

SEED PRODUCTION, DRY MATTER YIELD AND NUTRITIVE VALUE OF  
TWO STYLOSANTHES SPECIES AS AFFECTED BY FERTILIZER  
APPLICATION AND TIME OF HARVEST AT MOROGORO.

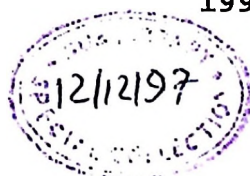
BY

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## ABSTRACT

A study comprising two field experiments was conducted to examine the effects of nitrogen (N) and phosphorus (P) fertilizer application and time of harvest on seed production, dry matter (DM) yield and nutritive value of *Stylosanthes hamata* and *Stylosanthes guianensis* at Morogoro. Split-plot experimental design was used in the study.

In experiment I, two levels of N (0 and 30 kg/ha) and two levels of P (0 and 30 kg/ha) were arranged factorially as a main-plot treatment. In experiment II, four levels of P (0, 30, 60, and 90 kg/ha) were applied with 30 kg N/ha as a main-plot treatment. In both experiments sub-plots were harvested at 50 % flowering stage, 4<sup>th</sup>, 5<sup>th</sup>, 6<sup>th</sup> and 7<sup>th</sup> week post 50 % flowering stage.

The results showed that N application increased seed yield, DM yield and crude protein (CP) % of *S.hamata* by 67.3, 45.68 and 9.63 percent as compared to the control, respectively. N application also increased CP %, *in vitro* dry matter digestibility (IVDMD) %, *in vitro* organic matter digestibility (IVOMD) % and metabolizable energy (ME) content of *S.guianensis* by 4.44, 5.92, 3.64 and 3.59 percent over the control, respectively. However, the DM and seed yield of *S.guianensis* tended to decline with N application. Phosphorus fertilizer application on the other

hand did not affect seed yield and DM yield of *S.hamata*. However, it increased the leaf:stem ratio, harvesting index and seed yield of *S.guianensis*. The over all quality of herbage produced declined in both species with P application in terms of digestibility and subsequently the ME content as compared to the control. Maximum return per Tanzanian Shilling (Tsh) invested on N was obtained from *S.hamata* kept for both seed and fodder production (12.02 Tsh), followed by the same species kept for seed production alone (9.75 Tsh). The maximum return per Tsh invested on P was obtained from *S.guianensis* kept for seed production alone (8.02 Tsh), followed by the same species kept for both seed and fodder production ( 5.05 Tsh).

In both *S.hamata* and *S.guianensis* increasing time of harvest increased harvesting index, seed yield and herbage DM yield. However, peak seed yield was not yet attained within the range of harvesting time considered for *S.hamata* while it was at the 6<sup>th</sup> week for *S.guianensis*. In both *Stylosanthes* species ash %, CP %, and DCP content declined with increasing time of harvest. However, the acid detergent fibre (ADF) %, and acid detergent lignin (ADF) % in DM of the two species responded to increasing time of harvest differently. Both ADF and ADL % in DM increased in *S.hamata* and declined in *S.guianensis* with increasing age of the plant. This trend was reflected on the *in vitro* digestibility value of the feed which declined continuously

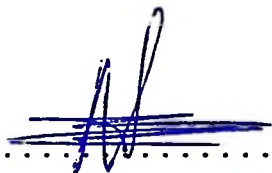
in *S.hamata* and increased after the 5<sup>th</sup> week in *S.guianensis*.

It was concluded that starter dose of N application enhanced seed production, DM yield and quality of the forage in *S.hamata*; where as *S.guianensis* benefited only in terms of quality improvement of the forage. Application of P was not beneficial under Morogoro condition for *S.hamata* while for *S.guianensis*, P application at the rate of 60 kg P/ha gave higher seed yield and quality forage than the rest of P levels tested.

Large yield differences were observed between early Vs. late harvesting time in both *S.hamata* and *S.guianensis* in terms of seed yield, DM yield and quality of herbage produced. This preliminary work, therefore, suggested that harvesting time for optimum seed production should be at the 7<sup>th</sup> and 6<sup>th</sup> week post 50 % flowering for *S.hamata* and *S.guianensis*, respectively.

DECLARATION

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

Signature:..........

Date.....14/11/97.....

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Lastly but not least I would like to thank my mother, Kedija Said, my brothers, my sisters and friends, who contributed a lot in one way or another for the education I have attained.

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DEDICATION

To my beloved father, the late **HASSEN IMAMU**, who wished and did every thing he could to see us get education at a higher level. Praise be to Allah ! I have tried to fulfil his dream.

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## LIST OF ABBREVIATIONS

%	Percent
ADF	Acid detergent fibre
ADL	Acid detergent lignin
ANOVA	Analysis of variance
AOAC	Association of official analytical chemists
App	Appendix
ARC	Agricultural Research Council
CEC	Cation exchange capacity
CF	Crude fibre
cm	Centimetre
CP	Crude protien
cv	Cultivar
CV	Coefficient of variation
DASP	Department of Animal Science and Production
DCP	Digestible crude protein
DM	Dry matter
DMyld	DM yield
DODM	Digestible organic matter in DM
g	gram
GLM	General linear Model
ha	Hectare
HT	Harvesting time
ILCA	International Livestock Centre for Africa
IVDMD	<i>In vitro</i> dry matter digestibility
IVOMD	<i>In vitro</i> organic matter digestibility

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kg	Kilogram
LSR	Leaf:stem ratio
m	Meter
MAAF	Ministry of Agriculture, Fisheries and Food
ME	Metabolizable energy
MJ	Megajoule
mm	Millimetre
NORAD	Norwegian Agency for Development Cooperation
NRC	National Research Council
p	level of significance
P	Phosphorus
ppm	Parts per million
RF	Rainfall
SAS	Statistical analysis system
SEM	Standard error of means
SUA	Sokoine University of Agriculture
Syld	Seed yield
USDA	United state Department of Agriculture

## CHAPTER I

## 1.0 INTRODUCTION

Nutritional limitations are among the complex interacting factors that affect livestock production (Van Soest, 1994; Cooke, 1982; Agishi and de Leeuw, 1986). In sub-humid and semi-arid areas, it is primarily manifested in terms of quantity and quality of forage intake (Minson, 1990), as forages are the most important and cheapest feedstuff available in these areas (Wellving, 1984). Increasing animal outputs such as milk, meat etc. is mostly also handicapped by the low quality and quantity of available feed resources (Mlay and Urio, 1989; Shem and Kimambo, 1994). However, there is an evidence that improved forages and legumes can produce feed of higher quality than natural pasture. Species like *Stylosanthes hamata* and *Stylosanthes guianensis* are among such valuable forage legumes used in sub-humid and semi-arid areas to improve the nutritive value of low quality feed resources (Agishi, 1982; Agishi and de leeuw, 1986).

Experience in sub-humid Africa and Australia showed that introduction of *Stylosanthes* species alone increased animal production by up to ten fold (Gilland et al., 1980; Tothill, 1986; Mohammed-Saleem and Von-Kaufmann, 1986; Lemma and Abubeker, 1995). However, wider use of *Stylosanthes* species encounter a number of difficulties in

different localities such as low DM yield in fodder banks of West Africa (Williams and Gardener, 1984; Mohammed-Saleem and Otsyina, 1986), scarcity of land and where land is not a limiting factor cultivation of *Stylosanthes* species is constrained by lack of adequate seed supplies (Crowder and Chheda, 1982). Specifically the later deserves attention as the seed yield of *Stylosanthes* species are low in sub-humid Africa compared to other commercial species found in tropical Australia.

The major reason for low seed yield of *Stylosanthes* species and other forage legumes is limited understanding of crop development in a given locality (Hill and Loch, 1993). As a result seeds are not always grown in suitable environments, and there may also be lack of proper knowledge of how best to manipulate their development under different seasonal conditions, on different soils and in different climates. A number of investigators agree that seed yield of forage crops such as *Stylosanthes* species can be increased with the use of best agronomic practices through out the production process (Ritchiecown, 1970; Humphreys, 1979; Crowder and Chheda, 1982; Chatterjee and Das, 1989). However, published information available in this line of work is scanty in Africa (e.g. Ethiopia and Tanzania) as compared to efforts made for food crop seed production, with the exception of Kenya and Zimbabwe (Jutzi, 1986).

The possibility of maximizing returns from pasture seed crop land through multiple use of their crops for both seed and forage is well documented (Humphrey, 1979; Chatterjee and Das, 1989). Nevertheless, DM yield and especially the nutritive value of non-seed residue is not well assessed particularly in response to different agronomic manipulation aimed at seed production. This includes fertilizer application practice and late harvesting time employed for seed production. Information available in this line of work is scanty for *Stylosanthes* and deserves research in order to quantify and come up with tangible benefits of *Stylosanthes* seed crop residue as an alternative animal feed beside its seed yield. Promotion of such strategy, production of seed and the use of non-seed residue as an animal feed, is likely to attract more farmers in forage seed production enterprises.

Therefore, a study was conducted to investigate the effect of Nitrogen (N) and phosphorus (P) fertilizer application and different times of harvest on the seed production, herbage dry matter yield, chemical composition and *in vitro* digestibility of non-seed residue produced from *Stylosanthes* species at Morogoro with the following objectives:-

1. To assess the impact of N and P fertilizer application on seed production and herbage dry matter yield

produced from seed crop of *S.hamata* and *S.guianensis*.

2. To asses the overall impact of N and P fertilizer application on chemical composition and *in vitro* digestibility of *S.hamata* and *S.guianensis*.

3. To determine best time of harvest of *S.hamata* and *S.guianensis* seed crop that gives higher seed yield and quality in a single harvest.

4. To evaluate the potential of *S.hamata* and *S.guianensis* crop residue as an animal feed in terms of chemical composition and *in vitro* digestibility.

5. To determine optimum time of harvest that allows optimum utilization of herbage DM yield produced from stands of *S.hamata* and *S.guianensis* based on DM yield and some nutritive value indicators.

## CHAPTER II

## 2.0 LITERATURE REVIEW

## 2.4 The role of forage legumes

The role that legumes play in farming systems has been covered by a large number of contemporary reviews, notably Wilson (1978), Mannelje *et al.* (1980), Norman (1982), Crowder and Chheda (1982), Haque and Jutzi (1984), Agishi (1985) and Tothill (1986). The primary role that legumes play is to fix atmospheric  $N_2$  through their symbiotic relationship with *Rhizobium* species, usually associated with the host's root system. This fixation of atmospheric  $N_2$  leads to two dependent or consequential roles of legumes: (1) their capacity to increase soil fertility and (2) the generally high levels of protein in the herbage and hence its high forage or mulching quality.

Fixation of N is the product of two symbiotically interdependent organisms (the host legume plant and the bacterium), and therefore, the process may be affected by the reaction of one or the other or both to different factors. As a broad generalisation, fixation is proportional to the vigour of the host plant and therefore is affected by factors that affect plant growth, i.e. water, temperature, nutrients and light (Tothill, 1986). This generalisation may be upset by factors that specifically affect the activity of the *Rhizobium* rather than the host. These may be temperature, soil pH, nutritional status (particularly N and Mo) and genetic

capacity (Tothill, 1986).

### 2.1.1 Effect of forage legumes on herbage quality

Legumes have long been known to be highly nutritious for animals. As expected, the fixation of N leads to generally higher protein levels in the plant's tissue (Tothill, 1986). Mannetje et al. (1980) reported crude protein (CP) levels in temperate legumes, tropical legumes and tropical grass of 23.5, 21.2 and 12.2 %, respectively, when grown under identical controlled environmental conditions, even though the grass received 112 kg N/ha in 4 months (Table 1). Dry matter digestibility of the three groups were 76, 72.8 and 70.5 %, respectively. Phosphorus concentrations of the tissues were similar.

Table 1: Quality components of forages grown under identical controlled environments.

	Temperate legume	Tropical legume	Tropical grass + N
Crude protein (%)	23.5	21.2	12.2
Dry matter digestibility (%)	76.4	72.8	70.5

Source: Mannetje et al. (1980).

Because of the initially higher levels of protein in the legume tissues, it takes longer for their protein content to fall to less than 6.5 %, the lowest protein threshold for animal maintenance, thus prolonging the period during which its forage value is high (Tothill, 1986).

#### **2.1.2 Effect of forage legume supplementation on animal performance**

The other role of forage legumes that could be common to all areas in the tropics is as a feed supplement with crop residues and agricultural by-products. Some of these residues and by-products are grazed *in situ* by livestock or used mainly as a mulch or are burned, e.g. maize and sorghum stover, sugar-cane tops, coca husks, coffee hulls. Supplementing some of these with urea/molasses can make them suitable for at least a maintenance feed for livestock, and their feeding value can further be enhanced by supplementing them with a leguminous forage (Preston and Leng, 1986; Tothill, 1986; Abubeker *et al.*, 1995).

On the other hand, introducing legumes into the native pastures alone increased animal production by up to ten times (Tothill, 1986). Similarly in Ethiopia, Lemma and Abubeker (1995) reported from Bako Research Centre five fold increment in liveweight gain of Horro bulls grazing on stylo oversown natural pasture as compared to bulls grazing in sole natural pasture. Improved liveweight gains were

also reported in other studies, e.g. stylo pasture in Queensland (Gillard *et al.*, 1980), a 3-year accumulation of 880 kg/ha from steers grazing guinea grass plus centro and 660 kg from guinea grass (*Panicum maximum*) alone in Queensland (Grof and Harding, 1970); 526 kg/ha from centro plus grass and 127 from grass alone in Uganda (Stobbs, 1965); 150 kg/ha from Stylo plus *Hyparrhenia rufa* and 90 kg from *H. rufa* alone in Peru (Santhirasegaram, 1975). Renovation of native pastures by strip sowing or intersowing *Stylosanthes hamata* resulted in least weight loss of bulls grazing the inter sown stand in the dry season in the 2 of the 3-years and had the greatest liveweight gain in the remaining year (Musa, 1989).

### **2.1.3 Effect of forage legumes on soil fertility**

Forage legumes play an important role in developing sustainable and low input crop production system (Mulongoy and Kang, 1986). Recently there has been an increase in the interest of including herbaceous and woody forage legumes in crop production systems as a source of mulch, green manure and supplementary browse to develop sustainable and low-input production system (Brewbaker *et al.*, 1982; Sumberg, 1984; Kang and Duguma, 1985).

Forage legumes can fix atmospheric N when they are effectively nodulated, and thus can contribute to the N economy of cropping systems. On low N soils, the amount of

N fixed is closely correlated with legume dry matter production (Skerman, 1977; Vallis et al., 1983). Annual dry matter yields of forage legumes that are useful in live and in *situ* mulch systems range between 1500 and 7500 kg/ha in Africa (Skerman, 1977; Mulongony and Akobundu, 1985), with N yields ranging from 30 to 300 kg/ha per year.

