* DMD of all treatment combinations were evaluated. The grass and legume components in the grass/legume mixed swards were hand-sorted, weighed fresh, oven-dried and DM content calculated then used to estimate the DM yield. Subsamples of the grass and legume components were processed and analysed for CP, ash, NDF and ADF contents, Also *in vitro* DMD was determined from the subsamples. From the measurements, the legume (%) and the legume N contribution were estimated.

3.1 Pasture establishment

Pre-ploughing operations started during the second week of October, 1987. The operations included the demarcation of the experimental site, soil sampling and clearing the area of bush and other vegetation.

An area of 800 m² was demarcated on land which had remained uncultivated for the past 5 years. The 0 - 15 cm top - soil was sampled on two occasions. The first occasion was on 11 October, 1987 (prior to the commencement of the experiment), while the second occasion was just after the termination of the experiment, on 6 June, 1988. The samples were taken from six random locations on the

experimental site, bulked into one composite sample, sub-sampled then submitted to the Soil Science Department for chemical analysis. The results are shown in Table 10.

The area was disc-ploughed on 16 October, 1987, then harrowed a fortnight later. The area was then divided into four blocks of 5 m x 13 m, which were in turn sub-divided into 10 plots each of 1.6 m x 5 m. There were paths of 2, 1 and 0.5 meters along the margins and between plots, respectively (Appendix 2)

Phosphatic fertilizer in the form of triple superphosphate (TSP) was broadcast by hand at the rate of 60 kg P/ha (equivalent to 300 kg TSP/ha). The fertilizer was raked - in lightly using a hand rake. Nitrogen fertilizer in the form of calcium ammonium nitrate (CAN) was applied at the rate of 50 kg N/ha (equivalent to 192 kg CAN/ha) to all the 40 plots just before planting on the 26th November, 1987, to stimulate the growth of the plants. The N treatments were applied to the appropriate plots after cutting herbage to a uniform stubble height of 10 cm, on 23 - 26 March, 1988.

The legume seeds used in this experiment were obtained from the Livestock Production Research Institute (LPRI), Mpwapwa, Tanzania. Both the siratro and centro seeds were hand-sorted to obtain seeds of uniform size. The seeds were scarified by rubbing between two sheets of sandpaper before they were sown on 21 and 22 November, 1987.

Siratro seeds were sown at 32 cm between rows and 15 cm within rows, to attain a seed rate of 2.5 kg/ha. Centro seeds were sown at 32 cm between rows and 20 cm within rows, so as to attain a seed rate of 3 kg/ha. The sowing depth was approximately 2 and 3 cm for siratro and centro, respectively.

Brachiaria brizantha was planted one week later using fresh root-stocks obtained from a nearby field. The root - stocks in the grass alone plots were planted in rows with a spacing of 25 cm and 40 cm within and between rows, respectively. In the grass/legume mixture plots, the spacing was 45 cm within rows and 60 cm between rows.

There was rain for only three days after planting, followed by an unusually long dry spell. This condition necessitated the watering of all the plots till the beginning of the long rains in March 1988. Due to the long period of moisture stress following planting, the establishment of the plants was not as good as was expected i.e. it was less than 20% of the expected establishment especially for the centro. However, all the empty spaces were re-sown to fill in the gaps on the 12 December, 1987. The plots were clean-weeded by uprooting all the weeds manually. The paths were cleaned routinely using a hand - hoe.

The plots were mown from 23 to 26 March, 1988, leaving a uniform stubble of 10 cm. The experimental field layout is shown in Appeneix 2.

3.2 Herbage sampling

Sampling of the herbage was done twice during the regrowth period. Table 8 shows the dates on which sampling of the herbage was done.

Whole plot samples were cut using an auto - reciprocating mower. A border strip of 0.5 m wide was discarded from each of the plots leaving a sample area of 0.6 m x 4 m per plot.

The fresh samples were weighed in the field using a 25 - kg spring balance hoisted on a metal frame. The grass/legume mixture samples were hand - sorted into component species before weighing. Then, the samples were packed in labelled polythene bags and transported to the Animal Science Department Laboratory where they were sub-sampled into 500 g lots. The samples were placed onto trays oven - dried at a temperature of 80°C for 24 hours. After drying, the samples were taken out of the oven and left out to cool at room temperature for about half an hour. The dry weights were taken and used to estimate the DM yields and botanical composition.

The dried samples were milled in a Christy and Norris laboratory mill fitted with 1 - mm sieve. The milled materials were thoroughly mixed, then sub-sampled and placed in air - tight sample bottles for use in chemical analysis and *in vitro* DMD determination.

**Table 8 : Dates of herbage sampling, stage of regrowth (days) of the
herbage and the number of plots samples**

Date	Stage of regrowth (days)	Number of plots sampled
6/4/1988	42	20
3/6/1988	70	20

3.3 Chemical analysis

The samples were analysed for contents of CP, DM, ash, NDF, ADF and DMD. The CP content was determined as Kjeldahl-N using procedures described by the Association of Official Analytical Chemists (AOAC 1985). The N values obtained were multiplied by a factor of 6.25 to give the percentage CP values. Percent ash content was calculated as a residue after incineration in a muffle furnace at 500°C. Percent NDF and ADF were determined according to the procedures described by Goering and Van Soest (1978). Two standard samples were included in each *in vitro* run, and the digestibility coefficients of the samples were adjusted to the standard values using the procedures of Reid *et al.* (1962).

The donor animals were rumen - fistulated Mpwapwa steers maintained on a good quality Rhodes grass hay with no concentrates.

3.4 The legume N contribution to the grass/legume mixed sward

The total N yields of the mixed swards *Brachiaria/siratro* and *Brachiaria/centro*) and those of *B. brizantha* alone receiving 0, 100 and 200 kg N/ha were calculated from the DM yield (kg DM/ha) multiplied by percent N of the sample, and expressed as kg N/ha. The legume N contributions were estimated using two methods (i) to relate the N yield of *B. brizantha* without fertilizer N application to the total grass/legume mixture N yield, and (ii) graphically, by extrapolating from the fertilizer N rate - grass yield response line as shown in Figure 3.

3.5 Statistical analysis

The experimental design was a 2 x 5 factorial in four randomized blocks. The factors were two N sources, that is, fertilizer N at three levels (0, 100 and 200 kg/ha) and legume N [two legume species were used (siratro and centro)] and two stages of growth (42 and 70 days). The experimental field layout is shown in Appendix 2.

The data on DM, CP and DDM, percent ash, CP, NDF, ADF and DMD were subjected to the analysis of variance for a randomized complete block design (Appendix 3). The statistical model adopted was as shown below :-

$$Y_{ijk} = \mu + \tau_i + \beta_j + (\tau\beta)_{ij} + \epsilon_{ijk}$$

where :

Y_{ijk} = value of a single observation from the i^{th} N source, j^{th} stage of growth and k^{th} replication

μ = overall mean effect

τ_i = effect of the i^{th} N source $i = 1, 2, \dots, 5$

β_j = effect of the j^{th} stage of growth $j = 1, 2$

$(\tau\beta)_{ij}$ = effect of the interaction between the i^{th} N source and the j^{th} stage of growth

ϵ = random error component

The treatment means were compared using the Duncan's New Multiple Range and t-tests as described by Montgomery (1984). Similarly, simple correlation and regression analyses between % DMD and other chemical constituents were performed according to Montgomery (1984).

4. RESULTS

4.1 Weather conditions during the experimental period

Meteorological data for a 17-year period (1971 - 1987) and for the experimental period (October 1987 - June 1988) are presented in Table 9.

4.1.1 Rainfall

The total rainfall for the 1987/1988 season was below the expected total. The 1987/1988 short rains (November - January) amounted to only 57% of the corresponding period of the 17 year total. The long rains (March - May) were also lower during the experimental period compared with the expected total for the corresponding period. The rainfall in April and May was much lower than expected (99.8 mm compared with 282.3 mm) (Table 9).

4.1.2 Temperature

The mean monthly minimum and maximum temperatures during the experimental period were close to those of the corresponding period of the 17-year mean. The mean temperature for the experimental period was close to the 17 - year mean, (26.22°C compared with 24.56°C, respectively).

4.2 Soils

As shown in Table 10, both available P and total N contents were higher at the end of the experiment (June, 1988) than those in the

Table 9 : Mean monthly rainfall and temperatures (minimum and maximum) for a 17-year period (1971-1987) and for the experimental period (October, 1987 to June 1988)

Month	Temperature (mm)		Temperature (°C)			
	1971-1987	Exp. period	1971 - 1987		Exp. period	
			Min.	Max.	Min.	Max.
January	96.4	93.7	19.7	31.4	22.3	33.7
February	89.2	33.7	19.5	32.1	22.2	33.0
March	120.4	191.9	19.5	31.6	21.8	32.4
April	187.0	87.1	19.3	29.6	21.3	30.5
May	95.3	12.7	17.6	28.4	18.5	29.7
June	19.5	44.8	14.7	27.6	18.5	28.7
July	15.0		15.1	27.5		
August	7.1		14.4	28.2		
September	8.7		15.6	29.8		
October	33.0		17.1	31.5		
November	71.2		18.7	32.1		
December	111.4		19.9	31.8		
Total/mean	854.2	463.9	17.6	30.1	20.8	31.3

Source: Sokoine University of Agriculture Meteorological Station

Table 10 : Chemical analysis fo surface soil (0 - 15 cm) samples from
the experimental site*

Sample	pH	Organic carbon (%)	Total nitrogen (%)	Available nutrients (m.e./100 g soil)			
				P	Ca	Mg	K
I	6.3	1.70	0.070	6.31	5.75	4.89	1.03
II	6.1	1.78	0.117	9.10	-	-	1.07

* Analysis done at the Soil Science Department, Sokoine University of
Agriculture

Key: I - October, 1987 sample

II - June, 1988 sample

sample taken prior to the experiment (October, 1987). Available P increased by 44% while total N content in the soil increased by more than 67% (0.07 to 0.117%). The soil pH and organic carbon contents were not affected by the experimental treatments

4.3 Dry matter content (%) in the herbage

Table 11 shows the effects of stage of growth and fertilizer N rate or legume species on the DM content of *B. brizantha* herbage.

The mean DM content of *B. brizantha* was not affected ($P > 0.05$) by advancing stage of growth from 42 to 70 days. Similarly, the mean DM content of the grass/legume mixtures was not affected by advancing stage of growth (from 26.81 to 27.19%). However, the mean DM content of the legume species in the mixture increased from 28.25 to 30.50% with advancing stage of growth.

On average, fertilizer N rate of legume species (siratro or centro) had no significant ($P > 0.05$) effect on the DM content of *B. brizantha* herbage. Overall, the centro component in the mixture had a higher DM content than the siratro component (34.75% compared to 24.00%, respectively). Similarly, the overall mean DM content of the *Brachiaria*/centro mixture was higher than that of *Brachiaria*/siratro mixture. At 42 days, *Brachiaria*/centro had a higher DM content (29.63%) than *Brachiaria*/siratro (24.14%), whereas, at 70 days, the two grass/legume mixtures had similar DM contents.

Table 11 : Effects of stages of growth and fertilizer N rate or legume species on the

DM content of B. brizantha herbage

Fertilizer N rate/ legume spp.	Stage of growth						Means ***		
	42 days			70 days					
	Grass	Legume	Mean	Grass	Legume	Mean	Grass	Legume	Mean
0	25.50 ^{ab*}			27.00 ^{ac}			26.26 ^{AB}		
100	27.75 ^{ab}			26.25 ^{ac}			27.00 ^{AB}		
200	23.75 ^a			24.25 ^{abc}			24.00 ^B		
<u>Brachiaria/siratro</u>	24.75 ^{ab}	21.50 ^d	24.14 ^a	26.50 ^C	26.50 ^{ac}	26.50 ^C	25.63 ^B	24.00 ^A	24.80 ^A
<u>Brachiaria/centro</u>	29.00 ^b	35.00 ^e	29.63 ^{bc}	27.00 ^C	34.50 ^e	27.89 ^{ac}	28.00 ^A	34.75 ^B	31.38 ^B
Mean **	26.15 ^A	28.25 ^B	26.89 ^D	26.20 ^A	30.50 ^C	27.19 ^D	26.18 ^{AB}	29.38 ^C	28.10 ^C

* - Means within the same row or column with the same superscript(s) are not significantly different ($P > 0.05$) from one another.

** - The overall stage of growth means were compared using the t-test (columns 1 & 4; 2 & 5 and 3 & 6).

*** - The overall fertilizer N or legume species means were compared using the Duncan's New Multiple Range and t-tests (columns 7, 8 and 9) .