A number of reports have indicated that forage legumes increase the organic matter and N contents of the soil. Observations by Lal et al. (1979) and Wilson et al. (1982) showed small increases in soil N content ranging from 0.01 to 0.06 % over a 2-year period.

## 2.2 Genus *Stylosanthes*

The species of genus *Stylosanthes* have been widely tested in tropical and sub-tropical environment (Burt et al., 1970; Villarreal and Chavez, 1991; Costa et al., 1991; and Souza-filho et al., 1991). Variability in morphological characters of different taxons of the genus *Stylosanthes* was studied by Battistin and Martins (1988), and they found that variation within and between species was high, indicating a high capacity for adaptation to different environments.

*Stylosanthes guianensis* commonly known as stylo, is native to Latin America (Mohlenbrock, 1963). It is now wide spread in the tropics and naturalized as a pasture plant in many countries, including Hawaii, Fiji, Malaya, India, and

some African countries such as Kenya, Nigeria, Uganda, Ethiopia, and Zimbabwe (Grof, 1970). Whereas *Stylosanthes hamata* occurs mainly in the West Indies, in the Caribbean area generally, and in coastal areas of Venezuela and Colombia bordering the Caribbean, it also occurs in coastal areas of Southern Florida in the United States. It is now spread in tropical African countries where it is grown as fodder bank (Mohammed-Saleem and Von Kaufmann, 1986; Skerman, 1988).

In Australia , where *Stylosanthes* species are grown widely, Anthracnose, head blight and web blight cause most of the losses in *Stylosanthes*, particularly in seed crops grown in wet regions on the coast or table lands (O'Brien and Pont, 1977). Anthracnose is caused by *Colletotrichum gloeosporioides*, head blight by *Botrytis cinerea*, and web blight by *Rhizoctonia* spp. An obvious method of control is to avoid planting species of *Stylosanthes*, particularly for seed, in such areas. On stylo cultivars (*Stylosanthes guianensis*), both anthracnose and web blight are not as severe as Townsville stylo (*Stylosanthes humilis*) and Caribbean stylo (*Stylosanthes hamata*), while all presently grown *Stylosanthes* species are susceptible to head blight.

Multi-locational analysis of adaptability and yield stability index study conducted in Colombia by Pizarro et al. (1985) concluded that *Stylosanthes guianensis* had a wide adaptability, high productivity and capacity to

respond to quality changes of the environment.

### 2.2.1 Herbage dry matter yield of *Stylosanthes* species

Herbage dry matter (DM) yield of *Stylosanthes guianensis* and *Stylosanthes hamata* ranged from 4.18-11.0 and 1-10 t/ha, respectively (Table 2). Blouard and Thuriaux (1962) recorded no significant differences in yield from four cutting regimes over 24 months in Zaire. The average annual yield from four cuts over 24 months was 7281 and 6785 kg/ha/year when cut every three months and 6845 and 6529 kg/ha/year when cut every 4.5 months at 15 and 25 cm, respectively. In Costa Rica *Stylosanthes guianensis*, did not recover in time for cutting at 3 weeks (Villarreal and Chavez, 1991). The highest DM production was obtained at 12 weeks of growth (Costa et al., 1991).

### 2.2.2 Nutritive value of *Stylosanthes* species

Crude protein figures for *Stylosanthes guianensis* range from 12.1 to 18.1 percent for the whole plant (Cameron, 1985; Skerman, 1988). Van Rensburg (1967) recorded 7.9 percent for the stem and 13.6 percent for the leaf. Crude fibre figures ranged from 21.7 to 37.7 percent. Milford (1967) recorded 11.8 percent crude protein with a digestibility of 52.6 percent, and 37.7 percent crude fibre with a digestibility of 42.2 percent. The digestibility of the dry matter was 48.4 percent and voluntary intake of dry

Table 2: Dry matter yield of *Stylosanthes guianensis* and *Stylosanthes hamata* in some tropical countries.

Species	Country	DM yield (t/ha/year)	Source
<i>S. guianensis</i>	Brazil	15-20	Otero (1952)
	Zaire	35	Risopoulos (1966)
	Madagascar	43-70	Grainer (1965)
	Fiji	4.18	Payne et al. (1955)
	Zambia	4.6	Van-Rensburg (1967)
	North Queensland	11.0	Gilchrist (1967)
	India	7.5-10.0	Chatterjee et al. (1985)
	<i>S. hamata</i>	India	7.23-10.0
Ghana		1.0-1.2	Barnes and Addo-Kwafo (1996)

matter  $33.9 \pm 4.3$  g/kg liveweight per day, the lowest of the tropical legumes tested. The plant material tested was green, fairly stemy, unfrosted and seeding freely, growing at lawes, Queensland. Risopoulos (1966) in Zaire recorded a range of 15 to 17 percent crude protein, 33 to 40 percent crude fibre. Nwosu (1960) in Nigeria prepared a meal with 17.17 percent crude protein and 28.9 percent fibre.

For *Stylosanthes hamata*, protein levels are reasonable and greater than 10 % (Macala and Kiflewahid, 1996). *In vitro* digestibility are in the order of 60 to 65 percent (Skerman, 1988). The phosphate level of the forage however depend on the status of the soil in which the stylo is growing. On low phosphate soils, low levels of forage P can be expected, especially towards maturity.

### 2.2.3 Seed production of *Stylosanthes* species

Seed production of *Stylosanthes guianensis* is heavy, but shed on ripening rendering only a fraction of the seed to be mechanically harvested. Risopoulos (1966) recorded 100 to 200 kg/ha in Zaire, and at the IRI Research Inistitute at Campinas, Brazil, the yield was about 100 kg/ha (Skerman, 1988). In North Queensland, yields averaged 90 to 100 kg/ha, reaching up to 330 kg/ha (Gilchrist, 1967). In india 300 to 400 kg/ha has been recorded (Chatterjee et al., 1985).

For *Stylosanthes hamata* yields of up to 700 kg/ha have

been obtained for seed in the pod in North Queensland for 'Verano'. Normal commercial yields are in the range of 300 to 600 kg/ha (Skerman, 1988).

Seed production in *Stylosanthes* species is affected by season (Ciotti, 1986). Flowering time is an important attribute of potential pasture plants, early flowering being desirable to allow plants to set seed before the end of the growing season. In *Stylosanthes* the time at which flowering commences is often related to day length ('T Mannelje, 1966, Cited by Burt et al. (1970)). Spike density was positively related to number of long days, which favoured first flower appearance on the terminal apices of lateral rather than of main shoots (Trongkongsin and Humphreys, 1988a).

Levels of hard seededness in commercial seed lots of *Stylosanthes* species in Australia varied from 0 to 98 %, but there were substantial proportions of hard seed in some seed lots of all species. Immersion of seed pods in boiling water for 1 minute resulted in almost complete break down of hard seededness in all species. In *Stylosanthes hamata* this generally resulted in reasonable germination (> 60 %), but in *Stylosanthes guianensis*, *Stylosanthes scabra* and *Stylosanthes humilis* it was accompanied by death of many seeds (McIvor and Gardener, 1987).

### 2.3 Effect of fertilizer application on forage crops

Nutrients obtained from the soil and applied fertilizers are among the limiting factors which impose restrictions on plant growth and development, and potential yields. Each nutrient plays a different role and successful forage production requires adequate supplies of all the essential elements. However, N and P are among the nutrients deficient in tropical soils and hence limiting the growth of both forage grass and legumes (Woodhouse and Griffith, 1973; Blair-Rains, 1986).

Nitrogen is extremely vital in both forage quality and yield. It is a major constituent of proteins, and the chlorophyll of green plants is a nitrogenous compound (Woodhouse and Griffith, 1973). It is therefore essential for photosynthesis, growth and reproduction.

Phosphorous also plays a vital role in both plant and animal growth. In plants it is required in photosynthesis, transfer of energy within the plant, and the synthesis and breakdown of carbohydrates (Woodhouse and Griffith, 1973). It makes up a large part of the nucleus of the plant cell and also present in the cytoplasm. It is a key nutrient in growth and cell division and tends to be concentrated in young, actively growing tissues. Since these tissues are generally the most palatable and nutritious, high-quality forage requires an adequate supply of P.

Inadequate level of N and P in the soil contributes to

the poor nutritional status of forage crops and frequently restricts animal carrying capacity. As a result the need for P, especially in combination with N, would appear to be greater than is commonly supposed (Whyte, 1964). Here P is important to legumes not only in improving their yield, nodulation and feeding quality, but also in improving soil fertility and the yield of subsequent crops. Hence one can expect that output of grasslands and grazing lands can be increased by application of fertilizers (Crowder and Chheda, 1982). The magnitude of increase is influenced by the climatic and edaphic factors and their interaction with species composition of the grazing lands. Sizable amounts of nutrients are needed for maximum herbage yields and often exceed that which most soils can supply, especially under intensive management systems.

Some soils are found to be low in available plant nutrients so that improved pasture plants can not be established until deficiencies are remedied. On soils with higher fertility it is possible to develop improved pastures without applied fertilizers, but even then nutrient deficiencies eventually limit growth of plants.

The quantity of nutrients available in the soil for plant use varies by itself with soil type, available moisture, temperature, microbiological activity and previous use of the land. The extraction of nutrients from the soil is roughly proportional to the yields of herbage,

but is also a function of the chemical composition of the herbage. Method of utilization will also determine whether the removed nutrient is eventually returned to the soil as in the case of grazing or completely lost under cutting conditions.

With respect to seed production, generally the use of excessively high levels of fertilizer is usually economical for pasture seed crops (Humphrey, 1979). The highest fertilizer application increased growth and proved to be more effective than inoculation in Brazil for *Stylosanthes guianensis* (Xavier et al., 1990). Fertilization practice which give good vegetative growth of tropical forage crops will usually give high seed yields, if the development of the crop to maturity is not interrupted by drought or frost.

### **2.3.1 Nitrogen fertilizer application to forage crops**

The response by forage grasses to applied N in terms of increased yield and chemical composition is well known and documented in the tropics (Grof and Harding, 1970; Hendy, 1972; Crowder, 1974; Crespo et al., 1975 and Crowder, 1977). Differences in response to applied N in terms of dry matter production are due to factors such as species, stage of growth, amount and time of N applied, soil moisture and climatic conditions. Notable yield increase of dry matter have been recorded under humid or irrigated conditions.

There is little or no response to applied N in the arid and semi-arid regions found in many parts of the tropics and sub-tropics. Probably soil moisture is the most limiting factor in these areas.

Tropical legumes for seed production usually show an economic response to applied N in the establishment year from 11 to 110 kg/ha , according to the species (Skerman, 1988). On poorly drained land, a slow release fertilizer is advisable.

Legumes may supply considerable amounts of N to pastures by N<sub>2</sub> fixation, but top dressing of N fertilizer is carried out on mixed grass-legume pasture in order to improve herbage dry matter yield. It is known that both nodulation and N<sub>2</sub> fixation in legumes are inhibited under high availability of N (Raggio and Raggio, 1962) and the application of N also reduces the proportion of white clover, in mixed grass-white clover (*Trifolium semipilosum* Fres.) pasture (Sugawara et al., 1994). However, such responses to N vary with species, cultivar, Rhizobium strain and time of N application (Frame and Newbould, 1968). Low temperature also limits the rate of symbiotic N fixation in the root nodules of legumes, which in turn limits herbage yield in winter (Bolland, 1985). In contrast, as temperatures increases in spring, the rate of N fixation no longer limits herbage production in legumes, and subsequent seed yields are similar in the presence or

absence of N fertilization.

For N fixing legumes, P is required in the early stages of growth as it enhances numbers, weight and leg-haemoglobin content of nodules as well as shoot weight (Toothill, 1986). Akeampong and Mamo (1994) concluded that seedling of *Sesbania sesban* benefit from application of P depending on the initial soil P status. However, there is little advantage of P fertilization in a soil which is low in N to meet the requirement of the seedling. In such a case, a starter dose of N is required for good establishment and growth of *Sesbania sesban*. In Cuba, Tang and Menendez (1987) conducted an experiment on two *Stylosanthes guianensis* cultivars (Congo and CIAT-184) inoculated with 3 *Rhizobium* strains (IH-21, IH-101 and CIAT-71) and 0 or 150 kg N/ha application. Here total DM yields ranged from 13.71 t/ha with *Rhizobium* strain IH-101 to 16.59 t/ha with N in CIAT-184. Total N yields ranged from 282.3 kg/ha with IH-21 to 366.2 kg/ha with N in Congo and from 301.2 kg in CIAT-71 to 421 kg with N in CIAT-184. Similarly Wellving (1984) recommended low rates of N as optional for young swards of *Macroptilium atropurpureum* (siratro) and stylo in Zambia.

In a drought year, high levels of N fertilizer will grow a leafy crop which exhausts soil moisture earlier, and drought stresses may be accentuated during flowering and seed maturation. On the other hand, in a very wet year high

levels of N may cause the crop to lodge on the ground, making the seed difficult to recover. On soils where N is readily leached, care should be taken to ensure that N nutrition is satisfactory during the period of inflorescence development after flower initiation has occurred within the leaf sheath.

**a) Effect of nitrogen fertilizer application on seed  
production of forage crops**

Nitrogen availability is a dominant factor controlling the rates of the various processes which result in seed formation. Positive responses to N have been recorded in many tropical grass seed crops (Humphrey, 1979). N-fertilization is shown to be the most effective way of substantially increasing seed yields of grasses when moisture and other nutrients are not limiting (Chadhoker and Humphreys, 1970, 1973; Boonman, 1972a, 1972b, 1972c). These should be set against the persistent misconception (Black, 1957, Cited by Humphrey (1979)) that N increases vegetative growth at the expense of reproductive development. Increment is brought about by a higher photosynthetic capacity of a well-grown canopy produced in response to high N supply; or it may also arise from a high proportion of shoots flowering. The latter effect is quite common in tropical grasses and contributes to a greater number of fertile tillers and increased length or

branching of the inflorescence. For example, the proportion of fertile tillers at peak flowering in *Chloris gayana* was reported to be 57 % of the total N treatments, as compared to 7 % in control plots with no N (Henzell and Oxenham, 1964).

Nitrogen fertilizer increased some seed yield components and decreased others in all detailed studies of tropical pasture response cited (Henzell and Oxenham, 1964; Wigg *et al.*, 1973; Stillman and Tapsall, 1976; Humphrey, 1979). For example, seed set may be reduced, particularly at high levels of N applications. Seed weight is not affected, or only marginally altered, by additions of N. Effects on germination percent, which influences the pure live seed yield, appear to be inconsistent (Humphreys, 1979). Stillman and Tapsall (1976) reported increased germination percentage with increasing N applications while other researchers (e.g. Wiggs *et al.*, 1973) noted a decrease. Still others did not observe a clear relationship between germination percentage and N rate (Crowder and Chheda, 1982). In general timing and level of N fertilizer application, and the cultivar used determine which components are increased or not (Humphreys, 1979).