The DM content of *B. brizantha* in the *Brachiaria*/siratro treatment increased by 7% (from 24.75 to 26.50%), while that in *Brachiaria*/centro decreased by 7%, with advancing stage of growth from 42 to 70 days. The DM content of the siratro component in the mixture increased by 23% (from 21.50 to 26.50%), while that of centro was not affected by advancing stage of growth. The DM content of *Brachiaria*/siratro mixture increased by nearly 10% (from 24.14 to 26.49%) while that of *Brachiaria*/centro mixture was not significantly affected by advancing stage of growth.

Increasing fertilizer N rate from 0 to 100 kg N/ha had no significant effect on the DM content of *B. brizantha* at 42 days. However, increasing the fertilizer N rate from 0 to 200 kg N/ha caused a slight but non-significant decrease in the DM content of *B. brizantha* (from 25.50 to 23.75%). At 70 days, increasing the fertilizer N rate from 0 to 100 kg N/ha did not cause any significant effect on the DM content of *B. brizantha*. Similarly, increasing the fertilizer N rate from 0 to 200 kg N/ha caused a non-significant effect on the DM content of the grass.

4.4 Crude protein content (%) in herbage

Table 12 shows the effects of stage of growth and fertilizer N rate on legume species on the CP content of *B. brizantha* herbage.

The mean CP content of *B. brizantha* decreased ($P < 0.05$) with advancing stage of growth from 8.70% at 42 days to 6.95% at 70 days.

Table 12 : Effect of stage of growth and fertilizer N rate or legume species on the CP content of B. brizantha herbage

[illegible]

* - Means within the same row and column with the same superscript(s) are not significantly different ($P > 0.05$) from one another.

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** - The overall stage of growth means were compared using the t-test (columns 1 & 4, 2 & 5 and 3 & 6).
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*** - The overall fertilizer N or legume species means were compared using Duncan's New Multiple Range and t-tests (column 7, 8 and 9).

Similarly, there was a significant decrease ($P < 0.001$) in the CP content of both the legume components and that of the mixture with advancing stage of growth. The rate of decline in the CP content of *B. brizantha* was lower in the grass/legume mixture (17%) than in the N fertilized grass swards (25%).

The mean CP content of *B. brizantha* increased ($P < 0.001$) with increasing fertilizer N rate. On average, increasing fertilizer N rate from 0 to 100 kg N/ha increased the CP content by 16%, whereas, increasing the N rate from 0 to 200 kg N/ha caused an increase of 38% in the CP content of the grass.

Siratro increased ($P < 0.05$) the CP content of *B. brizantha*, whereas, centro had no significant effect on the CP content of the grass.

On average, the mean CP content of siratro and centro were significantly different ($P < 0.05$). (14.9% for siratro and 16.02% for centro (*Brachiaria*/siratro mixture had higher CP content than *Brachiaria*/centro mixture (8.99% compared to 7.68%).

The mean CP content of *B. brizantha* receiving 100 and 200 g N/ha, in the *Brachiaria*/siratro and *Brachiaria*/centro mixture decreased by 25, 25, 16 and 19%, respectively, with advancing stage of growth. The CP content of *B. brizantha* without fertilizer N was not affected by advancing stage of growth.

The mean CP content of the siratro and centro components in the grass/legume mixture declined by 16 and 18%, respectively. Similarly, the CP content of *Brachiaria*/siratro and *Brachiaria*/centro mixtures declined by 15 and 18%, respectively, with advancing stage of growth.

Increasing the fertilizer N rate from 0 to 100 kg N/ha increased ($P < 0.001$) the CP content of the grass by 24% at 42 days, while, increasing the N rate from 0 to kg N/ha caused an increase of 47%. At 70 days, increasing the N rate from 0 to 200 kg N/ha increased the CP content by only 27%, while, there was no significant change with the 100 kg N/ha rate.

Legume species had no significant effect on the CP content *B. brizantha* either at 42 or 70 days.

The CP content of the siratro and centro components in the grass/legume mixture were similar at both 42 and 70 days of growth. The CP content of the *Brachiaria*/siratro mixture was consistently higher than that of the *Brachiaria*/centro mixture at both 42 and 70 days (Table 12).

4.5 Dry matter yield (kg/ha)

Table 13 shows the effects of stage of growth and fertilizer N rate or legume species on the DM yield of *B. brizantha* herbage.

The mean DM yield of *B. brizantha* increased ($P < 0.001$) with advancing stage of growth by 29% (from 3643 to 4686 kg DM/ha) from 42

Table 13 : Effects of stage of growth and fertilizer N rate or legume species on the DM yield of B. brizantha herbage

Fertilizer N rate/ legume spp.	Stage of growth								
	42 days			70 days			Total***		
	Grass	Legume	Total	Grass	Legume	Total	Grass	Legume	Total
0	2646 ^{d*}			3292 ^d			5938 ^C		
100	4031 ^{bcd}			5659 ^{ab}			9727 ^B		
200	5307 ^{bc}			7333 ^a			12640 ^A		
<u>Brachiaria/siratro</u>	3492 ^{cd}	789 ^e	4281 ^c	4174 ^{bcd}	1181 ^f	5355 ^c	7666 ^{BC}	1970 ^A	9636 ^A
<u>Brachiaria/centro</u>	2739 ^d	484 ^e	3223 ^{cd}	2937 ^d	438 ^e	3375 ^{cd}	5676 ^C	922 ^B	6598 ^B
** Mean	3642 ^A	637 ^C	3752 ^D	4686 ^B	810 ^C	4365 ^D	8327 ^B	1447 ^B	8117 ^{AB}

* - Means within the same row or column with the same superscript(s) are not significantly different ($P > 0.05$) from one another.

** - The overall stage of growth means were compared using the t-test (column 1 & 4; 2 & 5 and 3 & 6).

*** - The overall fertilizer N rate or legume species means were compared using Duncan's New Multiple Range and t-tests (columns 7, 8 and 9).

to 70 days. The DM yield of the legume species in the mixtures was not affected ($P > 0.05$) by advancing stage of growth from 42 to 70 days. Similarly, the DM yield of the grass/legume mixtures was not affected by advancing stage of growth.

The DM yield of *B. brizantha* increased ($P < 0.001$) with increasing fertilizer N rate from 0 to 200 kg N/ha. Increasing fertilizer N rate from 0 to 100 kg N/ha, caused an increase of 63% in the total DM yield of *B. brizantha* (from 5938 to 9727 kg DM/ha). Increasing the N rate from 0 to 200 kg N/ha caused a 113% increase in the total DM yield of the grass (from 5938 to 12640 kg DM/ha). Legume species had no significant ($P > 0.05$) effect on the DM yield of *B. brizantha*.

On average, the DM yield of the siratro component in the mixture was higher than that of centro (1970 kg DM/ha compared to 922 kg DM/ha). Similarly, the *Brachiaria*/siratro mixture produced significantly higher DM yield than the *Brachiaria*/centro mixture (9636 kg DM/ha compared to 6598 kg DM/ha). Similarly, the *Brachiaria*/siratro produced 1.6 times the DM yield of *B. brizantha* without fertilizer N.

The DM yield of *B. brizantha* receiving 200 kg N/ha increased by 38% (from 5307 to 7333 kg DM/ha) with advancing stage of growth from 42 to 70 days. However, *B. brizantha* without fertilizer N, *B. brizantha* receiving 100 kg N/ha, *B. brizantha* in the

Brachiaria/siratro and in the *Brachiaria*/centro mixtures was not affected ($P > 0.05$) by advancing stage of growth from 42 to 70 days.

Increasing the fertilizer N rate from 0 to 200 kg N/ha caused a 101% increase in the DM yield of *B. brizantha* (from 2646 to 5307 kg DM/ha) at 42 days. At 70 days, increasing the fertilizer N rate from 0 to 100 kg N/ha caused a 73% increase, while, increasing the N rate from 0 to 200 kg N/ha caused a 123% increase in the DM yield of *B. brizantha* (Figure 1). Legume species had no significant ($P > 0.05$) effect on the DM yield of *B. brizantha* at either 42 or 70 days.

The DM yield of the siratro and centro components in the mixtures were similar at 42 days, while at 70 days, siratro produced higher DM yield than centro (1181 kg DM/ha compared to 438 kg DM/ha). The DM yields of the *Brachiaria*/siratro and the *Brachiaria*/centro mixtures were similar at 42 and 70 days of growth.

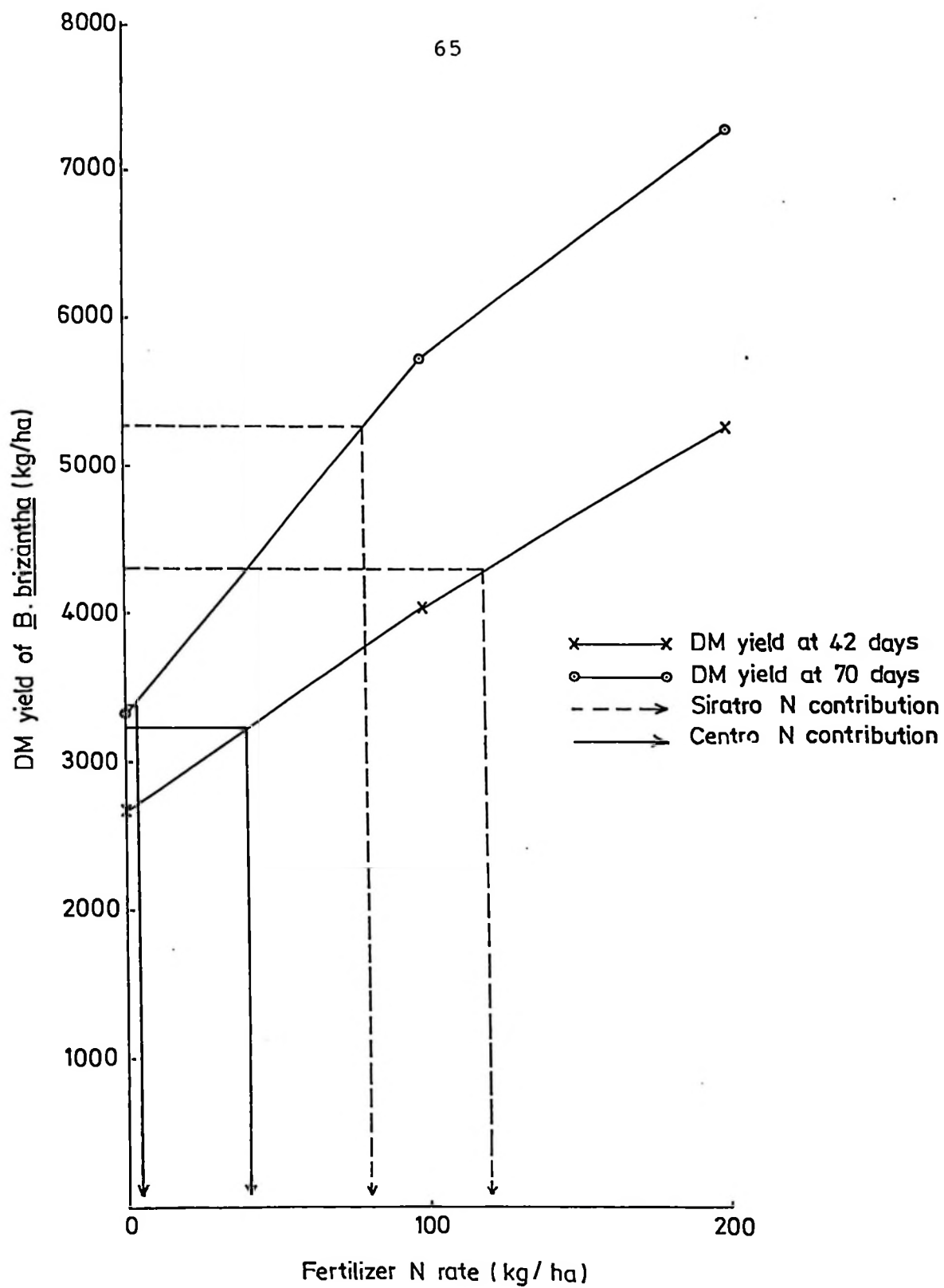


Fig. 1. Effects of stage of growth and fertilizer N rate/legume species on DM yield of *B. brizantha*.

4.6 Crude protein yield (kg/ha)

Table 14 shows the effects of stage of growth and fertilizer N rate or legume species on the CP yield of *B. brizantha* herbage.