Reproductive stems formation in long-day plants may benefit from an intensification of carbohydrate metabolism. Short-day plants appear to need an intensification of N metabolism for flower formation (Chailakhyan, 1968, Cited

by Humphrey (1979)). Certainly, tropical grasses such as *Paspalum dilatatum*, *Paspalum plicatulum* and *Panicum maximum* flower earlier under high N conditions. Application of N fertilizer to tropical grass seed crops is almost universally profitable; negative effects only occur if a toxic level is applied, if other nutrients are unbalanced, if environmental stresses (drought or frost) preclude seed harvest, or if seed recovery problems (lodging) occur. The safest N application time is early in the life of the crop. Crop growing conditions will modify the effect of N on seed quality, but careful attention to choosing the correct harvest time and to seed grading will ameliorate any negative effects N fertilizer may exert (Humphreys, 1979).

In legume seed crops, application of N fertilizer during the later development phase increased seed yield from 21 to 31 percent, according to timing (Table 3). Increment is brought about through increasing effect of N fertilizer on number of raceme per runner and seed size. Similar responses to applied N occurred in seed crops of *Desmodium uncinatum* at the University of Queensland farm, Mt. Cotton (Nicholls et al, 1973, Cited by Humphreys (1979)). Redrup (1965), Cited by Humphrey (1979) reported problems of reduced second year vigour where rates of more than 112 kg N/ha were employed on legume seed crops.

In general, the successful use of nitrogenous fertilizer to legume seed crop requires the control of

other limitations to legume seed production, such as grass and weed invasion, which may be intensified by this

Table 3: Effect of nitrogen treatments on components of seed production of *Desmodium uncinatum*.

Components	Nitrogen treatment			
	N <sub>0</sub>	N <sub>PF</sub>	N <sub>F1</sub>	N <sub>FA</sub>
Runner density (No./m <sup>2</sup> )	206.2	216.0	216.1	205.3
Racemase per runner	5.04 <sup>a**</sup>	6.10 <sup>b</sup>	6.00 <sup>b</sup>	5.30 <sup>a</sup>
Floral node per raceme	13.7	14.2	14.3	14.4
Seeds per floral node	3.31 <sup>b</sup>	2.72 <sup>b</sup>	2.77 <sup>a</sup>	3.37 <sup>b</sup>
Seed size (mg)	3.93 <sup>a</sup>	4.56 <sup>cd</sup>	4.42 <sup>bc</sup>	4.24 <sup>b</sup>
Seed yield (g/m <sup>2</sup> )	179.2 <sup>a</sup>	235.0 <sup>b</sup>	226.3 <sup>b</sup>	217.1 <sup>b</sup>

Source: Gibson and Humphreys (1973), Cited by Humphrey (1979).

\* weekly application of N from pre-flowering (N<sub>PF</sub>), Floral initiation (N<sub>F1</sub>), or floral appearance (N<sub>FA</sub>).

\*\* Figures followed by the same letter do not differ at the 5 percent level.

practice. However, the results of the investigations are sufficiently promising to encourage researchers and skilled seed producers to test this practice.

**b) Effect of nitrogen fertilizer application on herbage DM yield of forage crops**

Favourable environmental conditions, namely irrigation and high temperatures, combined with a soil inherently low in N produced large forage yield responses to applied N (Dowling and Bouma, 1985). Gill (1988) reported better dry matter yields (5.05 t/ha) from *Stylosanthes hamata* plots sown after the monsoon in areas fertilized with NP (20 kg N and 50 kg P<sub>2</sub>O<sub>5</sub>/ha) in contrast to 3.4 t/ha for plots without fertilizer. In another experiment Gill and Patil (1985b) reported herbage dry matter yields of 8.15, 9.81 and 9.27 t/ha for 1 year-old *Stylosanthes hamata* stands fertilized with 2 kg/ha as urea, Zn-coated urea or S-coated urea respectively compared with 7.23 t/ha with out N. Similar results were obtained in field trials conducted at Matanzas, Cuba, on *Stylosanthes guianensis* (Tang et al., 1990). In fact a depressive N effect on the number and dry weight of the nodules was observed (Lopez et al., 1984 ; Tang et al., 1990). All these results reported are in marked contrast to the lack of response found in sorghum by Harms and Tucker (1973) and Wheeler et al. (1980). Nitrogen top dressing has also an advantage by stimulating the plant

to reach maturity age earlier. Mohammed-Saleem (1972) indicated that 4100 kg of herbage DM was produced within 30 days with 75 kg N/ha application while in the absence of N almost 60 days were needed to produce the same amount of herbage.

**c) Effect of nitrogen fertilizer application on the nutritive value of forage crops**

In evaluating N fertilizer trials for pasture crops, dry matter yield is not the only criterion to be considered. crude protein content, fibre percentage, lignin and digestibility of the herbage are also important.

Nitrogen content of herbage is determined by means of chemical analysis, and crude protein calculated by multiplying this value by 6.25. Crude protein yield per unit area of land is often reported along with the yield of dry matter. This is simply a function of dry matter yield and crude protein percentage. Crude protein yields thus increases as dry matter yields increase.

Many researchers have shown that N fertilization increases the crude protein content at any stage of plant growth. Vicente-Chandler et al. (1974) reported from Puerto Rico increased crude protein content from 6.2 percent without N to 10.2 and 12.3 percent with 880 and 1760 kg/ha, respectively, of N applied annually. Feeding trials carried out with herbage of these grasses showed that crude protein

was readily digested by ruminants regardless of the N treatment. Other studies have also shown that crude protein content of grasses rises sharply with increasing levels of N (Chheda and Akinola, 1971; Crespo, 1974; Olsen, 1975). Nitrogen was observed to have the greatest effect on the plant composition relative to other mineral elements in fertilizers; as N increases the protein content, lignin and DM yield (McIlroy, 1962; Vicente-Chandler, 1974; Van Soest, 1994). At the same time this increase in N supply reduces the sugar content because amino acids and proteins are synthesised from sugars (McIlroy, 1962; Van Soest, 1994). Reduction in cell wall (fibre) is positive, while lignification is negative but can be cancelled by the cell wall change. Therefore, changes in digestibility depend on the balance of compensatory factors. Positive (McIlroy, 1962), negative, and insignificant changes in digestibility have been reported in response to N fertilization (Van Soest, 1994). Although increased amount of N and DM yield per ha is expected, on the average, N fertilization tends to reduce digestibility slightly.

### **2.3.2 Phosphorus fertilizer application to forage crops**

Phosphorus, like N is the most important nutrient in the successful establishment of forage legumes. In addition to its effects on dry matter yield of forage legumes, P often increases nodulations and hence increases N or crude

protein (Mohammed-Saleem and Von Kaufmann, 1986), P concentration or uptake by the plant.

A principal limitation to the successful establishment of legumes in the tropics is the widespread low P content of the soil (Blair-Rains, 1986). Many soils are heavily leached and highly acidic, being low in Ca as well as P. However, tropical legumes can tolerate high Ca:Mg ratios where the aluminium content is not sufficiently high so as to restrict root development (Crowder and Chheda, 1982).

For the development of a legume or legume-grass pasture it is imperative that phosphate be applied before or at the time of sowing. The quantity needed will vary with the legume species, however, higher quantities will be needed on soils having a high P-fixing capacity.

**a) Effect of phosphorus fertilizer application on seed production of forage crops**

The relationship between seed yield and amount of P applied is inconsistent. Bolland (1985), Rai and Kanodia (1980) found a linear relationship between seed yield and level of P applied. Seed yield increased by 7 to 24 kg/ha for each kg of applied P/ha for legumes. This depends on species, strain or cultivar, and location. The results are site specific, and probably also specific to a given season or year. Similarly in Nigeria, application of P for *Stylosanthes hamata* pasture gave improved seed production

(Mohammed-Saleem and Von-Kaufmann, 1986). Increase in seed yield due to application of P was also reported in *Dolichos lablab* by Verma (1975), in *Macroptilium atropurpureum*, *Stylosanthes humilis* and *Stylosanthes gracilis* by Rai and Kanodia (1980). In contrast Quinlivan et al. (1973) found a curvilinear relationship between seed yield and applied P. Seed yield responses declined with increasing P. In India there were no significant difference in seed yield of *Stylosanthes* species due to the application of 40 or 80 kg P<sub>2</sub>O<sub>5</sub>/ha, however, yields were higher with 40 kg P<sub>2</sub>O<sub>5</sub>/ha (Kanodia et al., 1985). The response in seed yield probably vary due to seasonal conditions in the year the seed is produced.

On red-yellow Podzolic soils in Southern Queensland, improved P supply (80 kg P/ha plus 20 kg P/ha annual maintenance) increased the inflorescence density of *Desmodium uncinatum*. This resulted in a 35 percent rise in seed yield (Nicholls et al., 1973). Inflorescence density in *Stylosanthes humilis* is also positively related to P addition. In one experiment (Shelton and Humphreys, 1971, Cited by Humphrey (1979)) reported that this effect increased seed yield by 20 percent under conditions where P addition increased yield of plant tops by 54 percent. The importance of P nutrition is often stressed more for the early phases of growth than for the later developmental stages (Humphrey, 1979). *Stylosanthes humilis* shows a

remarkable capacity to transfer P and sulphur from leaf and other tissue to meet the requirements of the developing seed (Robinson and Jones, 1972, Cited by Humphrey (1979)).

The time for appearance of first flowers (maturity grading) varied in tropical legumes between species, strain and cultivar, but was unaffected by P applications (Bolland, 1985). This result contrast with that of Rossiter (1978), who noted that, for moderately dense subterranean clover (*Trifolium subterraneum*) swards grown in boxes, P deficiency delayed the time of commencement of flowering. This is in agreement with what Humphreys (1979) reviewed that P is a very common deficiency and is almost universally associated with delayed flowering.

**b) Effect of phosphorus fertilizer application on herbage**

**DM yield of forage crops**

Phosphorus is important for successful establishment of forage legumes. It has a positive effect on the dry matter yield of forage legumes (Mohammed-Saleem and Von Kaufmann, 1985). In a field trial conducted in India, Mariyappan et al (1987) applied different levels of  $P_2O_5$  (0, 40, 80, 120 and 160 kg  $P_2O_5$ /ha) and 0 or 500 kg CaO/ha to *Stylosanthes gracilis* (*Stylosanthes guianensis*). Green fodder yield increased with increasing P up to 80 or 120 kg  $P_2O_5$ /ha, irrespective of lime application, and reached a maximum of 22.59 t/ha without lime or 21.47 t/ha with lime. But Crespo

and Curbelo (1990) conducted a green house experiment to estimate the response of *Stylosanthes guianensis* to different levels of P (0, 20, 40, 80, 160 and 320 kg P/ha), and they found maximum dry matter yield from pots receiving P at 23.3 kg/ha. In this experiment critical minimum P concentration in the plant amounted 0.16 %, while P phytotoxicity symptoms were present when 320 kg P/ha were applied and a P content of 0.71 % was attained. This finding is in agreement with what Bruce and Teitzel (1978) reported for granitic sand soil in Australia, that maximum dry matter yields were achieved with 25 kg P/ha. In another experiment, fertilization of P at doses of 150 units of  $P_2O_5$  per hectare increased about 63.7 % of forage production over the control treatment (Youkeu et al., 1985). In Australia, Dowling and Bouma (1985) did a series of field experiments to evaluate the usefulness of P as a predictor of responses to P application. A close relation ( $R^2 = 0.910$ ) was found between  $P_i$  in healthy green leaf tissue sampled in winter and field responses to P measured at the same time. The mean herbage yields (t/ha) was found to increase as the level of applied P increases (Table 4).

In Nigeria *Stylosanthes guianensis* cv cook responded most to increasing levels of P up to 80 kg  $P_2O_5$ /ha (Mohammed-Saleem and Von Kaufmann, 1986). Here nodulation was not affected by P application for the verano cultivar but there was a marked effect in the cook and schofield

Table 4: Phosphorus treatment levels (equivalent to kg/ha of single superphosphate) and mean herbage yields (t/ha) in the seven experimental sites conducted in Australia.

Phosphorus level (kg/ha)	mean herbage yield (t/ha)
50	2.14 ± 0.75
150	4.04 ± 1.05
300	5.0 ± 0.91
600	5.7 ± 0.92
1000	6.01 ± 0.93

Source : Dowling and Bouma, 1985.

cultivars. The same authors reported in the second year of the experiment, when no P was applied that productivity of cook and schofield declined by 60-70 %, but verano was only slightly affected. In Brazil, Guss *et al.* (1990) found shoot dry matter yield increase with increasing P rate for *Stylosanthes guianensis*. However, the lowest P use efficiency had been recorded for *Stylosanthes guianensis* as compared to *Neonotonia wightii*, *Centrosema* species cv EPAMIG 1111, and *Stylosanthes bracteata*. Application of P fertilizer is also known to increase both grass and legume yields in a mixed sward (Ranacou, 1986).

The effect of P application on nodule number and weight seems advantageous. But the effect of P on total N content of soil is inconsistent. Mohammed-Saleem and Von

Kaufmann (1986) reported that P application and legume growth increased soil organic C and N which suggest possibilities for enhancing integrated crop-livestock systems. However, Mariyappan *et al.* (1987) found no significant effect of P on total soil N.

**c) Effect of phosphorus fertilizer application on nutritive value of forage crops.**

Application of P often increases nodulation of forage legumes and hence increases N or crude protein (Mohammed-Saleem and Von Kaufmann, 1986) and P concentration or uptake by the plant. Phosphorus application may also increase the digestibility of herbage dry matter (Haque *et al.*, 1986; and Mohammed-Saleem and Von Kaufmann, 1986).

**2.4 Harvest time of tropical pasture crops**

Tropical pasture crops are often exposed to adverse climatic conditions which may result into rapid changes in quality. In addition because of the wild nature of these crops, flowering time and hence maturity is not synchronized which makes harvesting for both fodder and seed difficult (Humphrey, 1979; Van Soest, 1994; Chatterjee and Das, 1989). Therefore, identification of optimum harvesting time for each species in a given locality is believed to compromise the quality issue and the amount

produced of both fodder and seed from these crops.

#### 2.4.1. Effect of harvest time on seed production of forage crops

Experimental findings has shown that harvesting of pasture seed too early, will affect the pure live seed yield due to a high proportion of immature seeds. When delayed too long, large quantities of seed are shed on the ground (Crowder and Chheda, 1982). The capacity to germinate deteriorates rapidly during storage in many species when the seeds are harvested immature (Brzostowski and Owen, 1966). A 6-7 weeks interval between initial flowering date and optimum harvest date have been observed in *Setaria anceps*, *Chloris gayana* and *Panicum coloratum*. The maximum percentage of pure live seed was at a later stage than maximum yield of clean seed (Boonman, 1972a). Contrary to the common belief, considerable shattering of spikelet can be tolerated in many grass species (normally 20-30 %) without significant reduction in the pure live seed yield.