The mean CP yields of *B. brizantha*, legume species in the grass/legume mixture and the grass/legume mixture were not affected ($P > 0.05$) by advancing stage of growth from 42 to 70 days.

The CP yield of *B. brizantha* increased ($P < 0.001$) with increasing fertilizer N rate from 0 to 200 kg N/ha. Increasing fertilizer N rate from 0 to 100 kg N/ha, caused an increase of 91% in the total CP yield of *B. brizantha* (from 418 to 757 kg CP/ha). Increasing the N rate from 0 to 200 kg N/ha caused a 185% increase in the total CP yield yield of the grass (from 418 to 1193 kg CP/ha). Legume species had no significant ($P > 0.05$) effect on the CP yield of *B. brizantha*.

On average, the CP yield of the siratro component in the mixture was higher than that of centro (293 kg CP/ha compared to 159 kg CP/ha). *Brachiaria*/siratro mixture produced a significantly ($P < 0.05$) higher CP yield than *Brachiaria*/centro mixture (874 kg CP/ha compared to 534 kg CP/has). Similarly, the *Brachiaria*/siratro mixture produced about 2.1 times the CP yield of *B. brizantha*, without fertilizer N.

Table 14 : Effects of stage of growth and fertilizer N rate or legume species on the CP yield of B. brizantha herbage .

Fertilizer N rate/ legume spp.	Stage of growth					
	42 days			70 days		
	Grass	Legume	Total	Grass	Legume	Total ***
0	199 ^a *			219 ^a		418 ^C
100	376 ^{ab}			421 ^b		757 ^B
200	596 ^b			597 ^b		1193 ^A
<u>Brachiaria/siratro</u>	289 ^a	130 ^d	419 ^b	292 ^d	163 ^d	455 ^b
						581 ^C
						293 ^A
						874 ^A
<u>Brachiaria/centro</u>	199 ^a	95 ^f	294 ^e	176 ^a	64 ^f	240 ^e
						375 ^C
						159 ^B
						534 ^B
Mean **	332 ^A	113 ^B	357 ^C	341 ^A	114 ^B	348 ^C
						673 ^{ABC}
						226 ^{AB}
						704 ^{AB}

* - Means within the same row or column with the same superscript(s) are not significantly different ($P > 0.05$) from one another.

** - The overall stage of growth means were compared using the t-test (columns 1 & 4; 2 & 5 and 3 & 6).

*** - The overall fertilizer N rate or legume species means were compared using Duncan's New Multiple Range and t-tests (column 7, 8 and 9).

The individual treatments (*B. brizantha* at 0, 100 and 200 kg N/ha, *Brachiaria*/siratro and *Brachiaria*/centro) were not significantly ($P > 0.05$) affected by advancing stage of growth from 42 to 70 days. Similarly, the CP yield of the legume species (siratro or centro) and that of the *Brachiaria*/siratro or *Brachiaria*/centro mixtures was not significantly ($P > 0.05$) affected by advancing stage of growth from 42 to 70 days.

Increasing the fertilizer N rate from 0 to 200 kg N/ha caused a 199% increase in the CP yield of *B. brizantha* at 42 days (from 199 to 596 kg CP/ha). At 70 days, increasing the fertilizer N rate from 0 to 100 kg N/ha caused a 92% increase in the CP yield of the grass, while, increasing the N rate from 0 to 200 kg N/ha caused a 173% increase (Figure 2). Legume species had no significant ($P > 0.05$) effect on the CP yield of the grass at either 42 or 70 days.

The CP yield of siratro was consistently higher than that of centro at 42 and 70 days. Similarly, the CP yield of the *Brachiaria*/siratro mixture was consistently higher than that of the *Brachiaria*/centro mixture at 42 and 70 days growth.

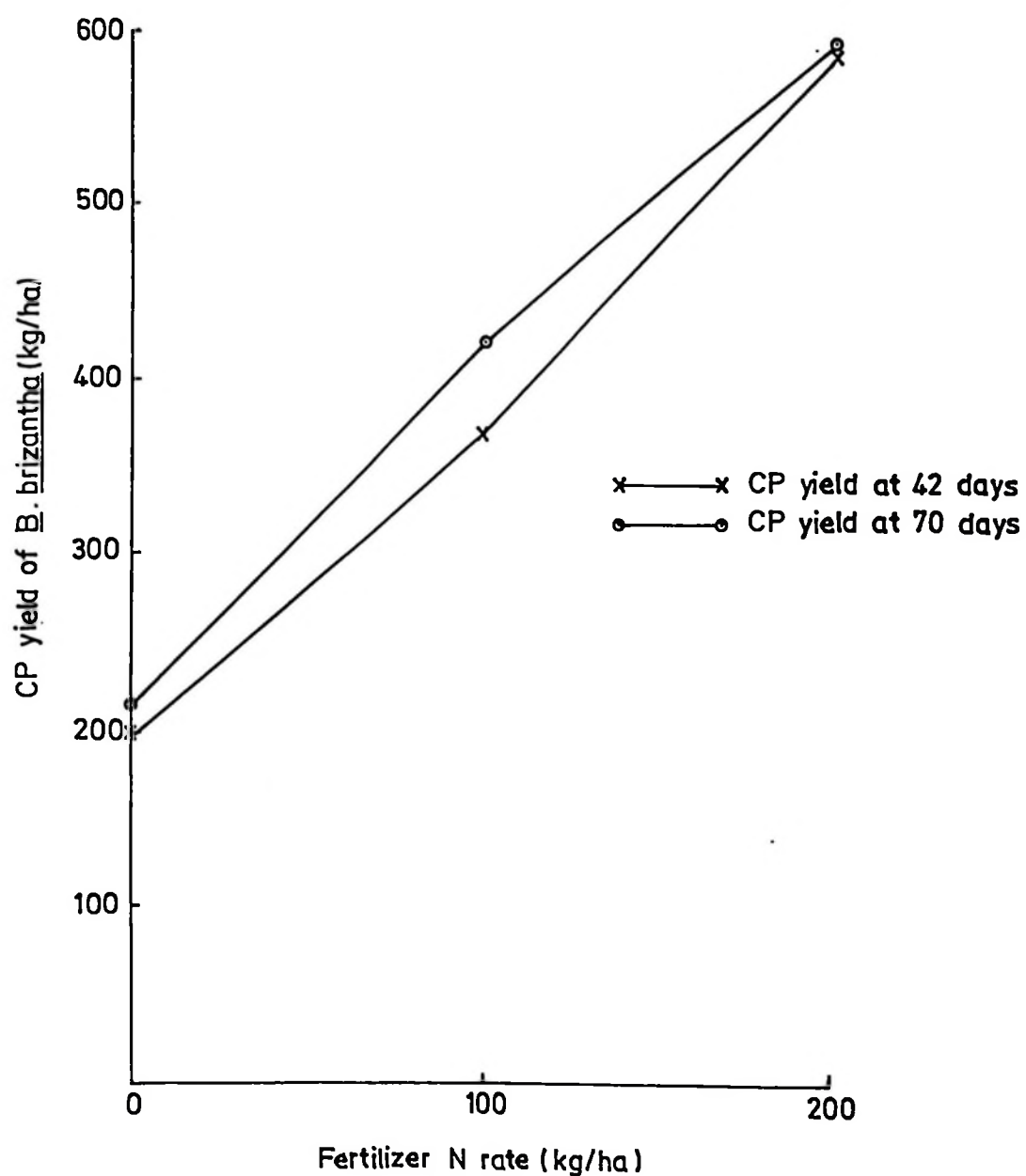


Fig. 2. Effects of stage of growth and fertilizer N rate/legume species on the CP yield of *B. brizantha*.

4.7 Ash content (%) in herbage

Table 15 shows the effects of stage of growth and fertilizer N rate or legume species on the ash content of *B. brizantha* herbage.

The mean ash content of *B. brizantha*, legume species in the grass/ legume mixtures and the grass/legume mixtures decreased ($P < 0.001$) with advancing stage of growth from 42 to 70 days. The rates of decline in the ash content were 7.6, 18.6 and 4.3%, respectively.

The ash content of *B. brizantha* decreased ($P < 0.01$) with increasing fertilizer N rate from 0 to 200 kg N/ha. Increasing the fertilizer N rate from 0 to 100 kg N/ha, caused a slight, non-significant decline in the ash content of the grass (from 9.02 to 8.55%). However, increasing the fertilizer N rate from 0 to 200 kg N/ha caused a significant ($P < 0.01$) decline in the ash content of the grass from 9.02 to 8.27%. Legume species had no significant effect on the ash content of the grass (Table 15).

On average, the ash content of siratro and centro in the grass/legume mixtures were similar. Similarly, the ash content of the *Brachiaria*/siratro and *Brachiaria*/centro mixtures were not significantly different from each other.

The ash content of *B. brizantha* receiving 100 and 200 kg N/ha declined by 17 and 11.6%, respectively, with advancing stage of growth from 42 to 70 days. However, in *B. brizantha* without fertilizer N,

Table 15 : Effects of stage of growth and fertilizer N rate or legume species on the ash content of B. brizantha herbage.

Fertilizer N rate/ legume spp.	Stage of growth							
	42 days				70 days			
	Grass	Legume	Mean		Grass	Legume	Mean	Mean ***
0	9.25 ^{ab*}				8.78 ^{ac}			9.02 ^{AB}
100	9.35 ^{ab}				7.75 ^c			8.55 ^{BC}
200	8.80 ^a				7.76 ^c			8.27 ^c
<u>Brachiaria/siratro</u>	9.90 ^b	8.52 ^d	9.64 ^b		9.03 ^{bd}	7.00 ^c	8.63 ^a	9.47 ^{AB}
<u>Brachiaria/centro</u>	9.00 ^{abd}	8.27 ^d	8.92 ^b		9.43 ^b	6.68 ^c	9.12 ^{ab}	9.22 ^{AB}
Mean **	9.26 ^A	8.40 ^C	9.28 ^E		8.55 ^B	6.84 ^D	8.88 ^F	8.93 ^{ABC}
								7.62 ^A
								9.08 ^B

* - Means within the same row or column with the same superscript(s) are not significantly different (P > 0.05) from one another.

** - The overall stage of growth means were compared using the t-test (column 1 & 4; 2 & 5 and 3 & 6).

*** - The overall fertilizer N rate or legume species means were compared using Duncan's New Multiple Range and t-tests (columns 7, 8 and 9).

Brachiaria/siratro and *Brachiaria/centro* treatments, the ash content of the grass was not significantly affected by advancing stage of growth.

Increasing the fertilizer N rate from 0 to 200 kg N/ha had no significant ($P > 0.05$) effect on the ash content of the grass either at 42 or 70 days growth. Similarly, the legume species had no significant ($P > 0.05$) effect on the ash content of the grass either at 42 or 70 days.

The ash content of siratro and centro in the grass/legume mixtures did not differ significantly ($P > 0.05$) either at 42 or 70 days. Similarly, the ash content of *Brachiaria/siratro* and *Brachiaria/centro* mixture were similar at both 42 and 70 days.

4.8 Neutral-detergent fiber (%)

Table 16 shows the effects of stage of growth and fertilizer N rate or legume species on the NDF content of *B. brizantha* herbage.

The mean NDF content of *B. brizantha*, legume species in the mixtures and the grass/legume mixtures increased ($P < 0.01$) by 5.9, 10.2 and 5.4%, respectively, with advancing stage of growth from 42 to 70 days.

There was no significant ($P > 0.05$) fertilizer N rate or legume species effect on the NDF content of the grass. On average, the NDF content of siratro and centro in the grass/legume mixtures were

similar (Table 16). Similarly, the mean NDF content of the *Brachiaria*/siratro and *Brachiaria*/centro mixtures were not significantly different from each other (66.18% compared to 65.62%).

The NDF content of *B. brizantha* receiving 100 kg N/ha and *B. brizantha* in the *Brachiaria*/siratro treatment increased ($P < 0.001$) by 10 and 9.6%, respectively, with advancing stage of growth from 42 to 70 days. However, the NDF content of *B. brizantha* without fertilizer N, that receiving 200 kg N/ha and that in the *Brachiaria*/centro mixture did not change significantly ($P > 0.05$) with advancing stage of growth from 42 to 70 days.

Increasing the fertilizer N rate from 0 to 200 kg N/ha had no significant ($P > 0.05$) effect on the NDF content of the grass either at 42 or 70 days. Similarly, the legume species had no significant ($P > 0.05$) effect on the NDF content of the grass either at 42 or 70 days.