Harvest date is critical in species that have a defined peak of flowering and in those that shatter easily. Such species should generally be harvested about 3-4 weeks post peak flowering. A delay in harvesting by 1 week from the optimum date (3 weeks after peak flowering) reduced seed yield of *Stylosanthes guianensis* by 25 per cent (Loch et al., 1976).

Judging the correct harvesting time of tropical pasture seed crop has special difficulties. Many species flower over a long period, producing inflorescence with seed which ripens unevenly and falls as it ripens (Humphrey, 1979).

Maki et al. (1967), Cited by Maki et al. (1970) studied various agronomic traits which influence seed yield and concluded that the most important characters influencing seed yield seemed to be weight of 100 spikes and seed weight of 100 spikes in timothy, and panicle number in orchard grass. In the first harvest year both total weight and seed weight of 100 spikes of timothy decreased with later dates of harvest. In the second year there was a significant effect of harvest dates on the inflorescence number of timothy (*Phleum pratense*) which may be caused by the losses of the inflorescence resulting from lodging with later dates of harvest. Thus, Maki et al. (1970) suggested autumn defoliation followed by fertilization as a method to increase tillering and increase both yield and seed weight of 100 panicles. Spike density was also positively related to number of long days, which favoured first flower appearance on the terminal apices of lateral rather than of main shoots (Trongkongsin and Humphreys, 1988 and Humphrey, 1988a).

#### 2.4.2 Effect of harvest time on herbage DM yield of forage crops

Dry matter yield, crude protein percentage and *in vitro* digestible dry matter contents of herbage is known to increase with increasing date of harvest or interval between harvest in case of perennial crops. Mufandaedza (1976) did an experiment on the effects of frequency of cutting on various strains of *Stylosanthes guianensis*. He found increased dry matter yield of herbage with increasing interval between harvest (2-, 4-, 8- and 16- week-intervals). Brolmann and Boman (1988) examined yield of *Stylosanthes guianensis* under 6 harvesting regimes in United State of America (USA). A single harvest at the end of the growing season yielded the highest dry matter accumulation. Frequent cutting reduced the cumulative yield by more than 50 % for most accessions. The decrease under the frequent harvesting was related to slow growth. Yield of some accessions was increased 10-fold when cutting was deferred until the end of the growing season.

In another study conducted by Xande *et al.* (1989) on the growth of *Stylosanthes guianensis cv schofield* cut for hay at different stages, increased dry matter yield with delay cutting was observed on a curvilinear basis, increasing sharply between 70 and 80 days. In the same study the percentage of leaves for *Stylosanthes guianensis* was greater in the dry season (41 %) than in the wet season

(30 %). The relationship between time of flowering (a good indicator for the growth stage of the plant) and dry matter production, was however, not consistent in Puerto Rico (Ramos-Santana and Tergas, 1990).

#### **2.4.3 Effect of harvest time on nutritive value of forage crops**

Several studies have shown that the digestibility of forage plant parts decrease with maturity, and that this is correlated with increasing lignin content (Christian et al., 1970; Minson, 1990). Nevertheless, there are important exceptions. Soybean hulls and maize bran are relatively devoid of lignin and are highly digestible. Individual forages vary in the degree to which they decline in value with age, the effect being in part related to maturity (development, heading, seed production) and in part to the environment in which the plant is growing. Plants that remain vegetative over a longer period may not decline in quality (Van Soest, 1994).

The effect of age of cutting on % N and N yield is negatively related and inconsistent. Grof et al. (1970) found significantly greater N yields in plant tops under 6- and 12-week cutting than 18-week defoliation treatment. Similarly 4 times cutting after 30 days intervals gave slightly lower fodder yields, higher protein yields and a lower number of root nodules than 3 times cutting at 45

days interval after a uniform cut of 90 days after sowing (Mariyappan *et al.*, 1987). Xande *et al.* (1989) found a decline in N content with increased age of cutting. In the same experiment organic matter digestibility by sheep was not affected by age of cutting.

Clements (1970) suggested that % N and digestibility are negatively associated with yield at pre-flowering stages and also that quality of dead herbage after seed dispersal may be virtually unrelated to yield at any preceding stage. Therefore, selection for late flowering or summer green leaf yield would be beneficial. However, neither of these approaches is relevant to the dry-season pasture, where the diet consists of standing dead herbage and where late flowering and summer growth may well prejudice plant survival.

## CHAPTER III

## 3.0 MATERIALS AND METHODS

## 3.1 Experimental site

The field experiment was conducted at Magadu Dairy Farm Unit, from February to August 1996. Magadu dairy farm unit is an area within the campus of Sokoine University of Agriculture (SUA). The University is situated between 6 and 7° South, 37 and 38° East at an altitude of 500 m above sea level. The soil of the experimental site is sandy clay in textural class. It is slightly acidic to near neutral pH, low in total N, Bray P and has fair cation exchange capacity (Table 5).

The area experiences a bimodal rainfall regime with short rains during November and January, and the long rains during March to May. The annual rainfall varies between 600-1000 mm with an average of about 860 mm. Two distinct seasons are identified: December to May as wet season and June to November as dry season.

## 3.2 Experimental species

The study was conducted using *Stylosanthes guianensis* cv cook ILCA No.4 and *Stylosanthes hamata* cv verano ILCA No. 75. These two species were selected in this particular study because of their adaptation and well known performance in other similar agro-climatic zones, such as the sub-humid mid altitude parts of Ethiopia and Nigeria.

Table 5: Initial soil analysis data of the experimental site (December, 1996).

Parameters considered	Result
pH in H <sub>2</sub> O (1:2.5 Ratio)	6.7
pH in CaCl <sub>2</sub> (1:2 Ratio)	5.2
pH in KCl (1:2.5 Ratio)	6.1
% Organic Carbon	1.38
% Nitrogen	0.11
P Bray ppm	2.22
Exchangeable bases me/100 g	
CEC me/100 g	12.0
Na <sup>+</sup> (Exchangeable)	0.774
Ca <sup>++</sup> (Exchangeable)	4.62
Mg <sup>++</sup> (Exchangeable)	3.1
K <sup>+</sup> (Exchangeable)	0.308
% Sand	45
% Coarse Silt	2
% Fine Silt	12
% Clay	41
Textural Class	Sandy Clay

### 3.3 Experimental treatments

For each *Stylosanthes* species two separate field experiments were conducted using a split-plot design.

Four different fertilizer combinations, composed of N and P at two rates (0 and 30 kg/ha) were randomly allocated as a main-plot treatment for both *Stylosanthes* species in experiment I (Table 6). In the second experiment four levels of P (0, 30, 60 and 90 kg/ha) were randomly allocated as a main plot treatment (Table 6). Since two of the fertilizer treatment combinations (B & D) were the same type the second one was excluded in the actual field work (App.Fig. 1.1 and App.Table 1.2).

Five different harvesting times for seeds were applied for both *Stylosanthes* species as shown in Table 7 for both experiment I & II. These were replicated three times.

### 3.4 Experimental design

A total of 2150 m<sup>2</sup> area was used for the experiment. This area was divided into 30 plots for each species which was replicated 3 times. The plot size was 2 \* 3 m with 0.8 m path between plots and 1 m between replicates. A 3 m wide passage between the two pasture species was kept. 40 cm spacing was used between rows and the seeding rate was 6 kg/ha for both species.

Table 6: Description of main-plot treatments applied in experiment I and II for both *Stylosanthes* species.

Main plot treatment number	code	Description
Experiment I		
1	A ( $N_0P_0$ )	0 Kg N/ha + 0 kg P/ha
2	B ( $N_1P_0$ )	30 kg N/ha + 0 kg P/ha
3	C ( $N_0P_1$ )	0 kg N/ha + 30 kg P/ha
4	D ( $N_1P_1$ )	30 kg N/ha + 30 kg P/ha
Experiment II		
1	B ( $N_1P_0$ )	30 kg N/ha + 0 kg P/ha
2	D ( $N_1P_1$ )	30 kg N/ha + 30 kg P/ha
3	E ( $N_1P_2$ )	30 kg N/ha + 60 kg P/ha
4	F ( $N_1P_3$ )	30 kg N/ha + 90 kg P/ha

In the actual field work six different fertilizer combination treatments (A, B, C, D, E and F) were randomly assigned to a group of five consecutive sub plots as a main plot treatment. The main-plots were further divided into 5 sub-plots to be harvested at 50 % flowering, 4<sup>th</sup>, 5<sup>th</sup>, 6<sup>th</sup> and 7<sup>th</sup> week post 50 % flowering. This design gave different schedules of harvesting as shown on Table 8.

Table 7: Description of sub-plot treatments applied in experiments I & II for both *Stylosanthes* species.

Sub-plot treatment number	Description
1	Harvesting at 50 % flowering
2	Harvesting 4 weeks post 50 % flowering
3	Harvesting 5 weeks post 50 % flowering
4	Harvesting 6 weeks post 50 % flowering
5	Harvesting 7 weeks post 50 % flowering

Table 8: Date of harvesting of *Stylosanthes hamata* and *Stylosanthes guianensis* used in the field experiment.

Species	Fertilizer treatment	Harvesting date (Age in weeks post 50 % flowering)				
		0	4	5	6	7
<i>S. hamata</i>	A (N <sub>0</sub> P <sub>0</sub> )	7 Apr	5 May	12 May	19 May	26 May
	B (N <sub>1</sub> P <sub>0</sub> )	7 Apr	5 May	12 May	19 May	26 May
	C (N <sub>0</sub> P <sub>1</sub> )	5 Apr	3 May	10 May	17 May	24 May
	D (N <sub>1</sub> P <sub>1</sub> )	7 Apr	5 May	11 May	19 May	26 May
	E (N <sub>1</sub> P <sub>2</sub> )	7 Apr	5 May	11 May	19 May	26 May
	F (N <sub>1</sub> P <sub>3</sub> )	6 Apr	4 May	11 May	18 May	25 May
<i>S. guianensis</i>	A (N <sub>0</sub> P <sub>0</sub> )	15 June	13 July	20 July	27 July	3 Aug
	B (N <sub>1</sub> P <sub>0</sub> )	7 June	5 July	12 July	19 July	26 July
	C (N <sub>0</sub> P <sub>1</sub> )	28 June	26 July	2 Aug	9 Aug	16 Aug
	D (N <sub>1</sub> P <sub>1</sub> )	7 June	5 July	12 July	19 July	26 July
	E (N <sub>1</sub> P <sub>2</sub> )	28 June	26 July	2 Aug	9 Aug	16 Aug
	F (N <sub>1</sub> P <sub>3</sub> )	22 June	20 July	27 July	3 Aug	10 Aug

### 3.5 Sampling and measurements

#### 3.5.1 Determination of 50 % flowering stage

Four plants per sub-plot were identified and marked for monitoring. These plants were identified using a systematic random sampling procedure from the middle four rows using a 2 m rope marked at 62.5, 87.5, 112.5, and 137.5 cm for the first, second, third and fourth rows respectively. The marked plants were tagged by using a sisal fibre string at the first day of blooming. These plants were daily monitored for flower appearance until date of 50 % flowering stage was established in both *S.hamata* and *S.guianensis* receiving different fertilizer combination treatment (Main-plot treatment).

#### 3.5.2 Seed yield

A quarter of a plot was considered for the determination of seed yield. The total biomass of the plant including the inflorescence (head) were cut using a knife at ground level. The whole fresh weight was recorded. From this a sub-sample composed of 15 randomly picked plants were taken to establish a harvesting index (seed to above total ground biomass in %) and moisture determination. Seed yield per plot was calculated by multiplying harvesting index with total biomass produced per plot on DM basis.

### 3.5.3 Non-seed dry matter yield.

A quarter of a plot was considered for the determination of non-seed residue produced. The same procedure was followed as 3.5.2 to obtain harvesting index. The index was used to determine the non-seed dry matter yield produced per plot.

### 3.5.4 Leaf:stem ratio

Depending upon the sub-plot treatment plots were receiving as shown in Table 8, all plants considered for determination of 50 % flowering stage were harvested and bulked together to make a bulk sample of 4 plants per plot. This was sorted out into leaf (including the petiole) and stem to determine the leaf:stem ratio.

### 3.5.5 Climatic data

Data on temperature, rainfall and evaporation were obtained from the meteorological station situated within the University which is about 1500 m from the experimental site. The pattern of average rainfall, evaporation and temperature for the past 24 years and during the experimental period, i.e. January to August is shown in Fig. 1 and Fig. 2, respectively. The trend showed that 1996 was an average year.

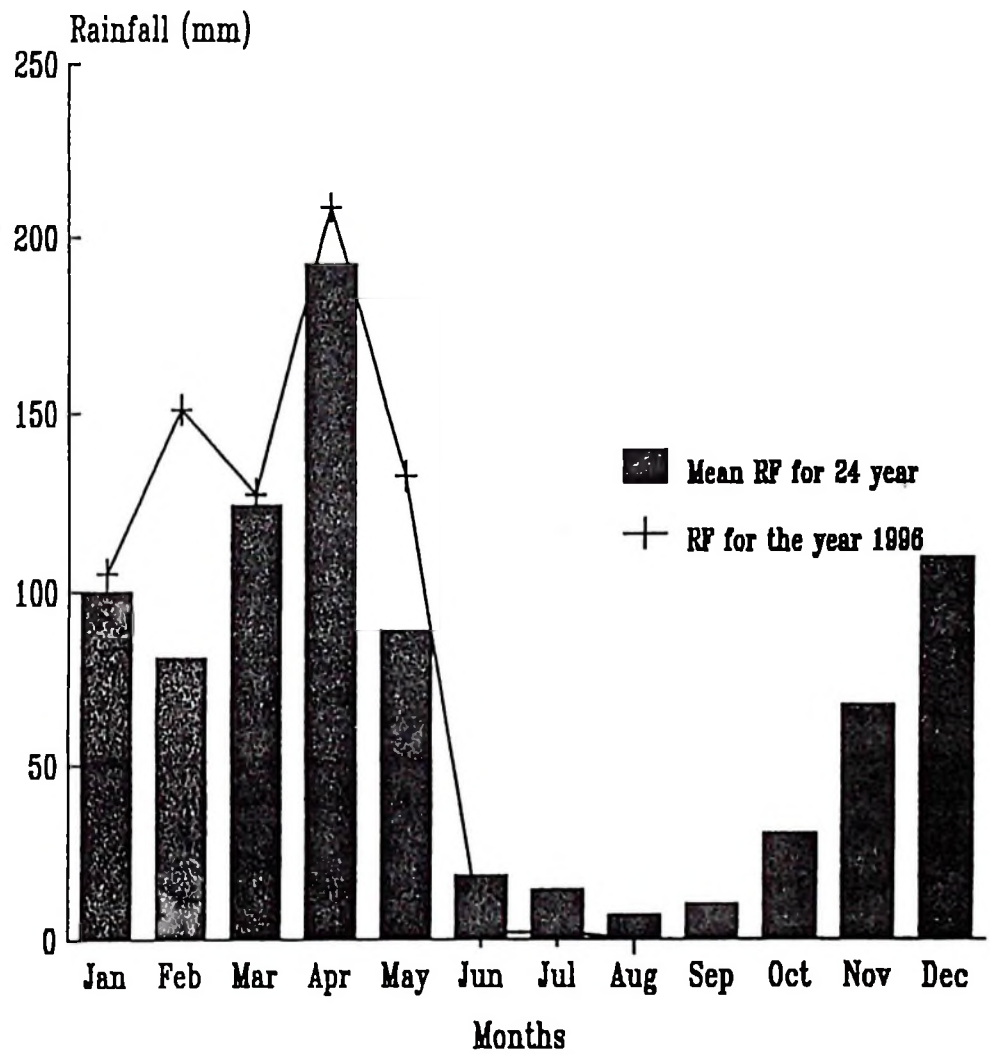


Figure 1: Rainfall pattern for 24 year average and 1966 growing season at SUA meteorological station;