The NDF content of siratro and centro in the grass/legume mixtures did not differ significantly from each other either at 42 or 70 days. Similarly, the NDF contents of *Brachiaria*/siratro and *Brachiaria*/centro mixtures were similar at both 42 and 70 days (Table 16).

Table 16 : Effect of stage of growth and fertilizer N rate of legume species on the NDF (%) of B. brizantha herbage

Fertilizer N rate/ legume spp.	stage of growth					
	42 days			70 days		
	Grass	Legume	Mean	Grass	Legume	Mean
0	65.33 ^{a*}			66.82 ^A		66.08 ^A
100	62.18 ^a			68.42 ^b		65.30 ^A
200	66.02 ^{ab}			69.10 ^b		67.56 ^A
<u>Brachiaria/siratro</u>	64.55 ^a	55.36 ^C	63.41 ^a	70.77 ^{bd}	61.40 ^a	68.94 ^b
<u>Brachiaria/centro</u>	65.27 ^{ad}	58.18 ^C	65.53 ^a	67.30 ^d	63.76 ^a	66.89 ^b
Mean **	64.67 ^A	56.77 ^C	64.47 ^E	68.48 ^B	62.58 ^D	67.92 ^F
				66.58 ^A	59.68 ^A	65.90 ^A

* - Means within the same row or column with the same superscript(s) are not significantly' (P > 0.05) different from one another.

** - The overall stage of growth means were compared using the t-test (column 1 & 4; 2 & 5 and 3 & 6) .

*** - The overall fertilizer N rate or legume species means were compared using Duncan's New Multiple Range and t-tests (columns 7, 8, 9) .

4.9 Acid-detergent fiber (%)

Table 17 shows the effects of stage of growth and fertilizer N rate or legume species on the ADF content of *B. brizantha* herbage.

The mean ADF content of *B. brizantha* increased ($P < 0.001$) by 12% (from 36.19 to 40.59%) with advancing stage of growth from 42 to 70 days. However, the ADF content of the legume species in the mixtures was not affected ($P > 0.05$) by advancing stage of growth, whereas, that of the grass/legume mixtures increased ($P < 0.001$) by 18% (from 38.24 to 45.14%).

There was no significant ($P > 0.05$) fertilizer N rate or legume species effect on the ADF content of the grass.

On average, the ADF content of siratro and centro in the grass/legume mixtures and that of the *Brachiaria*/siratro and *Brachiaria*/centro mixtures were similar (Table 17).

The ADF content of *B. brizantha* receiving 100 and 200 kg N/ha and that in the *Brachiaria*/siratro mixture increased ($P < 0.001$) by 17, 16 and 15%, respectively, with advancing stage of growth from 42 to 70 days. The ADF contents of the *B. brizantha* without fertilizer N and of the *Brachiaria*/centro mixture did not change significantly ($P > 0.05$) with advancing stage of growth from 42 to 70 days.

Table 17 : Effects of stage of growth and fertilizer N rate or legume species on the ADF (%) of B. brizantha herbage

Fertilizer N rate/ legume spp.	Stage of growth							
	42 days			70 days			Mean ***	
	Grass	Legume	Mean	Grass	Legume	Mean	Grass	Legume
0	36.05 ^{a*}			38.07 ^{ab}			37.06 ^B	
100	34.63 ^a			40.63 ^b			87.63 ^B	
200	35.88 ^a			41.53 ^b			38.71 ^{AB}	
<u>Brachiaria/siratro</u>	37.35 ^a	43.83 ^C	38.57 ^a	42.83 ^{bc}	45.54 ^C	44.19 ^C	40.09 ^{AB}	44.65 ^C
<u>Brachiaria/centro</u>	36.98 ^a	45.92 ^C	37.91 ^a	39.78 ^{ab}	45.82 ^C	42.38 ^{bc}	38.36 ^{AB}	45.87 ^C
Mean **	36.19 ^A	44.89 ^C	38.24 ^D	40.59 ^B	45.68 ^C	45.14 ^E	38.13 ^{AB}	45.29 ^C
							41.69 ^C	

* - Means within the same row or column with the same superscript(s) are not significantly different from one another. (P > 0.05)

** - The overall stage of growth means were compared using the t-test (columns 1 & 4; 2 & 5 and 3 & 6).

*** - The overall fertilizer N rate or legume species means were compared using Duncan's New Multiple Range and t-tests (columns 7, 8 and 9).

Increasing fertilizer N rate from 0 to 200 kg N/ha had no significant ($P > 0.05$) effect on the ADF content of the grass either at 42 or 70 days. Similarly, the legume species had no significant ($P > 0.05$) effect on the ADF content of the grass either at 42 or 70 days.

The ADF contents of siratro and centro in the grass/legume mixtures were similar at both 42 and 70 days. The ADF contents of the *Brachiaria*/siratro and *Brachiaria*/centro mixtures were also similar at both 42 and 70 days (Table 17).

4.10 *In vitro* dry matter digestibility (%)

Table 18 shows the effects of stage of growth and fertilizer N rate or legume species on the IVDM of *B. brizantha* herbage.

The mean IVDM of *B. brizantha* declined ($P < 0.001$) by 10.6% (from 75.34 to 67.35%) with advancing stage of growth from 42 to 70

Table 18 : Effects of stage of growth and fertilizer N rate or legume species on the IVDMD (%) of B. brizantha herbage .

Fertilizer N rate/ legume spp.	Stage of growth					
	42 days			70 days		
	Grass	Legume	Mean	Grass	Legume	Mean
0	74.95 ^{a*}			69.92 ^{ab}		72.44 ^A
100	77.07 ^a			67.03 ^b		72.05 ^A
200	76.13 ^a			64.03 ^b		70.08 ^A
<u>Brachiaria/siratro</u>	73.75 ^a	74.25 ^a	74.00 ^a	65.25 ^b	67.00 ^b	65.59 ^b
<u>Brachiaria/centro</u>	75.00 ^a	56.25 ^d	73.04 ^a	70.50 ^{ab}	52.25 ^d	68.37 ^b
Mean **	75.34 ^A	65.25 ^C	73.52 ^D	67.35 ^B	59.63 ^C	66.98 ^F
						71.36 ^{AB}
						62.44 ^C
						66.78 ^{AB}

* - Means within the same row or column with the same superscript(s) are not significantly (P > 0.05) different from one another.

** - The overall stage of growth means were compared using the t-test (column 1 & 4; 2 & 5 and 3 & 6) .

*** - The overall fertilizer N rate or legume species means were compared using Duncan's New Multiple Range and t-tests (columns 7, 8 and 9) .

days. However, the IVDMD of the legume species in the grass/legume mixtures was not significantly affected by advancing stage of growth. The mean IVDMD of the grass/legume mixtures declined ($P < 0.001$) by about 9% with advancing stage of growth (from 73.52 to 66.98%).

There was no significant ($P > 0.05$) fertilizer N rate or legume species effect on the IVDMD of the grass.

On average, the IVDMD of the siratro component in the grass/legume mixture was higher than that of the centro component (70.62% compared to 54.25%). Similarly, the percentage IVDMD of the *Brachiaria*/siratro mixture was higher than that of the *Brachiaria*/centro mixture (70.06% compared to 63.50%).

The IVDMD of *B. brizantha* receiving 100 and 200 kg N/ha and that in the *Brachiaria*/siratro mixture declined ($P < 0.001$) by 13, 16 and 11.5% with advancing stage of growth from 42 to 70 days.

Increasing fertilizer N rate from 0 to 200 kg N/ha had no significant ($P > 0.05$) effect on the IVDMD of the grass either at 42 or 70 days. Similarly, legume species had no significant effect on the IVDMD of the grass either at 42 or 70 days.

The IVDMD of siratro was consistently higher than that of centro at both 42 and 70 days. However, the IVDMD of the *Brachiaria*/siratro and *Brachiaria*/centro mixtures was similar at both 42 and 70 days

(Table 18).

4.11 Digestible dry matter yield (kg/ha)

Table 19 shows the effects of stage of growth and fertilizer N rate or legume species on the DDM yield of *B. brizantha* herbage.

The mean DDM yields of *B. brizantha*, the legume species in the mixtures as well as the grass/legume mixtures were not significantly affected by advancing stage of growth.

The DDM yield of *B. brizantha* increased ($P < 0.001$) with increasing fertilizer N rate from 0 to 200 kg N/ha. Increasing fertilizer N rate from 0 to 100 kg N/ha caused an increase of 63% in the total DDM yield (from 4243 to 6905 kg DDM/ha). Similarly, increasing the N rate from 0 to 200 kg N/ha caused 84% increase in the total DDM yield of the grass (from 4243 to 7794 kg DDM/ha). Legume species had no significant ($P > 0.05$) effect on the DDM yield of *B. brizantha*.

On average, the DDM yield of the siratro component in the grass/legume mixture was higher than that of centro (1372 kg DDM/ha compared to 502 kg DDM/ha). Similarly, the *Brachiaria*/siratro mixture produced a significantly higher DDM yield than the *Brachiaria*/centro mixture (6689 kg DDM/ha compared to 4638 kg DDM/ha). Similarly, the *Brachiaria*/siratro mixture produced 1.4 times the DDM yield of *B. brizantha* without fertilizer N.

Table 19 : Effects of stage of growth and fertilizer N rate or legume species on the DDM
yield of B. brizantha ,herbage

Fertilizer N rate/ legume spp.	Stage of growth								
	42 days			70 days			Total ***		
	Grass	Legume	Total	Grass	Legume	Total	Grass	Legume	Total
0	1982 ^{b*}			2261 ^b			4243 ^B		
100	3102 ^a			3803 ^a			6905 ^A		
200	3262 ^a			4532 ^a			7794 ^A		
<u>Brachiaria/siratro</u>	2560 ^b	582 ^d	3142 ^a	2757 ^b	790 ^C	3547 ^a	5317 ^B	1372 ^A	6689 ^A
<u>Brachiaria/centro</u>	2053 ^b	273 ^{Cf}	2326 ^b	2083 ^b	229 ^f	2312 ^b	4136 ^B	502 ^B	4638 ^B
Mean **	2592 ^A	428 ^C	2734 ^D	3087 ^A	510 ^C	2930 ^D	5730 ^B	937 ^E	5664 ^{AB}

* - Means within the same row or column superscript(s) are not significantly (P > 0.05) different from one another .

** - The overall stage of growth means were compared using the t-tests (columns 1 & 4, 2 & 5 and 3 & 6) .

*** - The overall fertilizer N rate or legume species totals were compared using Duncan's New Multiple Range and t-tests (Totals within a column with a superscript in common are not significant (P > 0.05) different from one another (columns 7, 8 and 9) .

The individual treatments, that is, *B. brizantha* receiving 0, 100 and 200 kg N/ha, the *Brachiaria*/siratro and *Brachiaria*/centro mixtures were not affected by advancing stage of growth from 42 to 70 days. The DDM yield of the siratro component in the mixture increased by 36% (from 582 to 790 kg DDM/ha) while, the DDM yield of centro in *Brachiaria*/centro mixture did not show any significant change with advancing stage of growth from 42 to 70 days.

At 42 days, increasing fertilizer N rate from 0 to 100 and 200 kg N/ha resulted in increases of 57 and 65%, respectively, compared to the grass alone without fertilizer N. At 70 days, the corresponding increases were 68 and 100%, respectively. Legume species had no significant ($P > 0.05$) effect on the DDM yield of *B. brizantha* at either 42 or 70 days.

The DDM yield of the siratro component in the grass/legume mixture was consistently higher than that of centro. Similarly, the *Brachiaria*/siratro mixture produced higher DDM yield than the *Brachiaria*/centro mixture, both at 42 and 70 days.

4.12 Legume N contribution to the grass/legume mixture N yield

Table 20 shows the effect of stage of growth and fertilizer N rate or legume species on the N yield of *B. brizantha* and the *Brachiaria*/siratro or *Brachiaria*/centro mixtures.

From Table 20, it can be seen that the N contributed by each of the legumes (siratro or centro) in the grass/legume mixtures was calculated by subtracting the N yield of the grass without fertilizer N from the total N yield for that mixture.

The overall siratro N contribution in the mixture was four times that of centro (73 kg N/ha compared to 18 kg N/ha).

At 42 days, the siratro N contribution to the *Brachiaria*/siratro mixture was 2.3 times, while at 70 days, it was more than 12 times that of centro in the *Brachiaria*/centro mixture.