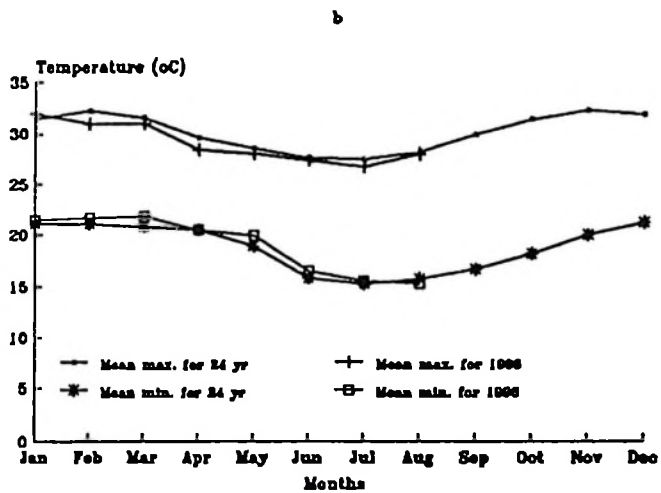
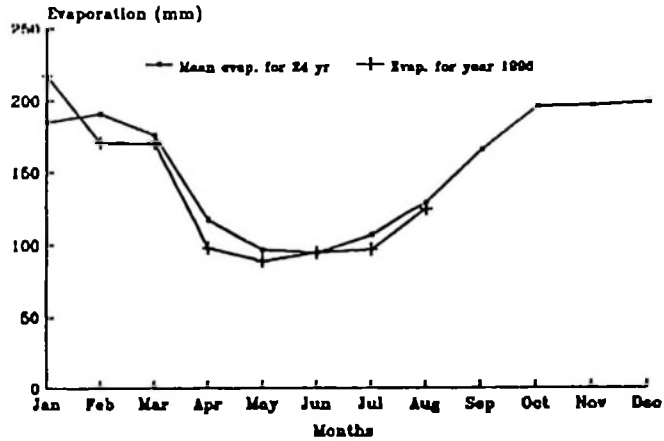


Figure 2: Mean evaporation (a) and temperature (b) for 24 year average and 1996 growing season at SUA.

### **3.6 Laboratory analysis**

#### **3.6.1 Seed quality analysis**

Seed quality analysis were done at a laboratory of the Ministry of Agriculture (Tanzanian Official Seed Certification Agency) located within SUA campus. A representative sub-sample obtained from each plot was analyzed for moisture and germination percentage following the procedure described by International Seed Testing Association (1985).

#### **3.6.2 Chemical analysis of non-seed residue**

All analysis were carried out at Sokoine University of Agriculture, Department of Animal Science & Production. Dry matter, ash and total N were determined by standard procedures (AOAC, 1985). Acid detergent fibre (ADF) and acid detergent lignin (ADL) were determined according to Goering and Van Soest (1970).

#### **3.6.3 Digestibility**

The two stage technique according to Tilley and Terry (1963) was used in determination of *in vitro* dry matter (IVDMD) and Organic matter digestibility (IVOMD) of non-seed residue produced from each plot. Digestible crude protein (DCP), metabolizable energy (ME) and rumen Microbial N requirement were calculated for each plot using

the following equation:-

$$\text{DCP} = (\text{CP (g/kg DM)} * 0.9115) - 36.7 \text{ (MAAF, 1975)}.$$

$$\text{ME} = 0.16 * \text{DOMD} \%$$

$$\text{Where, DOMD} \% = 0.92 * \text{IVOMD (MAFF, 1975)}.$$

Microbial N requirement = 1.25 g N/ME assuming 90 % of a feed N is available (ARC, 1980).

### 3.7 Economic analysis of fertilizer application

Seed yield and herbage DM yield produced from both *Stylosanthes* species pooled across replication and different times of harvest were utilized for both experiment I and II separately to calculate additional profit/loss in terms of Tanzanian Shilling (Tsh) due to application of fertilizers. The following cost were considered in the partial budget analysis in this particular study:

Cost of TSP fertilizer 15 000 Tsh/50 kg (Assuming that 48 % of TSP will be P). This gives 625 Tsh/kg P.

Cost of Urea 10 000 Tsh/50 kg (Assuming that 48 % of Urea will be N). This gives 416.6 Tsh/kg N.

Cost of legume seed 4 000 Tsh/kg (Sarwatt, 1996 personal communication).

Cost of hay 700 Tsh/bale (1 bale approximately equivalent to 15 kg DM) (Aboud, 1996 personal communication). This gives 46 Tsh/kg of DM.

### 3.8 Statistical analysis

The analysis of variance (ANOVA) for testing the effect of N, P and time of harvest effect were done using the General Linear Model (GLM) available in Statistical Analysis System (SAS, 1987). The data represent in general six different N and P fertilizer combination treatments and five different harvesting times of the crop for seed yield and quality, herbage dry matter yield, chemical composition and *in vitro* digestibility parameters.

The analysis involved using a split-plot technique. Nitrogen, P and N-P interaction variables formed the main-plot part in experiment I, and four levels of P (0, 30, 60 and 90 kg/ha) formed the main-plot part in experiment II. Harvesting time and all interactions involving harvesting time formed a sub-plot part. The first two models were used to study the effect of N and P fertilizer on the variables measured. For harvesting time a combined analysis over experiment I and II were employed on the variables measured as shown in model No. 3.

**Model 1**

The effect of N and P fertilizer on seed yield and quality, DM yield, chemical composition, *in vitro* digestibility, DCP and ME were studied using the model below in experiment I.

$$Y_{ijk1} = \mu + A_i + B_j + C_k + (BC)_{jk} + A_i(BC)_{jk} + D_1 + (BD)_{j1} + (CD)_{k1} + (BCD)_{jk1} + e_{ijk1}$$

$Y_{ijk1}$  = A single observation from the  $j^{\text{th}}$  level of N and  $k^{\text{th}}$  level of P assigned to  $l^{\text{th}}$  harvesting date and  $i^{\text{th}}$  replication.

$\mu$  = Over all mean

$A_i$  = The effect of  $i^{\text{th}}$  replication.

$B_j$  = The effect of  $j^{\text{th}}$  level of N.

$C_k$  = The effect of  $k^{\text{th}}$  level of P.

$A_i(BC)_{jk}$  = Error a

$D_1$  = The effect of  $l^{\text{th}}$  harvesting date.

$(BC)_{jk}$  = The effect of  $j^{\text{th}}$  level of N and  $k^{\text{th}}$  level of P interaction.

$(BD)_{j1}$  = The effect of  $j^{\text{th}}$  level of N and  $l^{\text{th}}$  harvesting date interaction.

$(CD)_{k1}$  = The effect of  $k^{\text{th}}$  level of P and  $l^{\text{th}}$  harvesting date interaction.

$(BCD)_{jk1}$  = The effect of  $j^{\text{th}}$  level of N,  $k^{\text{th}}$  level of P and  $l^{\text{th}}$  harvesting date interaction.

$$e_{ijkl} = \text{Error b.}$$

### Model 2

The effect of different levels of P fertilizer on seed yield and quality, DM yield, chemical composition and *in vitro* digestibility, DCP and ME content were studied using the model below in experiment II.

$$Y_{ijk} = \mu + A_i + B_j + (AB)_{ij} + C_k + (BC)_{jk} + e_{ijk}$$

$Y_{ijk}$  = A single observation from the  $j^{\text{th}}$  level of P fertilizer and  $k^{\text{th}}$  harvesting date assigned to  $i^{\text{th}}$  replication.

$\mu$  = Over all mean

$A_i$  = The effect of  $i^{\text{th}}$  replication.

$B_j$  = The effect of  $j^{\text{th}}$  level of P.

$(AB)_{ij}$  = Error a

$C_k$  = The effect of  $j^{\text{th}}$  harvesting date.

$(BC)_{jk}$  = The effect of  $j^{\text{th}}$  level of P and  $k^{\text{th}}$  harvesting date interaction.

$e_{ijk}$  = Error b.

### Model 3

The effect of different times of harvest on seed yield and quality, DM yield, chemical composition and *in vitro* digestibility, DCP content, ME content and Microbial N requirement were studied in combined analysis over

experiment I and II using the following model:

$$Y_{ijk} = \mu + A_i + B_j + (AB)_{ij} + C_k + (BC)_{jk} + e_{ijk}$$

$Y_{ijk}$  = A single observation from the  $j^{\text{th}}$  type of N and P fertilizer combination and  $k^{\text{th}}$  harvesting date assigned to  $i^{\text{th}}$  replication.

$\mu$  = Over all mean

$A_i$  = The effect of  $i^{\text{th}}$  replication.

$B_j$  = The effect of  $j^{\text{th}}$  N and P fertilizer combination.

$(AB)_{ij}$  = Error a

$C_k$  = The effect of  $j^{\text{th}}$  harvesting date.

$(BC)_{jk}$  = The effect of  $j^{\text{th}}$  N and P fertilizer combination and  $k^{\text{th}}$  harvesting date interaction.

$e_{ijk}$  = Error b.

## CHAPTER IV

## 4.0 RESULTS

**General observation on the field experiment**

Planting date of both *Stylosanthes* species were on 15<sup>th</sup> February 1996. This was followed by heavy rainstorm two days after planting. This affected the initial plot cover stand of *S.guianensis* compared to *S.hamata* at germination, and hence replanting of missing rows was employed. Field monitoring of the plants for first date of blooming showed that *S.hamata* and *S.guianensis* had attained this stage at 45 and 75 days after planting regardless of the different fertilizer treatments applied. However, days required to 50 % flowering stage was slightly affected by application of the different fertilizer combinations in both *Stylosanthes* species. Days required to 50 % flowering stage ranged from 50-52 days in *S.hamata* compared to 113-134 days required in *S.guianensis* (Table 9).

Results of analysis of variance in experiment I showed that there was an interaction effect of either N or P with each other or with time of harvest for some studied parameters like leaf:stem ratio, ash percentage and ADF percentage in *S.guianensis* and CP percentage in *S.hamata* (App.Table 2.2 and 3.2). Analysis of variance in experiment II showed that interaction effect was observed for leaf:stem ratio of *S.guianensis* (App.Table 5.2). However, to draw a conclusive picture, combined analysis over experiment I and II was used to study the effect of time of

Table 9: Days required from planting to first blooming and 50 % flowering stage of *Stylosanthes* species as affected by different fertilizer combinations.

Fertilizer combination/Species	Days required to:	
	First blooming stage	50 % flowering stage
<i>S. hamata</i>		
0 kg N/ha + 0 kg P/ha	45	52
30 kg N/ha + 0 kg P/ha	45	52
0 kg N/ha + 30 kg P/ha	45	50
30 kg N/ha + 30 kg P/ha	45	52
30 kg N/ha + 60 kg P/ha	45	52
30 kg N/ha + 90 kg P/ha	45	51
<i>S. guianensis</i>		
0 kg N/ha + 0 kg P/ha	75	121
30 kg N/ha + 0 kg P/ha	75	113
0 kg N/ha + 30 kg P/ha	75	134
30 kg N/ha + 30 kg P/ha	75	113
30 kg N/ha + 60 kg P/ha	75	134
30 kg N/ha + 90 kg P/ha	75	128

harvest on the parameters considered in the study.

#### 4.1 Seed production of *S.hamata* and *S.guianensis*

##### 4.1.1 Effect of N fertilizer application on seed production

Both *S.hamata* and *S.guianensis* did not respond ( $p>0.05$ ) to initial N fertilizer application in terms of seed yield. Harvesting index was also not affected ( $p>0.05$ ) by initial N fertilizer application in both *S.hamata* and *S.guianensis*. However, *S.hamata* plots which received N tends to give higher over all mean seed yield and better harvesting index than the control while *S.guianensis* responded in the reverse order (Fig. 3).

Germination percentage of both *S.hamata* and *S.guianensis* seed was not affected by initial N fertilizer application (Table 10).

##### 4.1.2 Effect of P fertilizer application on seed production

Results from analysis of variance showed that seed yield of *S.hamata* was not affected ( $p>0.05$ ) by P fertilizer application in both experiment I and II (Fig. 4). In contrast, *S.guianensis* responded to P application in terms of seed yield in experiment II (App.Table 5.2). The seed yield of different P levels for *S.guianensis* were 1

Harvesting index of *S.hamata* was not affected by P fertilizer application (Table 11 and 12). However, for

*S. guianensis*, harvesting index significantly increased ( $p < 0.05$ ) in experiment II from 0.44 % at 0 level to 1.32 % significantly different ( $p < 0.05$ ) from each other. In *S. guianensis* seed yield had increased from 27.7 kg/ha to 99.2 kg/ha then followed by a decline to 53.8 kg/ha at 0, 60 and 90 kg P/ha levels, respectively (Fig. 5). at 60 kg P/ha (Table 12).

Germination percentage of both *Stylosanthes* species were not affected by P fertilizer application (Tables 11 and 12). However, a slight increasing trend was observed for *S. hamata* up to 30 kg P/ha followed by a decline thereafter (Table 12). In contrast, a continuous increasing trend was observed for *S. guianensis* as the level of P increased from 30 to 90 kg P/ha.

#### 4.1.3 Effect of time of harvest on seed production

Seed yield of *S. hamata* increased ( $p < .001$ ) linearly from 33.4 kg/ha at the 4<sup>th</sup> week to 187.5 kg/ha at the 7<sup>th</sup> week post 50 % flowering (Fig. 6). *S. guianensis* also showed significant difference ( $p < 0.01$ ) in seed yield between the different times of harvest considered. However, the trend was different from that of *S. hamata* in that seed yield increased from 4<sup>th</sup> week up to 6<sup>th</sup> week followed by a decline in the 7<sup>th</sup> week post 50 % flowering (Fig. 6).