The legume N contribution to the grass/legume mixture N yield was also estimated by extrapolation from the fertilizer N rate grass N yield response lines as shown in Figure 3.

It can be seen from Figure 3, that the *Brachiaria*/siratro mixture gave N yield equivalent to *B. brizantha* receiving over 120 kg N/ha at both 42 and 70 days of growth, as shown by the broken lines. The *Brachiaria*/centro mixture on the other hand, gave N yield equivalent to *B. brizantha* receiving about 5 and 50 kg N/ha at 42 and 70 days of growth, respectively.

Table 20 : Effects of stage of growth and fertilizer N rate or legume species on the N yield of B. brizantha Brachiaria/siratro and Brachiariacentro mixtures

Fertilizer N rate/ legume species	Stage of growth					
	42 days			70 days		
	Grass	Legume	Total	Grass	Legume	Total
0	32 ^{a*}			35 ^a		67 ^C
100	60 ^{ab}			67 ^b		127 ^B
200	95 ^b			96 ^b		191 ^A
<u>Brachiaria</u> /siratro	46 ^{ad}	21 ^C	67 ^{cd}	47 ^{ad}	26 ^C	73 ^b
<u>Brachiaria</u> /centro	32 ^a	15 ^{cd}	47 ^{be}	28 ^a	10 ^d	38 ^e
Mean **	53 ^A	18 ^B	57 ^C	55 ^A	18 ^B	56 ^C
						108 ^{ABC}
						41 ^{AB}
						118 ^{AB}

* - Within the same row or column with the same superscript(s) are not significantly different (P > 0.05) from one another.

** - The overall stage of growth means were compared using the t-test (column 1 & 4; 2 & 5 & 6) ÷

*** - The overall fertilizer N rate or legume species means were compared using Duncan's New Multiple Range or t-tests (columns 7, 8 and 9).

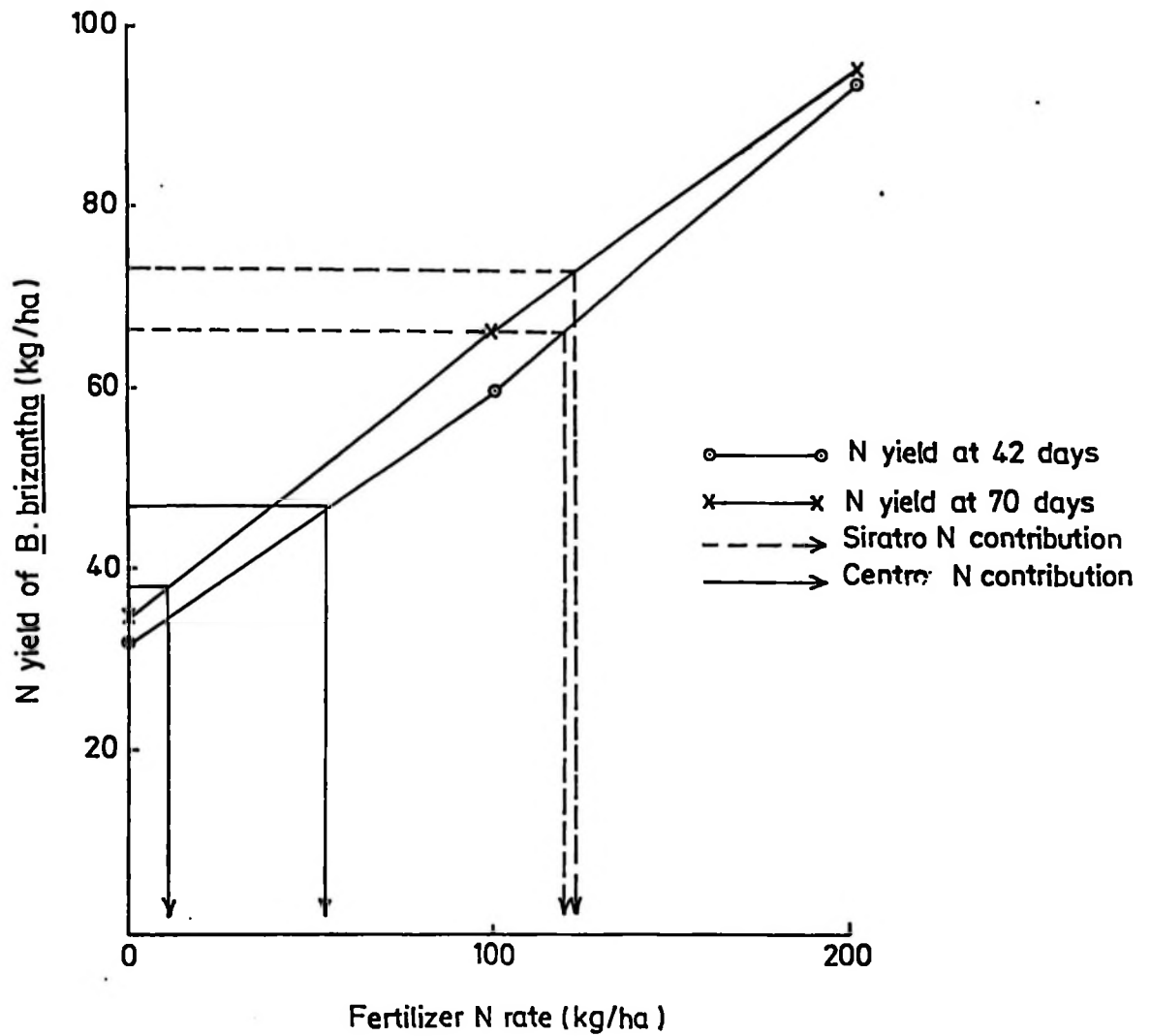


Fig. 3. Effects of stage of growth and fertilizer N rate on the N yield of *B. brizantha*.

4.13 Legume content (%) in the grass/legume mixtures

Table 21 shows the effects of stage of growth and legume species on the percentage legume content in the *Brachiaria*/siratro and *Brachiaria*/centro swards.

The mean legume content in the grass/legume mixtures was not significantly ($P > 0.05$) affected by advancing stage of growth (14.60% compared to 15.61% at 42 and 70 days, respectively).

On average, the siratro content in the *Brachiaria*/siratro mixture was higher than that of centro in *Brachiaria*/centro mixture (19.14% compared to 11.08%).

The content of siratro and centro in their respective mixtures were not affected ($P > 0.05$) by advancing stage of growth.

At 42 days, the siratro content (18.75%) was higher ($P < 0.05$) than the centro content (10.45%) in their respective grass/legume mixtures. However, 70 days, the content of siratro and centro in their respective mixtures were similar.

Table 21 : Effects of stage of growth and legume species on the legume content (%) in *Brachiaria*/siratro and *Brachiaria*/centro mixed swards

Grass/legume mixture	Stage of growth		
	42 days	70 days	Mean*
<i>Brachiaria</i> /siratro	18.75 ^a	19.53 ^a	19.14 ^a
<i>Brachiaria</i> /centro	10.45 ^b	11.68 ^{ab}	11.07 ^b
Mean :	14.60 ^a	15.61 ^{ab}	15.11

* Means within the same row or column with the same superscript(s) in common are not significantly different ($P > 0.05$) from one another

5. DISCUSSION

5.1 Dry matter (%) in the herbage

The DM content of *B. brizantha* and that of the grass/legume mixtures (*Brachiaria*/siratro and *Brachiaria*/centro) tended to increase with advancing stage of growth. The mean DM content of the legume species in the grass/legume mixtures increased significantly with advancing stage of growth (Table 11).

The increase in the DM content of *B. brizantha*, the legume species and the grass/legume mixtures, with advancing stage of growth, is in agreement with the findings reported by other workers. Butterworth (1969) reported an increase in the DM content of *B. brizantha* from 21% at 50 days to 23% at 80 days. Similarly, Mero and Kabatange (1988) observed an increase in the DM content of siratro from 24.8% at 123 days to 61.9% at 197 days.

The DM content of *B. brizantha* tended to decrease with increasing fertilizer N rate (from 26.25% at 0 to 24.00% at 200 kg N/ha). The results obtained in the present study are in agreement with the findings reported by Vicente-Chandler, Silva and Figarrella (1959) which showed a decline in the DM content of Guinea grass from 21.8% at 0 to 17.4% at 448 kg N/ha when cut every 40 days.

There was no significant difference between the DM content of *B. brizantha* alone without fertilizer N and that of the grass in the

mixtures.

Kretschmer (1966) in a study with pangola/siratro mixture in Florida, USA, observed that the DM content of pangola grass was lower when growing in association with siratro than when growing alone. He noted that the difference between the two was greatest when the contribution by siratro was greatest.

The lack of a significant decrease in the DM yield of the grass/legume mixtures in this study might have been caused by the low legume content in the mixtures (Table 21).

The observation that centro had a higher DM content than siratro is in accord with the results of Kidunda and Lwoga (1985) at SUA, Morogoro, Tanzania. They reported the DM contents of centro and siratro to be 25.15 and 20.80%, respectively, when cut at two to four months of growth.

The difference in the DM content between the two studies might probably be a result of the differences in the stage of growth at sampling.

It has been observed that, as the DM content of the herbage increases, the nutritive value and palatability decline. Crowder and Chheda (1982) and other workers concluded that the increase in the DM content of herbage is reflected in an increase in CWC at the expense

of the CC.

Thus, from the present study it can be concluded that in order to maintain the nutritive value of the herbage, without affecting the DM yield very adversely, it is advisable to incorporate forage legumes in pasture mixtures. Similarly, the pastures should be utilized before they are mature, that is, they should be grazed or harvested for hay just before inflorescence emergence when their DM content is still reasonably low.

5.2 Crude protein content (%) in herbage

The content of CP in *B. brizantha*, the legume species in the grass/legume mixtures as well as the grass/legume mixtures decreased with advancing stage of growth. The rate of decline in the CP content of the grass was faster in the N fertilized grass treatments than in the grass/legume mixtures.

These results are in agreement with those reported by other workers in the tropics. At Morogoro, Fredericksen and Kategile (1980) reported a decrease in the CP content of *B. brizantha* from 7.4% at one week to 4.8% at 6 weeks. Kidunda (1988) also reported similar findings in his study conducted at SUA, Morogoro, with four tropical grass and four legume species. He observed a decline in the CP content of *B. brizantha*, from 7.71 to 3.35%, siratro from 16.96 to 13.13% and centro from 17.52 to 11.51%, when sampled between two and four months.

The observation that the CP content of the grass in the grass/legume swards declined more slowly conforms with observations by Haydock and Norris (1967). They noted that the outstanding value of a legume/grass mixture rests on the property of the constancy of its N content. Akinola (1981) in Nigeria observed that the mean N content of *B. decumbens* in association with centro was 1.58% (9.89% CP) at 6 weeks and 1.25% (7.81% CP) at 8 weeks.

The present study showed that the CP content of *B. brizantha* increased with increasing fertilizer N rate. These results confirm earlier findings by several workers (Sivalingam 1965; Horrell and Newhouse 1966; Olsen 1972; Fredericksen and Kategile 1980). Olsen (1972) in Uganda, reported an increase in the CP content of *B. ruziziensis* from 6.7% at 0 to 16.8% at 2240 N/ha when harvested at 60 days.

The presence of siratro in the *Brachiaria*/siratro sward increased the CP content of the grass. The results confirm the observations made by Moore (1962) in Nigeria, Horrell and Newhouse (1966) in Uganda and Rukanda and Lwoga (1981) in Tanzania. They observed that the inclusion of a legume in pasture mixtures made an important contribution in maintaining adequate protein levels in the pasture. Moore (1962) found that centro increased the CP content of *C. plectostachyus* by over 30%. Similarly, Rukanda and Lwoga (1981) reported a 50% increase in the CP content of the pasture when siratro and *S. guianensis* were oversown in a *Themeda-Hyperrrhaenia* dominated

pasture.

One of the major problems affecting livestock production in many parts of Tanzania, is sub-optimal nutrition associated with protein deficiency in the natural grassland species, especially during the dry season. The only feasible and economical way to narrow the gap between the wet and dry seasons is to establish forage legumes into natural grasslands. Since the legumes are capable of maintaining their growth and quality for a longer period than grasses, their presence will boost the feeding value of the associate grass species, and hence, improve the productivity of the livestock grazing such pastures.

5.3 Dry matter yield (kg/ha)

The DM yield of *B. brizantha* increased with advancing stage of growth. The DM yield of the legume species in the grass/legume mixtures as well as that of the grass/legume mixtures were not significantly affected by advancing stage of growth.