Harvesting index also followed the same trend as seed

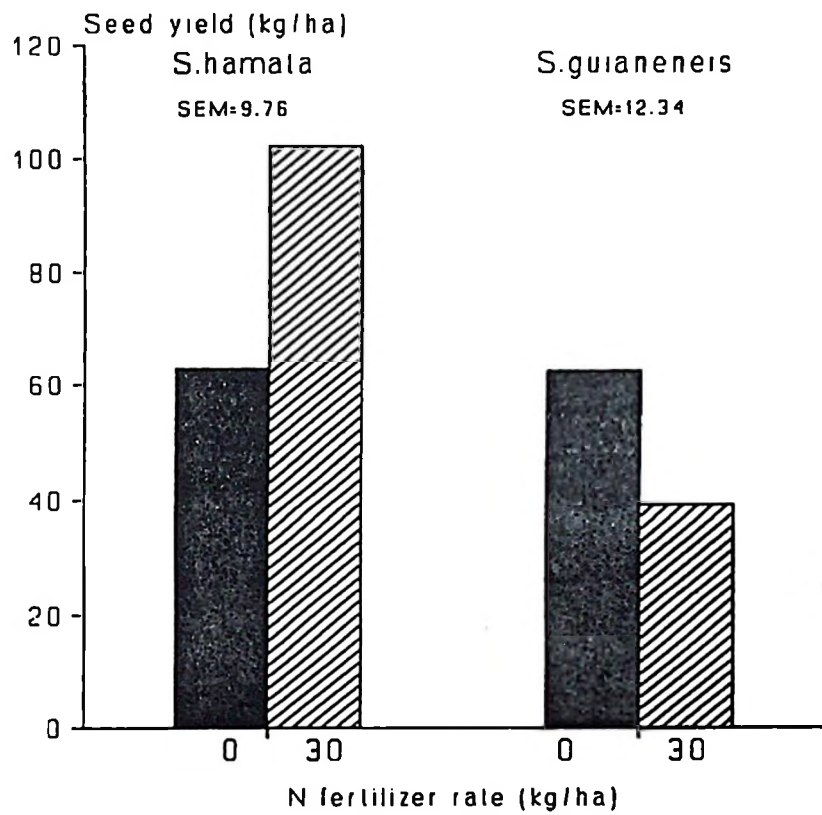


Figure 3: Effect of N application on seed yield of two *Stylosanthes* species.

Table 10: Effect of N application on harvesting index and germination of *Stylosanthes* species (Experiment I).

Species/ N-level	Index (%)	Germination (%)
<i>S.hamata</i>		
0 kg N/ha	2.53	37.5
30 kg N/ha	2.98	43.0
SEM	0.158	5.69
p <sup>1</sup>	ns	ns
<i>S.guianensis</i>		
0 kg N/ha	0.82	56.1
30 kg N/ha	0.42	58.5
SEM	0.12	3.62
p <sup>1</sup>	ns	ns

Means within the same column having different superscripts for each species are significantly different ( $p < 0.05$ ); ns= non-significant ( $p > 0.05$ ).

<sup>1</sup>=In this and the following subsequent tables presented corresponding to p in the same row: ns=refers to non-significant at  $p < 0.05$ ; \*=refers to significant at  $p < 0.05$ ; \*\*=refers to significant at  $p < 0.01$  and \*\*\*=refers to significant at  $p < 0.001$ .

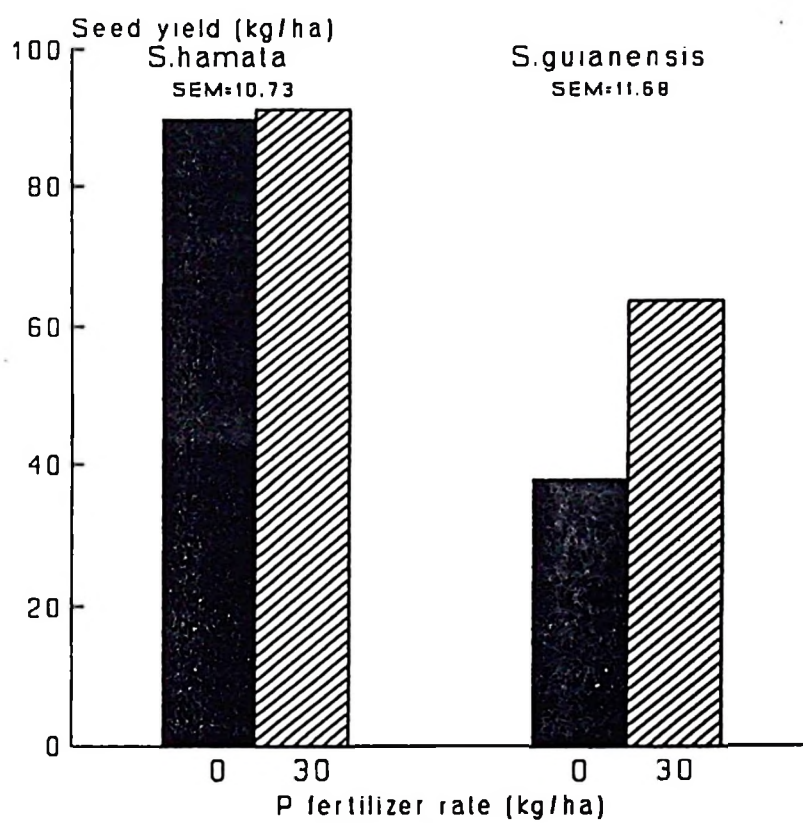


Figure 4: Effect of P application on seed yield of two *Stylosanthes* species (Experiment I).

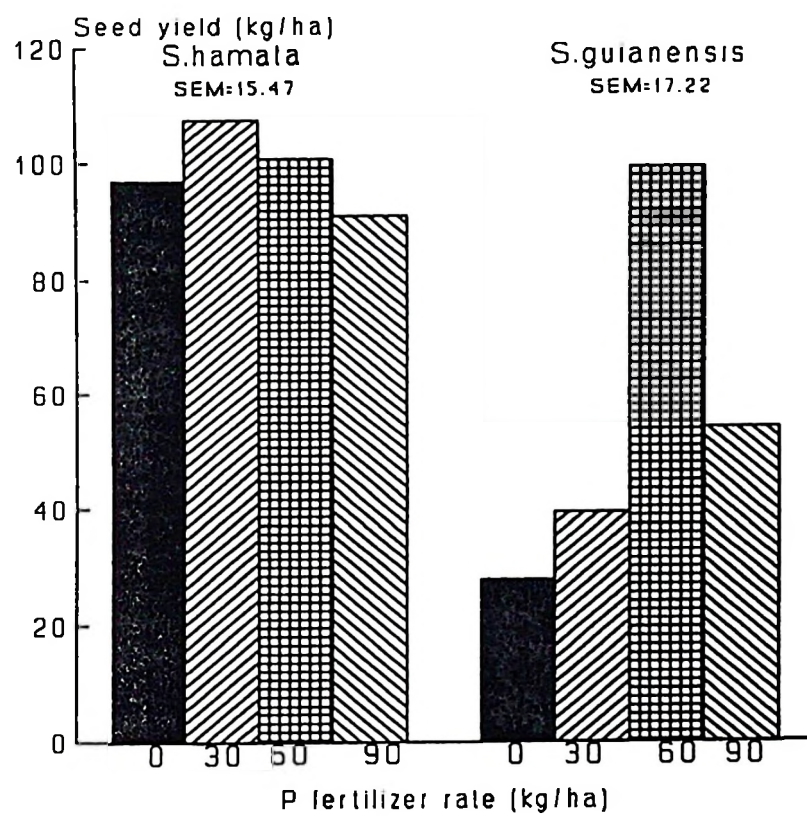


Figure 5: Effect of different rates of P application on seed yield of two *Stylosanthes* species (Experiment II).

Table 11: Effect of phosphorus application on harvesting index and germination of *Stylosanthes* species (Experiment I).

Species/ P-level	Index (%)	Germination (%)
<i>S.hamata</i>		
0 kg P/ha	2.77	40.13
30 kg P/ha	2.74	40.38
SEM	0.158	5.69
p	ns	ns
<i>S.guianensis</i>		
0 kg P/ha	0.43	58.0
30 kg P/ha	0.81	56.2
SEM	0.12	3.62
p	ns	ns

Means within the same column having different superscripts for each species are significantly different ( $p < 0.05$ );

Table 12: Effect of phosphorus application on harvesting index and germination of *Stylosanthes* species (Experiment II)

Species/P-level	Index (%)	Germination (%)
<i>S.hamata</i>		
0 kg P/ha	2.96	35.8
30 kg P/ha	3.0	46.1
60 kg P/ha	2.64	42.3
90 kg P/ha	2.72	36.8
SEM	0.207	4.36
p	ns	ns
<i>S.guianensis</i>		
0 kg P/ha	0.44 <sup>b</sup>	58.2
30 kg P/ha	0.40 <sup>b</sup>	57.9
60 kg P/ha	1.32 <sup>a</sup>	61.5
90 kg P/ha	0.76 <sup>b</sup>	65.9
SEM	0.182	5.75
p	**	ns

Means within the same column having different superscripts for each species are significantly different ( $p < 0.05$ ).

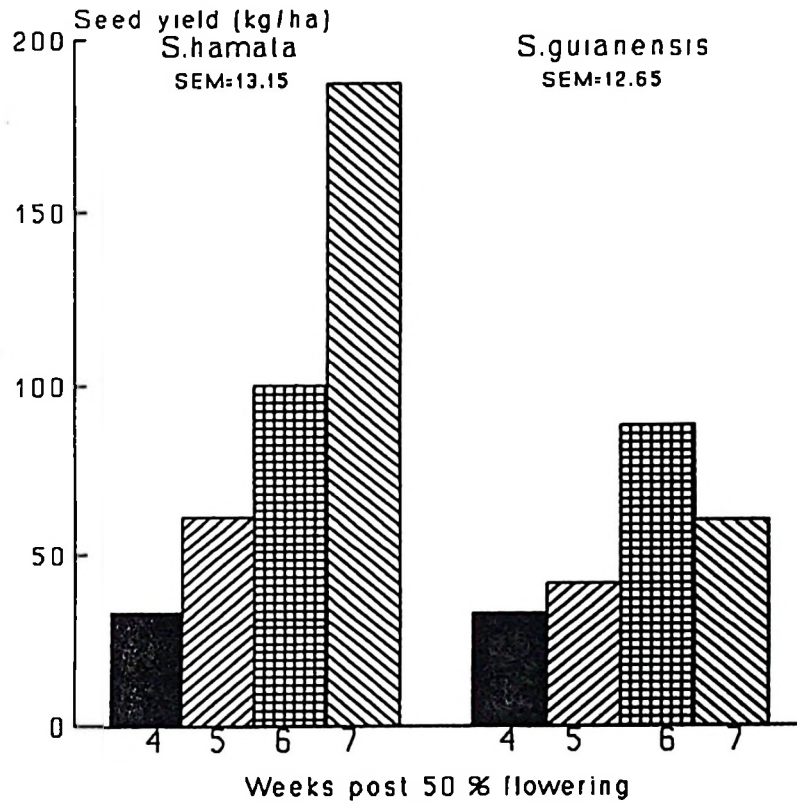


Figure 6: Effect of different time of harvest (post 50 % flowering) on seed yield of two *Stylosanthes* species.

yield in *S.hamata*. It increased significantly ( $p < 0.01$ ) from 0.99 at the 4<sup>th</sup> week to 5.1 % at the 7<sup>th</sup> week for *S.hamata*, while for *S.guianensis* it was not significantly different for the different times of harvest considered (Table 13).

Germination percentage was unaffected ( $p > 0.05$ ) by the different times of harvest employed in both *S.hamata* and *S.guianensis* (Table 13). However, there seems to be a slight decline in germination percentage as the time of harvest increases from the 5<sup>th</sup> week to 7<sup>th</sup> week post 50 % flowering.

#### 4.2 Herbage DM production of *S.hamata* and *S.guianensis*

##### 4.2.1 Effect of N fertilizer application on DM production

The response in DM yield to initial N fertilizer application for *S.hamata* was positive. Significantly higher ( $p < 0.05$ ) DM yield was observed in N applied plots than in the control as shown in Fig. 7. DM yield of *S.guianensis* on the other hand was not affected ( $p > 0.05$ ) by initial N fertilizer application (App.Table 3.2). A mean DM yield of 2923.3 and 8257.8 kg/ha were recorded for N applied plots compared to 2042.0 and 8479.6 kg/ha for plots without N in *S.hamata* and *S.guianensis*, respectively.

In both *Stylosanthes* species leaf:stem ratio was not affected by initial N fertilizer application (Table 14). However, the leaf:stem ratio increased slightly in

Table 13: Effect of time of harvest on harvesting index and germination of *Stylosanthes* species (Combined analysis over Experiment I and II).

Species/Time of harvest	Index (%)	Germination (%)
<i>S.hamata</i>		
4 week post 50 % flowering	0.99 <sup>d</sup>	42.0
5 week post 50 % flowering	1.69 <sup>c</sup>	42.3
6 week post 50 % flowering	3.14 <sup>b</sup>	40.4
7 week post 50 % flowering	5.1 <sup>a</sup>	34.3
SEM	0.184	5.56
p	***	ns
<i>S.guianensis</i>		
4 week post 50 % flowering	0.52	63.0
5 week post 50 % flowering	0.65	62.6
6 week post 50 % flowering	1.12	58.8
7 week post 50 % flowering	0.75	53.0
SEM	0.158	4.12
p	ns	ns

Means within the same column having different superscripts for each species are significantly different ( $p < 0.05$ ).

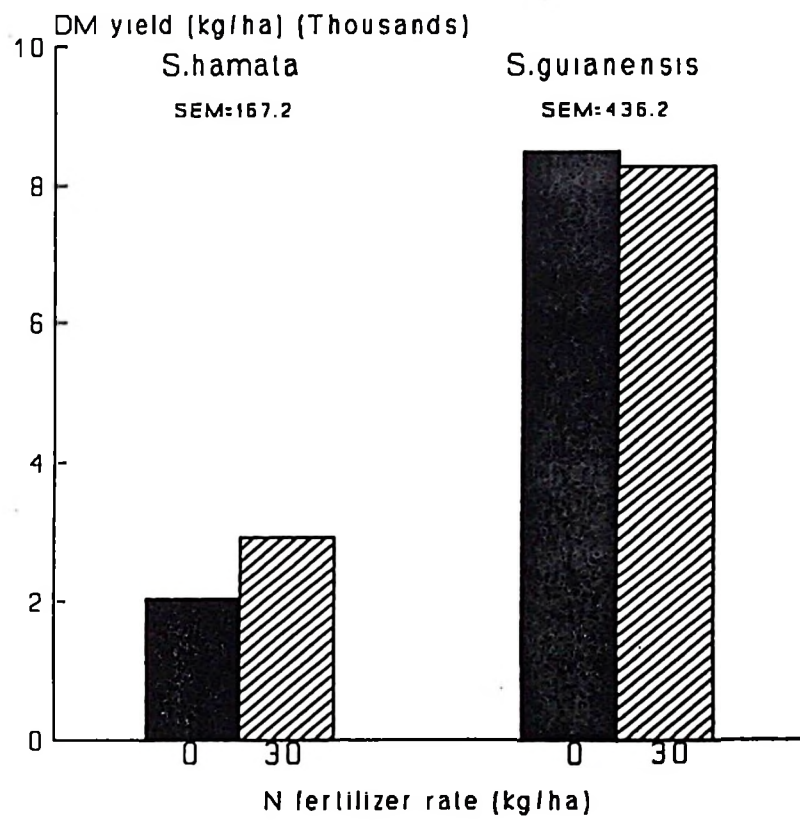


Figure 7: Effect of N application on DM yield of two *Stylosanthes* species.