These observations are in agreement with the results reported by Akinola (1981) in Nigeria. He reported increase in the DM yields of *B. decumbens*, siratro and *B. decumbens*/siratro from 4.46 to 6.89 ton/ha, 1.74 to 2.01 ton/ha and 6.20 to 8.90 ton/ha, respectively. The forages were cut at 6 - and 8 - week frequencies.

Similarly, Kidunda, and Lwoga (1985) in Tanzania, reported increase in the DM yield of *B. brizantha* from 9.5 to 14.51, siratro from 2.39 to 2.47 and centro from 3.34 to 3.80 ton/ha, when cut at 2 and 4 months of growth, respectively. The DM yields reported in the two studies are higher than those in the present study. The differences might have been due to the different stages of growth at harvest, and probably because the species in their study were established in pure stands.

There was a highly significant increase in the DM yield of *B. brizantha* with increasing fertilizer N rate. These findings confirm the results by Fredericksen and Kategile (1980) who reported an increase in the DM yield of *B. brizantha* from 2.8 to 9.8 ton/ha at 0 and 187.5 kg N/ha, respectively. The observation that the DM yield of the grass in the grass/legume mixtures and that of the mixtures were higher than that in the pure grass sward is in agreement with the results reported by Whitney and Green (1969) working at the Hawaii Agricultural Experiment Station. They reported that pangola grass in association with *D. canum* produced 1.4 times as much DM as pangola alone. Similarly, the total DM yield of pangola/*D. canum* mixture was twice that of pangola alone, as shown in Table 2.

It was observed in the present study that, the *Brachiaria*/siratro mixture was equivalent in DM yield to pure stand *B. brizantha* receiving between 80 and 120 kg N/ha as CAN (Figure 1). The *Brachiaria*/centro mixture was equivalent in DM yield to the pure grass

stand receiving between 5 and 40 kg N/ha as CAN.

The results in this study agree with those reported by Jones (1967) at Samford, who showed that siratro/grass mixtures produced DM yield equivalent to the grass alone (*Chloris gayana* or Nandi setaria) receiving 108 kg N/ha/year as urea. Reynolds (1982) in Western Samoa reported that tall guinea grass/siratro and tall guinea grass centro mixtures produced DM yield equivalent to the grass alone receiving 10 and 50 kg N/ha/year, respectively.

In many parts of Tanzania, the dry season may be as long as nine months. In such areas, there is a short period of herbage growth, followed by a long period of pasture shortage resulting from the slow growth of pastures. Since under Tanzania conditions, forage conservation in form of hay or silage is practiced only in state farms a larger proportion of forages dry out *in situ* and are grazed as standing hay. Grasses grazed in this condition are usually deficient in energy.

By incorporating forage legumes in grass-based pastures, the growth of the pasture mixtures is sustained over a much longer period, thus minimizing the period of nutritional stress to the ruminant livestock.

5.4 Crude protein yield (kg/ha)

The CP yield of *B. brizantha*, the legume species in the grass/legume mixtures and the grass/legume mixtures were not

significantly affected by advancing stage of growth. The results of this study are not in agreement with those observed by Mtengeti, E.J. at SUA, Morogoro (Personal communication, 1988) that the CP yield of *B. brizantha* decreased from 136.8 kg CP/ha at 40 days to 95.0 kg CP/ha at 60 days. Sivalingam (1965) in Sri Lanka, reported that the CP yield of *B. brizantha* decreased from 1471 to 1060 kg/ha, at cutting intervals of 30 and 60 days, respectively.

However, the results in the present study confirm those of Fredericksen and Kategile (1980) in an experiment conducted at SUA, Morogoro, who reported that the CP yield of *B. brizantha* reached a maximum towards the end of the experimental period (8 weeks).

The difference observed is probably a result of the delayed maturation of the plants caused by prolonged moisture stress in this experiment. Wilson (1984) in his study concluded that water stress *per se* slows or suspends the normal ageing process of leaves, thus delaying the setting in of the CWC.

The CP yield of *B. brizantha* increased substantially with increasing fertilizer N rate (Figure 2). Similar results have been reported by other workers. Olsen (1972) in a study conducted at Makerere University Farm, Kampala, Uganda, reported increase in the CP yield of *B. ruziziensis*, *C. gayana*, *P. maximum* and *S. sphacelata* with increase in fertilizer N rate from 0 to 2240 kg N/ha/a.

The CP yield of siratro in the *Brachiaria*/siratro mixture was higher than that of centro in the *Brachiaria*/centro mixture. Akinola (1977) in Nigeria, observed that centro in mixture with *B. brizantha* outyielded siratro in *Brachiaria*/siratro mixture. The difference is probably due to the inadequate rainfall during the course of the present study. Centro, according to Clements *et al.* (1983), is less resistant to moisture stress than siratro.

The *Brachiaria*/siratro mixture produced a higher yield of CP than either the *Brachiaria*/centro mixture or *B. brizantha* without fertilizer N application. These results are consistent with those reported by Akinola (1977) who found that *Brachiaria*/siratro mixture outyielded *Brachiaria*/centro mixture (766.25 kg CP/ha compared with 642.5 kg CP/ha). The observation that *Brachiaria*/siratro gave a higher CP yield than *B. brizantha* without N application is in agreement with the results of Reynolds (1982) at Alafua, Western Samoa, who reported that tall guinea grass/siratro produced 1.3 times as much CP as that of the grass alone.

The CP yields of the grass species (*B. brizantha*) and the grass/legume mixtures were very highly correlated with the DM yield ($r = 0.93$ and 0.95 , respectively). However, they were moderately correlated with the CP contents ($r = 0.61$ and 0.57 , respectively). It seems, therefore, that as the DM yields of grass and the grass/legume mixtures increased, there were corresponding increase in the CP yield.

From the results of this study, it can be seen that applying fertilizer N to *B. brizantha* - based pastures was more beneficial than establishing the grass in mixture with either siratro or centro.

Thus, given the high chemical fertilizer costs, it may be worth while to use siratro - based *B. brizantha* pastures accompanied with good grazing management so as to improve the production of livestock grazing such pastures.

5.5 Ash content (%) in herbage

The ash content of *B. brizantha*, the legume species in the grass/legume mixtures and the grass/legume mixtures (*Brachiaria*/siratro and *Brachiaria*/centro decreased with advancing stage of growth.

This is in agreement with the results of Sivalingam (1965) who found that the ash content of *B. brizantha* decreased from 9.34% to 7.31% at 30 and 90 days defoliation frequencies, respectively. Similarly, Kidunda (1988) at SUA, Morogoro, reported decrease in the ash content of *B. brizantha* from 5.39 to 3.99%, siratro from 5.24 to 4.52% and centro from 5.51 to 4.11%, with advancing stage of growth from two to four months. The difference in the ash content of the plant species observed in the present study is probably due to the different growth conditions and different stages of growth at cutting.

Crowder and Chheda (1982) explained that the decrease in the ash content of pasture plants is a result of decreased cell contents (CC) and increased CWC with advancing stage of growth. It was observed that, this was due to the increased rate of DM accumulation causing a dilution of the mineral content in proportion to the increase in bulk.

Fertilizer N rate had no significant effect on the ash content of *B. brizantha*. The results agree with the results reported by Sivalingam (1985) working at Maha, Sri Lanka, who reported a non-significant increase in the ash content of *B. brizantha* from 9.34 to 9.55 and 9.84%, when the N rate was increased from 0 to 44.8 and 134.4 kg N/ha; respectively.

The inclusion of siratro or centro in *Brachiaria*-based pasture resulted in a slight increase in the ash content of the grass. The results are in agreement with those of Rukanda (1979) in the study conducted at SUA, Morogoro, who reported a slight increase in the mean ash content of natural grassland oversown with siratro and Stylo (12.5%) compared with natural grassland alone (11.5%)

In livestock keeping areas of Tanzania, livestock depend almost entirely on pastures which, in most cases, are deficient in minerals. Such pastures have been reported to cause mineral deficiencies to livestock grazing them, where no mineral supplementation is practised.

In order to avoid or minimize the problem of mineral deficiencies

under such a situation it is essential to incorporate legume species in grass-based pastures to raise the ash content of the pasture mixtures. The pastures if utilized before they are mature, at least by the most vulnerable classes of cattle such as young calves and breeding stock, the problem of mineral deficiencies could be minimized.

5.6 Neutral-detergent fiber (%)

The NDF content of *B. brizantha*, the legume species in the grass/legume mixtures and the grass/legume mixtures, increased with advancing stage of growth.

These results are in agreement with the findings reported by other workers. The study by Kidunda (1988) showed increase in the NDF content of *B. brizantha* from 73 to 82%, siratro from 56 to 65% and centro from 60 to 68% with advancing stage of growth from 2 to 4 months. Similarly, the results agree with those by Johnson and Pezo (1965) in Peru, who reported an increase in CWC of *B. decumbens* from 70% at 42 days to 80% at 70 days.

The NDF content of *B. brizantha* and centro are lower in the present study than those reported by Kidunda (1988). The difference is probably a result of the moisture stress experienced by the plants in this study. It has been reported that moisture stress delays the normal ageing process of plant leaves (Wilson 1983), thus slowing down the rate of replacement of CC by CWC (Van Soest 1968). The NDF content of siratro is similar in the two studies, probably due to

the fact that the species is more resistant to drought (Kretschmer 1966) than the other species.

The NDF content of the grass was not affected by increasing fertilizer N rate. The results differ from those by Whitney (1974) who observed that fertilizer N application stimulated new growth of tissue with high protein content and low cell wall and lignin content. The difference was probably due to the short duration of the present study.

The presence of the legumes in the mixed swards had no significant effect on the NDF content of the grass. These results confirm those of Rukanda (1979) who reported similar CF values in natural grassland alone (32.6%) and natural grassland oversown with siratro and stylo (32.0%). The results reported by Smith (1962) at Mazabuka, Zambia, support the findings in the present study. He found that the CF content of Rhodes/stylo hay was 39.4% compared to that of Rhodes grass hay alone which was 41.8%.

The NDF content of siratro in this study was similar to that of centro. These results are contrary to those reported by Kidunda (1988) who found that centro had a higher NDF (64.57%) than siratro (58.76%) when cut after 2 and 4 months of growth. This difference is probably a result of the moisture stress which might have delayed the maturation of centro, thus delaying the setting in of the CWC in the plant tops, in the present study.

It has been observed in this and other studies, that advancing stage of growth in grass-based pastures is associated with increased CWC and high stem/leaf ratio. These attributes are negatively correlated with the quality and nutritive value of the pasture.

It follows, therefore, that in order to improve, or at least, to maintain the nutritive value of the grass-based pastures, the CWC and stem/leaf ratio should be kept as low as possible. This can be achieved by improving the N status of the soil, which stimulates the growth of new tissues with high protein content and low CWC and lignin content.

Under Tanzania conditions, incorporating forage legumes which are compatible with the existing grassland species is the most economical strategy of improving the soil N status, hence maintaining pasture growth for a longer time of the year. With sustained pasture growth of reasonably good quality, the production of livestock can be maintained over a longer time during the year.

5.7 Acid-detergent fiber (%)

The ADF content of *B. brizantha* and that of the grass/legume mixtures increased with advancing stage of growth. However, the ADF content of the legume species in the grass/legume mixtures were similar at both stages of growth.

The results of this study support those of Johnson and Peso (1965) who reported increase in the ADF content of Peruvian pasture species with advancing stage of growth. They reported an increase in the ADF content of *B. decumbens* from 40% at 42 days to 46% at 70 days. The ADF content of siratro was the same (39%) at 42 and 70 days of growth.

The present study showed no significant fertilizer N rate or legume species effect on the ADF content of *B. brizantha*. These results are in agreement with those of Deinum and Dirven (1975), who observed that higher N levels resulted in somewhat lower CWC and an insignificant increase in the digestibility of *S. sphacelata* and *B. ruziziensis*.

The ADF content of siratro and centro were similar in this study. This supports the results reported by Kidunda (1988) that the mean ADF content of siratro and centro when cut between 2 and 4 months were 45.04 and 47.04%, respectively.

Since the ADF content of both the grass component and that of the grass/legume are negatively correlated with the nutritive value (CP and DMD), efforts should always be made to keep the ADF content as low as possible in order to obtain quality forages. This is possible through either cutting or grazing the grass-based pastures at an early stage of growth between one and two months of regrowth. The establishment and maintenance of legume species in pasture mixtures helps to maintain the quality of the pastures at a reasonable level for a longer period of time.