Table 14: Effect of nitrogen application on leaf:stem ratio of *Stylosanthes* species (Experiment I).

Species/N-level	Leaf:stem ratio	
	<i>S.hamata</i>	<i>S.guianensis</i>
0 kg N/ha	1:1.01	1:1.69
30 kg N/ha	1:0.93	1:1.75
SEM	0.049	0.017
p	ns	ns

Means within the same column having different superscripts for each species are significantly different ( $p < 0.05$ ).

*S.hamata*. Significant interaction effect ( $p < 0.05$ ) was also observed between N fertilizer application and time of harvest in *S.guianensis* (App.Table 3.2). Nitrogen application to *S.guianensis* did not affect the leaf:stem ratio at 50 % flowering stage. While its effect was positive at the 4<sup>th</sup> and 5<sup>th</sup> week post 50 % flowering stage. This was reversed at the 6<sup>th</sup> and 7<sup>th</sup> week post 50 % flowering stage (Table 15).

#### 4.2.2 Effect of P fertilizer application on DM production

Dry matter yield produced from *S.hamata* and *S.guianensis* as affected by P fertilizer application is shown for experiment I and II in Fig. 8 and Fig. 9. respectively. In both experiments, DM yield was unaffected ( $p > 0.05$ ) by P fertilizer application for both *S.hamata* and *S.guianensis*. DM yield ranged from 2459.1 to 3043.1 kg/ha for *S.hamata*

Table 15: Interaction of nitrogen application and time of harvest on leaf:stem ratio of *S.guianensis* (Experiment I).

Time of harvest	N-levels		p
	0 kg N/ha	30 kg N/ha	
50 % flowering	1:1.72	1:1.64	ns
4 week post 50 % flowering	1:1.96 <sup>b</sup>	1:1.54 <sup>a</sup>	**
5 week post 50 % flowering	1:2.04 <sup>b</sup>	1:1.54 <sup>a</sup>	**
6 week post 50 % flowering	1:1.67 <sup>a</sup>	1:2.13 <sup>b</sup>	*
7 week post 50 % flowering	1:1.33 <sup>a</sup>	1:2.04 <sup>b</sup>	***
Mean	1:1.69	1:1.75	ns

Means within the same row having different superscripts are significantly different ( $p < 0.05$ ).

and from 7077 to 8919.7 kg/ha for *S.guianensis*.

Leaf:stem ratio was not significantly affected ( $p > 0.05$ ) by P fertilizer application in both *S.hamata* and *S.guianensis* in experiment I (Table 16). However, in experiment II, leaf:stem ratio of both *S.hamata* and *S.guianensis* were significantly affected ( $p < 0.01$ ) by P fertilizer application (Table 17). The highest value (1:0.56 and 1:1.19) were recorded for plots receiving 90 kg

P/ha and 60 kg P/ha in *S.hamata* and *S.guianensis*, respectively. While the lowest were recorded for plots receiving 60 kg P/ha and 30 kg P/ha in *S.hamata* and *S.guianensis*, respectively.

Significant interaction effect ( $p < 0.05$ ) was observed between P and N fertilizer application on leaf:stem ratio of *S.guianensis* (App.Table 3.2). Application of P to *S.guianensis* at the rate of 30 kg P/ha reduced the leaf:stem ratio from 1:1.61 to 1:1.89 with N while it increased leaf:stem ratio from 1:1.89 to 1:1.54 without N application (Table 18). Significant interaction effect ( $p < 0.05$ ) was also observed between P fertilizer application and time of harvest on leaf:stem ratio of *S.guianensis* (App.Table 3.2). Phosphorous application did not affect leaf:stem ratio of *S.guianensis* at 50 % flowering stage. However, the effect of P was negative at the 4<sup>th</sup> week and 5<sup>th</sup> week post 50 % flowering, and this was reversed at the late time of harvest as shown in Table 19. This indicates there might be an effect of P fertilizer in prolonging the growing period of *S.guianensis* which is an advantage from the nutritional point of view.

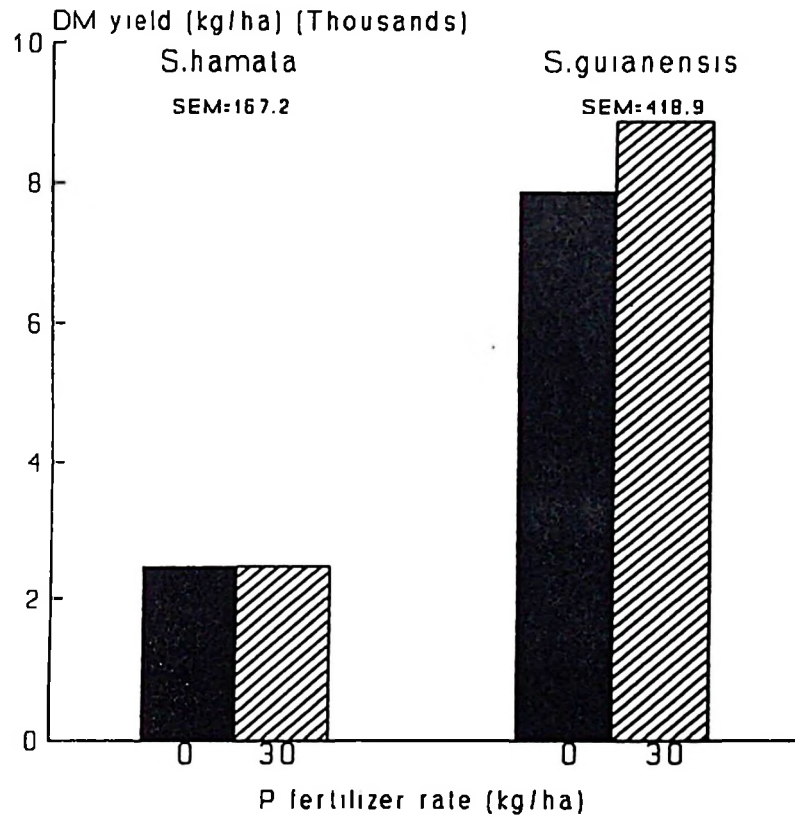


Figure 8: Effect of P application on DM yield of two *Stylosanthes* species (Experiment I).

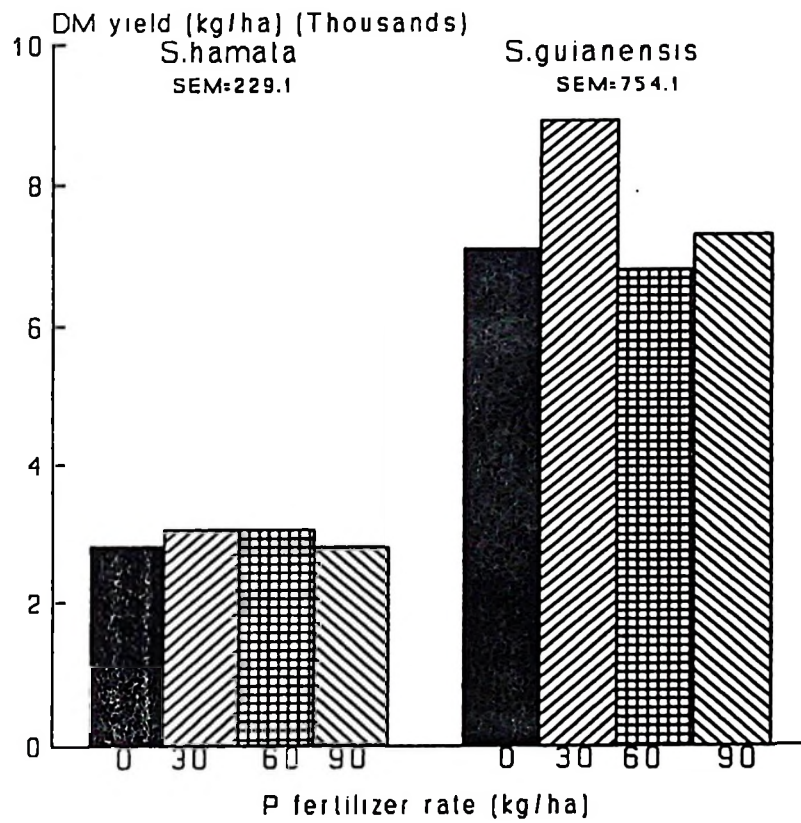


Figure 9: Effect of different rates of P application on DM yield of two *Stylosanthes* species (Experiment II).

Table 16: Effect of phosphorus application on leaf:stem ratio of *Stylosanthes* species (Experiment I).

P-level	Leaf:stem ratio	
	<i>S.hamata</i>	<i>S.guianensis</i>
0 kg P/ha	1:0.97	1:1.75
30 kg P/ha	1:0.96	1:1.69
SEM	0.049	0.016
p	ns	ns

Means within the same column having different superscripts for each species are significantly different ( $p < 0.05$ ).

Table 17: Effect of phosphorus application on leaf:stem ratio of *Stylosanthes* species (Experiment II).

P-level	Leaf:stem ratio	
	<i>S.hamata</i>	<i>S.guianensis</i>
0 kg P/ha	1:0.93 <sup>ab</sup>	1:1.61 <sup>bc</sup>
30 kg P/ha	1:0.92 <sup>ab</sup>	1:1.89 <sup>c</sup>
60 kg P/ha	1:1.10 <sup>b</sup>	1:1.19 <sup>a</sup>
90 kg P/ha	1:0.85 <sup>a</sup>	1:1.39 <sup>b</sup>
SEM	0.071	0.038
p	*	***

Means within the same column having different superscripts for each species are significantly different ( $p < 0.05$ ).

Table 18: Effect of phosphorus and nitrogen fertilizer application on leaf:stem ratio of *S.guianensis* (Experiment II).

N-level	N-levels		Difference
	0 kg N/ha	30 kg N/ha	
0 kg P/ha	1:1.89	1:1.61	**
30 kg P/ha	1:1.54	1:1.89	**
Difference	**	*	

\* and \*\* significant at  $p < 0.05$  and  $p < 0.01$ , respectively;

ns=non-significant  $p > 0.05$ .

Table 19: Interaction of phosphorus fertilizer application and time of harvest on leaf:stem ratio of *S.guianensis* (Experiment I).

Time of harvest	P-levels		p
	0 kg P/ha	30 kg P/ha	
50 % flowering	1:1.67	1:1.67	ns
4 week post 50 % flowering	1:1.64	1:1.79	ns
5 week post 50 % flowering	1:1.59 <sup>a</sup>	1:1.92 <sup>b</sup>	*
6 week post 50 % flowering	1:1.89	1:1.85	ns
7 week post 50 % flowering	1:1.96 <sup>b</sup>	1:1.35 <sup>a</sup>	**
Mean	1:1.75	1:1.69	ns

Means within the same row having different superscripts are significantly different ( $p < 0.05$ ).

#### 4.2.3 Effect of time of harvest on DM production

Dry matter yield of both *Stylosanthes* species was significantly affected ( $p < 0.01$ ) by the different times of harvest employed (App. Table 6.2 and 7.2). The lowest DM yield was recorded at 50 % flowering stage which was 805.9 and 5325.1 kg/ha for *S.hamata* and *S.guianensis*, respectively (Fig. 10). The highest value observed was 3288.9 at the 5<sup>th</sup> week for *S.hamata* and 8723.2 kg/ha at the 6<sup>th</sup> week for *S.guianensis* (Fig. 10).

Time of harvest significantly affected ( $p < 0.001$ ) leaf:stem ratio of *S.hamata* while its effect on *S.guianensis* was insignificant (Table 20). The highest leaf:stem ratio value (1:0.60 and 1:1.49) were recorded for plots harvested at 50 % flowering stage in *S.hamata* and *S.guianensis*, respectively.

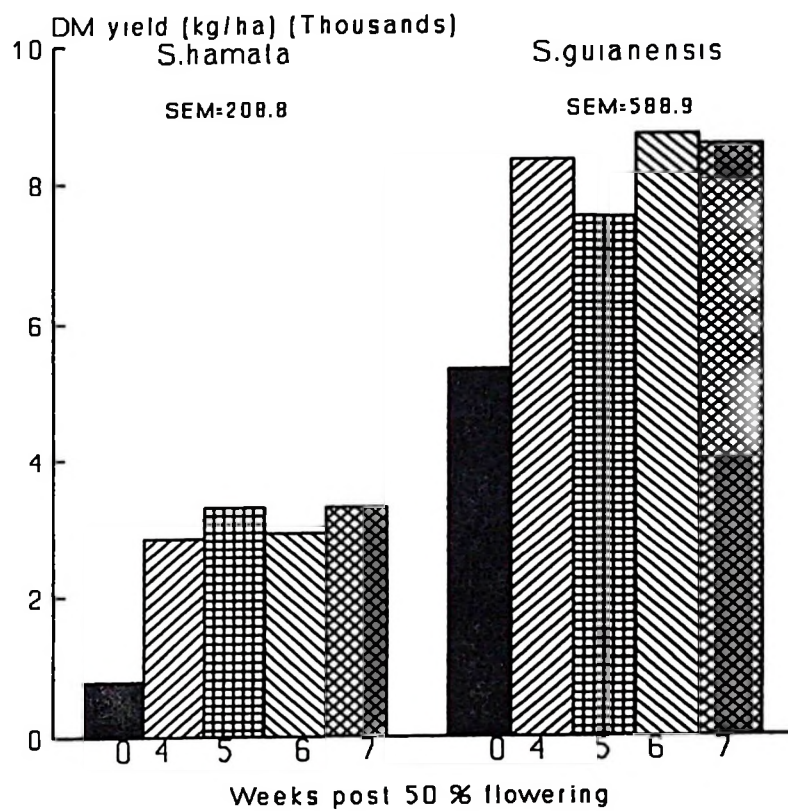


Figure 10: DM yield response of two *Stylosanthes* species to different times of harvest at and post 50 % flowering stage.

Table 20: Effect of time of harvest on leaf:stem ratio of *Stylosanthes* species (Combined analysis over experiment I and II).