5.8 *In vitro* dry matter digestibility

The IVDMD of *B. brizantha* and that of the grass/legume mixtures declined with advancing stage of growth. The IVDMD of the legume species in the grass/legume mixtures was not affected by advancing stage of growth. The rates of decline in IVDMD of the grass, legume species and grass/legume mixtures were 0.29, 0.20 and 0.23% units per day, respectively.

The results reported in this study are in agreement with those of Mero and Kabatange (1988) in a study they conducted at the Livestock Production Research Institute, Mpwapwa, where they found out that the mean IVOMD of *C. gayana*, *C. ciliaris*, *B. insculpta* and *P. maximum* declined from 73.28% at 123 days to 67.80% at 183 days of growth. These results also support those of Reid *et al.* (1973) at the Kabanyolo Experimental Farm, Makerere University, Uganda, who reported average decline in IVDMD of *B. ruziziensis*, siratro and centro to be 0.29, 0.24 and 0.14% units per day, respectively, when sampled after six to ten weeks of growth.

The observation in this study, that fertilizer N rate had no effect on the IVDMD of *B. brizantha* is consistent with the results of Sivalingam (1965) who reported that the IVDMD of *P. atropurpureum*, *P. maximum* and *B. brizantha* was influenced more by the frequency of defoliation than by the different levels of fertilizer N.

Legume species had no effect on the IVDMD of *Brachiaria*/siratro or *Brachiaria*/centro mixtures. These results agree with those of Rukanda (1979) who reported that the mean IVDMD of natural grassland oversown with siratro and stylo (55.7%) was similar to that of natural grassland alone (51.9%).

The IVDMD of siratro in *Brachiaria*/siratro mixture was higher than that of centro in *Brachiaria*/centro mixture. This is consistent with the results of Reid *et al.* (1973) who reported mean IVDMD of siratro and centro to be 64.02 and 56.82%, respectively.

The digestibility of forages is associated with the energy value of the forages. Forages of high digestibility have high energy values. Since animal production (milk and liveweight gain) require energy, it is essential to supply the animals with feeds of high energy content. The feeds with very high energy content are cereals and cereal by-products, which are required for human consumption and in the monogastric production (pigs and poultry).

The production of high quality forages is the alternative under such situations. Thus, incorporating compatible legume species in pasture mixtures is important since they maintain their nutritive value for a longer time than grasses. Also, under extreme conditions, when the CP content of the grass species has deteriorated below the critical level (7% CP), the presence of the legumes supply the protein required for rumen microbial synthesis. In this way, the presence of the legumes in the pasture mixtures helps to boost the utilization of

the structural carbohydrates in the ingested forage.

5.8 Digestible dry matter yield

The DDM yields of *B. brizantha*, legume species in the grass/legume mixtures and the grass/legume mixtures were not significantly affected by advancing stage of growth.

These results are in accord with those of other workers. Mero (1985) at Morogoro, found a non-significant increase in the DDM yield of *C. gayana* from 2270 kg/ha at 55 days (heading) to 3610 kg/ha at 112 days (maturity). Similarly, Mtengeti, E.J. (Personal communication, 1988) found that the mean DDM yield of *B. brizantha* was not significantly affected by advancing stage of growth from 20 days (2048 kg DDM/ha) to 40 days (2562 kg DDM/ha). The results of Kidunda (1988) showed that advancing stage of growth from two to four months caused a slight change in the DDM yield of siratro and centro. The DDM yield of siratro was 1391 kg/ha at two months and 1283 kg/ha at 4 months, while the corresponding yields of centro were 1852 and 1843 kg/ha, respectively.

The present study showed that there was a highly significant increase in the DDM yield of *B. brizantha* with increasing fertilizer N rate. These results are consistent with those of Sivalingam (1965) who reported increase in the DDM yields of *P. purpureum*, *P. maximum* and *B. brizantha* with increasing N rate from 0 to 432 kg N/ha. Similarly, these results confirm those of Mtengeti, E.J. (Personal

communication 1988) who reported an increase in the DDM yield of *B. brizantha* from 1028 kg /ha at 0 to 4374 kg/ha at 400 kg N/ha, and harvested at 40 days of growth.

The results that the DDM yield of *Brachiaria/siratro* was higher than that of grass alone without N application are in accord with those of Rukanda (1979). He reported that the DDM yield of natural grassland oversown with siratro and stylo (2.7 t/ha) was higher than that of natural grassland alone (1.9 t/ha).

The DDM yield of the grass and legume components of the mixture and the grass/legume mixtures were highly positively correlated with DM yields with r values of 0.93, 0.71 and 0.98, respectively. These results are in agreement with those found by other workers. Kayongo-Male *et al.* (1976) in Puerto Rico, found that the DDM and the DM yields were positively correlated ($r = 0.69$). The DDM yield of the grass in the mixture and the grass/legume mixtures were negatively correlated ($r = -0.44$ and -0.30 , respectively).

The DDM yield of forages is associated with the energy value of the forages. Thus, forages with high DDM yield have higher energy content than those with low DDM yield. However, DDM yield is negatively correlated with the nutritive value (crude protein and digestibility). It appears, therefore, that in deciding when to utilize the forages both the attributes (DDM and nutritive value) should be taken into consideration.

5.10 Legume N contribution to the grass/legume mixture N yields

The overall N yield of the *Brachiaria*/siratro mixture was higher than that of the *Brachiaria*/centro mixture (140 kg N/ha compared with 85 kg N/ha). A similar pattern was observed at 70 days of growth. These results agree with those of Akinola (1977) in Nigeria, who found that the *Brachiaria*/siratro mixture produced 122.6 kg N/ha compared with 102 kg N/ha by the *Brachiaria*/centro mixture.

Legume N contribution expressed as the increase in the N yield from the grass/legume mixture in excess of N yield from the unfertilized pure grass sward (Whitney, Kanehiro and Sherman 1967) was higher for siratro (73 kg N/ha) than for centro (18 kg N/ha). Siratro N contribution was more than 10 times (38 kg N/ha) that of centro (3 kg N/ha) at 70 days, while, at 42 days the two legume species made similar contributions to the grass/legume mixtures.

Legume N contribution estimation by extrapolation from the fertilizer N rate - grass N yield response lines (Whiteman 1980) showed that, siratro contributed N yield equivalent to *B. brizantha* receiving more than 120 kg N/ha in the form of CAN at both 42 and 70 days growth. Centro contributed N yield equivalent to *B. brizantha* receiving 5 and 50 kg N/ha, at 42 and 70 days, respectively.

The findings in the present study are consistent with those of Kretschmer (1966) in South Florida who found that siratro could contribute from 60 to 150 kg N/ha/a when in mixture with Pangola grass.

5.11 Legume content (%) in the grass/legume mixtures

The mean legume content in the grass/legume mixture tended to increase with advancing stage of growth. The mean siratro content in the *Brachiaria*/siratro mixture was higher (19.14%) than that of centro (11.07%) in the *Brachiaria*/centro mixture (Table 21). A similar pattern was observed in each of the two mixtures.

The mean centro content reported in this study, is within the range found in grazing trials in Uganda (Horrell and Newhouse 1966) and in Australia (Mellor, Hibberd and Grof 1973). They found that centro often contributed only 5 to 15% of the available herbage.

The siratro and centro contents reported in the present study are consistent with those of Reynolds (1982) in western Samoa. He reported 16 and 21% centro and siratro contents, respectively, when grown in association with tall Guinea grass.

The observation that the legume content tended to increase with advancing stage of growth is in accord with the findings of Jones (1967) at Samford, who found that the percentage siratro content in association with either Rhodes grass or Nandi setaria increased from

16 to 66% as the cutting interval increased from 4 to 16 weeks of growth.

In order to maximize the legume contribution to the overall productivity and nutritive value of the grass/legume mixtures, it is essential to maintain a high legume content (40 to 60%) in the mixture.

5.12 Relationship between the dry matter digestibility and chemical constituents

As can be seen in Table 22, that the IVDMD and CP content of the grass (*B. brizantha*) and the grass/legume mixtures *Brachiaria*/siratro and *Brachiaria*/centro) were positively correlated ($P < 0.05$). There was a very weak positive correlation between the IVDMD and CP content of the legume species in the mixtures.

The IVDMD of the grass, legume species and the grass/legume mixtures was negatively correlated with the fibrous constituents (NDF and ADF) of the species. The correlation coefficients were -0.75, -0.53 and -0.76 for the NDF contents of the grass, legume species in the mixtures and the grass/legume mixtures, respectively. Those between IVDMD and ADF contents were -0.87, -0.31 and -0.82, respectively.

Similarly, the CP content of the grass, legume species and the grass/legume mixtures were negatively correlated with the fibrous

constituents (NDF and ADF). However, the NDF and ADF content of the grass species in the mixtures and the grass/legume mixtures were highly positively correlated with r values of 0.80 and 0.68, respectively.

Table 22 : Relationship between IVDMD (%) and other chemical constituents

Parameter	Regression equation	Correlation coefficient (r)	Level of significance
DMD and CP (grass)	$Y = 3.22x + 43.25$	0.47	(P < 0.05)
DMD and CP (legumes)	$Y = 0.03x + 61.96$	0.006	NS
DMD and CP (mixtures)	$Y = 1.74x + 55.72$	0.49	(P < 0.05)
DMD and NDF (grass)	$Y = -1.20x + 151.53$	-0.75	(P < 0.05)
DMD and NDF (legumes)	$Y = 1.16x + 131.32$	-0.53	(P < 0.05)
DMD and NDF (mixtures)	$Y = 1.13x + 144.39$	-0.76	(P < 0.05)
DMD and ADF (grass)	$Y = -1.34x + 124.04$	-0.87	(P < 0.05)
DMD and ADF (legumes)	$Y = -1.02x + 108.44$	-0.31	NS
DMD and ADF (mixtures)	$Y = -1.21x + 118.79$	-0.82	(P < 0.05)
CP and NDF (grass)	$Y = -1.06x + 74.55$	-0.21	NS
CP and NDF (legume)	$Y = -1.22x + 78.52$	-0.52	(P < 0.05)
CP and NDF (mixtures)	$Y = -1.13x + 75.29$	-0.47	(P < 0.05)
CP and ADF (grass)	$Y = -1.29x + 48.54$	-0.41	(P < 0.05)
CP and ADF (legumes)	$Y = 0.26x + 41.25$	0.17	NS
CP and ADF (mixtures)	$Y = -0.46x + 44.02$	-0.19	NS
NDF and ADF (grass)	$Y = 0.86x - 18.80$	0.80	(P < 0.05)
NDF and ADF (legumes)	$Y = 0.53x + 35.73$	0.35	NS
NDF and ADF (mixtures)	$Y = 0.67x + 38.81$	0.68	(P < 0.05)

The results in the present study are in accord with those of Johnson and Pezo (1965) and Kayongo-Male *et al.* (1976) in Puerto Rico, Kayongo-Male *et al.* (1976) found that the CP content of tropical grass species was positively correlated ($r = 0.46$) with the IVDMD, but negatively correlated with ADF content ($r = -0.68$) and NDF content ($r = -0.63$). They also found that the ADF content of tropical grasses was highly positively correlated with the NDF content with a correlation coefficient of $+ 0.71$.

6. CONCLUSION

Improvement of the quantity and quality of pasture species, particularly grasses, is crucial to improved ruminant livestock productivity in Tanzania. Incorporating legume species in pasture mixtures has been found to be the most feasible and economic strategy under many tropical situations.

The present study has shown that, the legume siratro, when established in association with *B. brizantha*, improved both the herbage yield and nutritive value of the grass/legume mixture. The *Brachiaria*/siratro mixture was found to be superior to the *Brachiaria*/centro mixture in terms of the DM and N yields. The *Brachiaria*/siratro mixture produced DM and N yield equivalent to *B. brizantha* receiving between 80 and 120, and 120 kg N/ha in the form of CAN, respectively.

Thus, the results of this study show that *Brachiaria*/siratro mixtures if well managed can bring about a considerable improvement in the productivity of the livestock grazing such pastures. Therefore, it may be worth recommending at this point that a grazing trial involving the use of *Brachiaria*/siratro mixture be done to evaluate its suitability in terms of animal performance.

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APPENDICES**Appendix 1 : Description of pasture species used in the experiment****1.1 *Brachiaria brizantha* (Hochst. ex. A. Rich.) Stapf.**

Common names: Palisade grass: Signal grass.

The species is a tufted perennial with erect or sub-erect stems up to 4 m high. The leaves are glabrous or hairy, linear or linear lanceolate, 5 to 40 cm long and 6 to 15 cm wide. The panicle has 2 to 8 racemes which are 5 to 15 cm long and have narrow rachis (Sotomayor - Rios *et al.* 1960; Bogdan 1977; Loch 1977).

The species occurs throughout tropical Africa from sea level to 2400 m above sea level. It does well in areas receiving 800 mm of rainfall per annum. However, the species is highly drought resistant and grows well under shade (Sotomayor - Rios *et al.* 1960).

It is normally propagated vegetatively by use of fresh root - stocks or sprigs (Loch 1977; Akinola 1977). However, where seeds are available, propagation by seeds is possible (Loch 1977; Bogdan 1977) at a rate of 2 to 4.5 kg/ha. Vegetative establishment is rapid, and pastures can be grazed within 4 to 5 months and sometimes earlier (Loch 1977).

It requires a moderately good tilth. The root-stocks are cut about 15 cm above the crown and are stuck into the soil (Akinola

1977). The spacing when grown in pure stand is 45 cm within rows and 90 cm between rows (McIlroy 1972). Akinola (1977) at Shika, Nigeria used two different spacings. The low density spacing of 30 cm within and 75 between rows, and the high density spacing of 30 cm and 37.5 cm within and between rows, respectively. He observed higher DM yield for the high density spacing in the first harvest and the reverse was the case at the second harvest.

The species is very leafy and highly productive. Bogdan (1977) reported DM yield ranging between 5 and 36 ton/ha/a depending on soil fertility, moisture status and rate of fertilizer application. At Morogoro, Kidunda (1988) obtained a mean DM yield of 11.5 ton/ha from unfertilized plots cut four times during the growing season. However, Fredericksen and Kategile (1980) and Mtengeti E.J. (Personal communication, 1988) at the same place obtained less than 3 ton/ha.

The species has a high nutritive value compared with other improved tropical grass species (Sotomayor - Rios *et al.* 1960; Sivalingam 1965). Butterworth (1967) reported the mean CP content of *B. brizantha* samples cut at 50 days as 8.7%. The study by Kayongo-Male *et al.* (1967) in Puerto Rico, indicated mean CP, NDF, ADF and IVDMD values of the grass species cut at 30 days of 1.9, 70.1, 42.9 and 54.1%, respectively.

1.2 *Centrosema pubescens* (Benth)

Common names: Centro (Australia), Campanilla (Colombia), Jetirana (Argentina), Bejico de Chivo (Colombia), Butterfly pea.

Centro is a vigorous, deep - rooting, trailing and climbing herb (Harding and Grof 1970; Skerman 1977; Clements *et al.* 1983). It is very leafy, the leaflets are dark green elliptic or ovate elliptic (Clements *et al.* 1983).

The species is native to Central and south America and the Carribean. It has been naturalized in tropical Africa, South-East Asia and India. Tietzel and Burt (1976) described the species as the most widely distributed of the tropical legumes.

It prefers moist conditions with rainfall in excess of 1500 mm per annum, but grows in areas receiving 750 mm/annum. It is deep-rooted and so it is fairly resistant to drought, and has some ability to tolerate water-logging (Clements *et al.* 1983).

It grows on a wide range of soils from sandy loams to clay. It is propagated by seed, but once established it spreads from runners which root at the nodes. The seed rate is usually 2 to 6 kg/ha (McIlroy 1972). Seedling vigour is poor and establishment failures occur, particularly in pastures (Clements *et al.* 1983).

The species combines well with tufted tropical grasses including *P. maximum*, *M. minutiflora*, *C. gayana*, *P. purpureum*, *P. dilatatum* A. *gayanus* and *Brachiaria* species (Skerman 1977; Whiteman 1980; Clements *et al.* 1983).

The DM yields of centro vary widely depending on the fertility of the soils, rainfall, agronomic and cultural practices. Skerman (1977) reported that the species gave 40 ton/ha of green matter in Brazil. However, Kidunda and Lwoga (1985) at Morogoro, Tanzania, reported a mean DM yield of 3.4 ton/ha. The DM yields of the species when established in association with grasses as is often the case, depends on the percent legume in the mixture (Clements *et al.* 1983). In Nigeria, Akinola (1977) reported DM yields of the species (centro) of 1.69 and 1.78 to/ha when the percent legume contents in signal grass/centro sward were 17.1 and 18.8, respectively. In another study by the same author, the mean DM yields were 2.77 and 3.58 ton/ha when the legume was established in association with *B. decumbens*. The percent legume contents were 34.5 and 40%, respectively.

Centro in mixture with grasses increases the DM yields of the grasses (Tetteh 1972; Akinola 1977, 1981; Stobbs and Joblin 1966b). In a study in Uganda, Stobbs and Joblin (1966b) reported an increase in the DM yield of *H. rufa* of 18%, whereas, Tetteh (1972) in Ghana observed 67% increase in the DM yield of *D. decumbens* when centro was incorporated.

The chemical composition and digestibility of centro varies considerably (McIlroy 1972; Clements *et al.* 1983) McIlroy (1972) reported a range in CP content from 16 to 19% in the DM while Clements *et al.* (1983) observed a wider range from 17 to 25% in the DM.

1.3 *Macroptilium atropurpureum* (DC) Urb

Common name: Siratro

Siratro is a deep-rooted perennial with a trailing pubescent stem. The leaves are pinnately trifoliate, dark-green and slightly hairy on the lower surfaces. The inflorescence is a raceme with peduncle 10 to 30 cm long with 6 to 12 flowers crowded at the apex (Kretschmer 1966; Skerman 1977; Ostrowski 1978).

The species is indigenous to South and Central America. It grows at altitudes from sea level to 1800 m above sea level. It requires at least 615 mm and preferably more than 850 mm of rainfall per annum. The species is extremely drought resistant because of its inherent deep-rooting habit (Kretschmer 1966). However, the species is not tolerant to flooding thus it requires well drained soils. It is well adapted to a wide range of soil types and climatic conditions (Davies and Hutton 1970). It is established by seeds at a seed rate of 2 to 8 kg/ha (Skerman 1977).

The species combines well with several grasses including *C. gayana*, *C. ciliaris*, *P. maximum*, *Setaria* and *Brachiaria* species.

(McIlroy 1972; Skerman 1977; Ostrowski 1978). It is nearly always grown in grass mixtures (Bogdan 1977). In Tanzania, the DM yields of pure siratro under experimental conditions have been reported by Mero (1985) to be 2.07 ton/ha when harvested at 112 days. However, Kidunda and Lwoga (1985) at the same place obtained slightly higher yield of 2.40 ton/ha.

Grass/siratro mixed swards have been observed to produce higher total DM yields than either species alone in Tanzania, and in other countries in the tropics (Kretschmer 1966; Rukanda and Lwoga 1981; Kusekwa and Lwoga 1985). At Morogoro, Rukanda and Lwoga (1981) reported a 30% increase in the DM yield of *Themeda-Hyperrhaenia* dominated natural grassland oversown with siratro and stylo. Also, Kusekwa and Lwoga (1985) in an oversowing study at Tengeru (mean annual rainfall, 1100 mm), Northern Tanzania, observed that siratro contributed 32% to the DM yield of natural pastures dominated by *B. insculpta*, *C. dactylon* and *Panicum* spp.

The nutritive value of siratro is variable depending on the fertility of the soil and the stage of growth. Mero (1985) reported a mean CP content of 15.7% when sampled at 123 days, whereas, Mero and Kabatange (1988) at Mpwapwa, reported a value of 14.4% at 123 days of growth. It has a high digestibility ranging from 73.1% at 6 weeks to 60.1% at 16 weeks ((Reid *et al.* 1973). The DMD declines slightly with advancing stage of growth. Mero and Kabatange (1988) reported a daily decline in the IVDMD of 0.03% (69.9 to 67.8%) when harvested at 123

and 183 days of growth.

Appendix 2 : Analyses of variance

2.1 Dry matter content (%)

Source of variation	df	SS	MS	F
N source (A)	4	106.15	25.538	3.46 *
Stage of growth (B)	1	0.40	0.400	0.05 NS
Interaction (A x B)	4	25.35	6.337	0.83 NS
Residual	27	215.07	7.966	

* Significantly at 5% ($P < 0.05$)

NS Non-significant at 5% ($P > 0.05$)

2.2 Crude protein content (%)

Source of variation	df	SS	MS	F
A	4	35.20	8.801	17.98***
B	1	30.64	30.64	62.61***
(A x B)	4	3.90	0.975	1.99 NS
Residual	27	13.23	0.49	

2.3 Dry matter yield (kg/ha)

Source of variations	df	SS	MS	F
A	4	58598161.90	1564940.475	9.85***
B	1	12377675.02	1237765.025	8.32**
(A x B)	4	4569097.60	1142274.400	0.77 NS
Residual	27	40149667.18	1487024.710	

*** Significant at 0.1% ($P < 0.001$)

** Significant at 1% ($P < 0.01$)

2.4 Crude protein yield (kg/ha)

Source of variation	df	SS	MS	F
A	4	710504.65	185126.163	15.24*
B	1	960.40	960.400	0.08 NS
(A x B)	4	12511.35	3127.837	0.26 NS
Residual	27	328014.80	12148.80	

2.5 Ash content (%)

Source of variation	df	SS	MS	F
A	4	9.35	2.337	4.38 NS
B	1	8.10	8.100	15.19***
(A x B)	4	4.15	1.038	1.95 NS
Residual	27	14.40	0.533	

2.6 Neutral - detergent fiber (%)

Source of variation	df	SS	MS	F
A	4	29.15	7.287	1.34 NS
B	1	140.63	140.625	25.78***
(A x B)	4	41.25	10.313	1.89 NS
Residual	27	147.27	5.45	

2.7 Acid - detergent fiber (%)

Source of variation	df	SS	MS	F
A	4	85.15	21.288	3.17*
B	1	168.10	168.100	25.02***
(A x B)	4	25.15	6.288	0.94 NS
Residual	27	181.40	6.719	

2.8 *In vitro* dry matter digestibility (%)

Source of variation	df	SS	MS	F
A	4	53.65	13.412	1.45 NS
B	1	632.02	632.025	68.40**
(A x B)	4	74.35	18.588	2.01 NS
Residual	27	249.48	9.240	

2.9 *In vitro* dry matter yield (kg/ha)

Source of variation	df	SS	MS	F
A	4	18887107.15	4721776.787	8.01***
B	1	2785200.63	2785200.625	4.73*
(A x B)	4	1901408.75	475352.188	0.81 NS
Residual	27	15906348.38	589124.014	

APPENDIX 3. EXPERIMENTAL FIELD LAYOUT

	R ₁	R ₂	R ₃	R ₄
	5m			
1.6m	Brachiaria / Siratro (Late)	Brachiaria / Centro (Early)	Brachiaria / Centro (Early)	B. brizantha 200kg N/ha (Early)
0.5m	Brachiaria / Siratro (Early)	B. brizantha 0 kg N/ha (Early)	Brachiaria / Siratro (Late)	B. brizantha 100kg N/ha (Late)
	B. brizantha 100 kg N/ha (Late)	Brachiaria / Centro (Late)	B. brizantha 0 kg N/ha (Late)	Brachiaria / Siratro (Late)
	Brachiaria / Centro (Early)	B. brizantha 100 kg N/ha (Late)	B. brizantha 200kg N/ha (Early)	B. brizantha 0 kg N/ha (Early)
	B. brizantha 200 kg N/ha (Early)	Brachiaria / Siratro (Early)	B. brizantha 100 kg N/ha (Early)	B. brizantha 100 kg N/ha (Early)
	Brachiaria / Centro (Late)	B. brizantha 100 kg N/ha (Late)	B. brizantha 100 kg N/ha (Late)	Brachiaria Centro (Late)
	B. brizantha 100 kg N/ha (Early)	B. brizantha 200 kg N/ha (Late)	B. brizantha 0 kg N/ha (Early)	B. brizantha 0 kg N/ha (Late)
	B. brizantha 0 kg N/ha (Early)	Brachiaria / Siratro (Late)	B. brizantha 200 kg N/ha (Late)	Brachiaria / Centro (Early)
	B. brizantha 0 kg N/ha (Late)	B. brizantha 200 kg N/ha (Early)	Brachiaria / Centro (Late)	B. brizantha 200 kg N/ha (Late)
	B. brizantha 200 kg N/ha (Late)	B. brizantha 0 kg N/ha (Late)	Brachiaria / Siratro (Early)	Brachiaria / Siratro (Early)