P-level	Leaf:stem ratio	
	<i>S.hamata</i>	<i>S.guianensis</i>
50 % flowering stage	1:0.60 <sup>a</sup>	1:1.45
4 week post 50 % flowering	1:0.53 <sup>b</sup>	1:1.52
5 week post 50 % flowering	1:1.01 <sup>b</sup>	1:1.64
6 week post 50 % flowering	1:1.20 <sup>b</sup>	1:1.56
7 week post 50 % flowering	1:1.20 <sup>b</sup>	1:1.52
SEM	0.065	0.031
p	***	ns

Means within the same column having different superscripts for each species are significantly different ( $p < 0.05$ ).

#### 4.3 Chemical composition of *S.hamata* and *S.guianensis*

##### 4.3.1 Effect of N fertilizer application on chemical composition

The chemical composition of *S.hamata* and *S.guianensis* as affected by initial N fertilizer application is given in Table 21. The results showed that ash % in DM was unaffected for *S.hamata* while it increased significantly ( $p < 0.01$ ) from 9.17 % to 9.99 % in *S.guianensis* (Table 21). On average N application did not affect ( $p > 0.05$ ) the CP %

Table 21: Effect of nitrogen fertilizer application on chemical composition of *Stylosanthes* Species (Experiment I).

Species/N-level	Chemical composition % in DM			
	Ash	CP	ADF	ADL
<i>S.hamata</i>				
0 kg N/ha	9.33	12.09	46.86	11.07
30 kg N/ha	8.95	13.36	48.14	11.64
SEM	0.289	0.25	1.20	0.830
p	ns	ns	ns	ns
<i>S.guianensis</i>				
0 kg N/ha	9.17 <sup>b</sup>	14.43	47.34	12.47
30 kg N/ha	9.99 <sup>a</sup>	15.07	48.57	13.1
SEM	0.125	0.204	0.857	0.514
p	**	0.035	ns	ns

Means within the same column having different superscripts for each species are significantly different ( $p < 0.05$ ).

in DM in both *S.hamata* and *S.guianensis*. ADF and ADL % in DM was unaffected by initial N fertilizer application in both *Stylosanthes* species (Table 19). However, slightly higher values of ADF and ADL were recorded for N applied plots in *S.hamata* and *S.guianensis*.

#### 4.3.2 Effect of P fertilizer application on chemical composition

The chemical composition of *S.hamata* and *S.guianensis* as affected by initial P fertilizer application is given in

Tables 22 and 23. Ash % in DM was not significantly affected ( $p>0.05$ ) in both experiment I and II for *S.hamata*. However, application of P in *S.guianensis* significantly reduced ( $p<0.05$  and  $0.001$ ) the ash % in DM in experiment II as shown in Table 23. Similarly in experiment II P application reduced ash percentage of *S.guianensis* in the presence of N while its effect was insignificant in the absence of N fertilizer application (Table 24). CP % in DM was not affected by P fertilizer application in both experiment I and II for both *Stylosanthes* species. However, there seems to be a slight decline in CP % with increased level of P application. A significant interaction effect ( $p<0.05$ ) was also observed in *S.hamata* between P fertilizer application and time of harvest on CP percentage (App.Table 2.2). Phosphorus application significantly increased ( $p<0.05$ ) the CP percentage of *S.hamata* at 50 % flowering while its effect at post 50 % flowering was not significant (Table 25). In both experiments ADF and ADL percentage in DM was not affected by P application for *S.hamata* and *S.guianensis* ( $p>0.05$ ). However, significant interaction effect was observed between P fertilizer application and time of harvest on ADF percentage of *S.guianensis* (App.Table 2.2). ADF percentage of *S.guianensis* increased as a result of P application at 50 % flowering while its effect post 50 % flowering was inconsistent and not significant ( $p>0.05$ ) as shown in Table 26.

#### 4.3.3 Effect of time of harvest on chemical composition

Chemical composition of *S.hamata* and *S.guianensis* as affected by the different time of harvest is given in Table 24. In both *Stylosanthes* species the ash % in DM declined significantly ( $p < 0.01$ ) as the time of harvest was increased. The highest value 14.2 % and 10.68 % was observed at 50 % flowering stage for *S.hamata* and *S.guianensis*. CP % in DM declined significantly ( $p < 0.01$ ) as time of harvest increased in both *S.hamata* and *S.guianensis* (Table 27). The highest value recorded was at 50 % flowering stage which was 18.84 % and 15.74 % for *S.hamata* and *S.guianensis*, respectively. The lowest value was 10.09 % and 13.87 % at the 7<sup>th</sup> week for *S.hamata* and *S.guianensis*, respectively.

ADF % in DM increased significantly ( $p < 0.01$ ) from 33.51 % at 50 % flowering stage to 51.01 % at the 6<sup>th</sup> week for *S.hamata*. The ADL % in DM also significantly increased ( $P < 0.01$ ) for *S.hamata*. It was 6.3 % at 50 % flowering and increased to 13.99 % at the 7<sup>th</sup> week post 50 % flowering stage for *S.hamata*. On the other hand, both ADF % and ADL % in DM of *S.guianensis* significantly declined ( $p < 0.01$ ) with increasing time of harvest (Table 27). On average higher values were recorded for both ADF and ADL % of *S.guianensis* when harvested at 50 % flowering stage than plots harvested at 4<sup>th</sup>, 5<sup>th</sup>, 6<sup>th</sup> and 7<sup>th</sup> week post 50 % flowering stage (Table 27). However, this trend was not

Table 22: Effect of phosphorous application on chemical composition of *Stylosanthes* Species (Experiment I).

Species/P-level	Chemical composition % in DM			
	Ash	CP	ADF	ADL
<i>S. hamata</i>				
0 kg P/ha	9.14	13.01	49.12	10.62
30 kg P/ha	9.35	12.44	45.88	12.09
SEM	0.289	0.252	1.20	0.830
p	ns	ns	ns	ns
<i>S. guianensis</i>				
0 kg P/ha	9.81.	14.94	47.5	12.41
30 kg P/ha	9.35	14.57	48.41	12.82
SEM	0.125	0.204	0.856	0.514
p	ns	ns	ns	ns

Means within the same column having different superscripts for each species are significantly different ( $p < 0.05$ ).

Table 23: Effect of phosphorus application on chemical composition of *Stylosanthes* Species (Experiment II).

Species/P-level	Chemical composition % in DM			
	Ash	CP	ADF	ADL
<i>S.hamata</i>				
0 kg P/ha	9.27	13.33	40.30	11.0
30 kg P/ha	8.63	13.38	45.99	12.28
60 kg P/ha	8.70	11.72	49.0	11.04
90 kg P/ha	8.55	12.78	48.76	12.7
SEM	0.334	0.336	2.15	0.914
p	ns	ns	ns	ns
<i>S.guianensis</i>				
0 kg P/ha	10.38 <sup>a</sup>	15.06	47.41	13.51
30 kg P/ha	9.6 <sup>b</sup>	15.08	49.74	12.69
60 kg P/ha	9.66 <sup>b</sup>	14.28	47.89	12.6
90 kg P/ha	9.03 <sup>c</sup>	14.09	49.86	14.42
SEM	0.196	0.373	1.22	0.756
p	*	ns	ns	ns

Means within the same column having different superscripts for each species are significantly different ( $p < 0.05$ ).

Table 24: Interaction effect between phosphorus and nitrogen fertilizer application on ash percentage of *S.guianensis* (Experiment I).

P-level	N-levels		Difference
	0 kg N/ha	30 kg N/ha	
0 kg P/ha	9.01	9.65	ns
30 kg P/ha	9.27	8.63	ns
Difference	ns	*	

\* significant at  $p < 0.05$ ; ns=non-significant  $p > 0.05$ .

consistent across the different fertilizer treatments. A control plot which did not receive P fertilizer treatment showed increment in ADF and ADL % from 50 % flowering stage up to the 4<sup>th</sup> week then followed by a decline in both ADF and ADL % thereafter as shown in Table 26. In general, fertilizer treated plots remained unaffected or declined with increase in time of harvest in terms of ADF and ADL % from 50 % flowering stage as shown in Fig. 11a, 11b, 12a and 12b. The control showed increment up to the 4th week post 50 % flowering stage in terms of ADF and ADL percentage of *S.guianensis* followed by a slight decline thereafter.

Table 25: Interaction between phosphorus fertilizer application and time of harvest on CP percentage of *S.hamata* (Experiment I).

Time of harvest	N-levels		p
	0 kg N/ha	30 kg N/ha	
50 % flowering	18.28 <sup>b</sup>	19.89 <sup>a</sup>	*
4 week post 50 % flowering	12.87	11.70	ns
5 week post 50 % flowering	11.72	11.41	ns
6 week post 50 % flowering	11.7	10.16	ns
7 week post 50 % flowering	10.47	9.04	ns
Mean	12.09	13.36	ns

Means within the same row having different superscripts are significantly different ( $p < 0.05$ ).

Table 26: Interaction between phosphorus fertilizer application and time of harvest on ADF percentage of *S.guianensis* (Experiment I).

Time of harvest	P-levels		p
	0 kg P/ha	30 kg P/ha	
50 % flowering	46.25 <sup>b</sup>	54.05 <sup>a</sup>	**
4 week post 50 % flowering	50.91	49.15	ns
5 week post 50 % flowering	49.8	46.17	ns
6 week post 50 % flowering	46.29	49.17	ns
7 week post 50 % flowering	44.25	43.53	ns
Mean	47.5	48.41	ns

Means within the same row having different superscripts are significantly different ( $p < 0.05$ ).

Table 27: Effect of time of harvest on chemical composition of *Stylosanthes* species (Combined analysis over experiment I and II).

Species/Time of harvest	Chemical composition % in DM			
	Ash	CP	ADF	ADL
<i>S. hamata</i>				
50 % flowering stage	14.2 <sup>a</sup>	18.84 <sup>a</sup>	37.51 <sup>c</sup>	6.53 <sup>c</sup>
4 week post 50 % flowering	8.22 <sup>b</sup>	12.1 <sup>b</sup>	45.47 <sup>b</sup>	10.96 <sup>ab</sup>
5 week post 50 % flowering	7.72 <sup>bc</sup>	11.18 <sup>bc</sup>	47.56 <sup>b</sup>	12.56 <sup>a</sup>
6 week post 50 % flowering	7.75 <sup>bc</sup>	10.76 <sup>cd</sup>	55.01 <sup>a</sup>	13.59 <sup>a</sup>
7 week post 50 % flowering	6.95 <sup>c</sup>	9.94 <sup>c</sup>	54.25 <sup>a</sup>	13.99 <sup>a</sup>
SEM	0.361	0.341	2.14	0.869
p	***	***	***	***
<i>S. guianensis</i>				
50 % flowering stage	10.68 <sup>a</sup>	15.74 <sup>a</sup>	51.50 <sup>a</sup>	15.71 <sup>a</sup>
4 week post 50 % flowering	9.4 <sup>bc</sup>	14.24 <sup>b</sup>	49.34 <sup>ab</sup>	12.73 <sup>b</sup>
5 week post 50 % flowering	9.78 <sup>b</sup>	14.55 <sup>b</sup>	48.69 <sup>ab</sup>	11.69 <sup>bc</sup>
6 week post 50 % flowering	8.9 <sup>cd</sup>	14.4 <sup>b</sup>	46.72 <sup>bc</sup>	11.56 <sup>bc</sup>
7 week post 50 % flowering	8.80 <sup>d</sup>	13.87 <sup>b</sup>	45.05 <sup>c</sup>	10.26 <sup>c</sup>
SEM	0.171	0.306	1.09	0.693
p	***	**	**	***

Means within the same column having different superscripts for each species are significantly different ( $p < 0.05$ ).

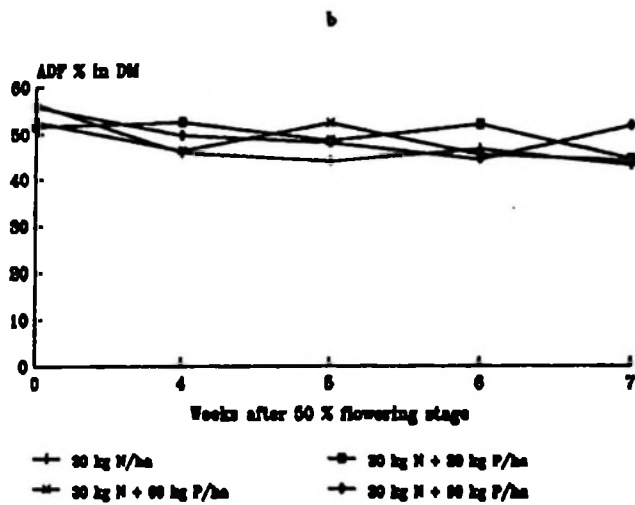
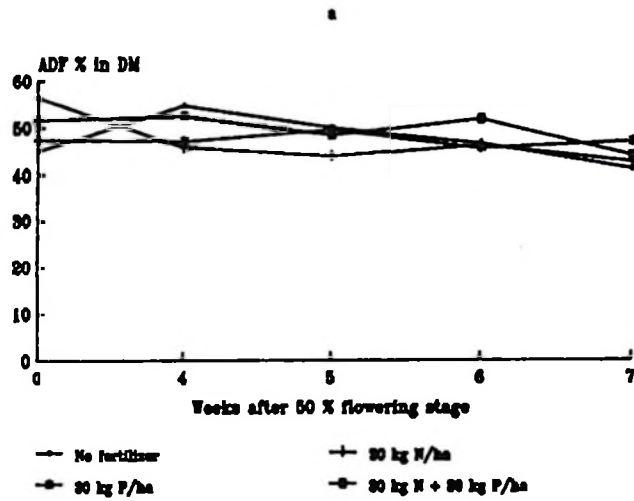


Figure 11: ADF % in DM of *S. guianensis* as affected by time of harvest and (a) different levels of P application and (b) two level of N and P fertilizer application.

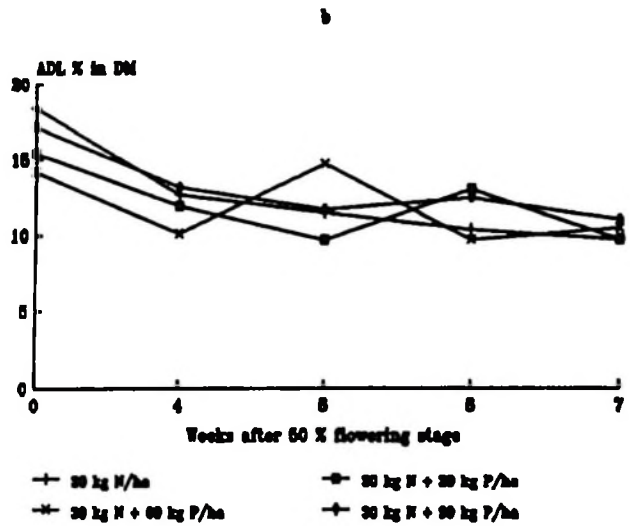
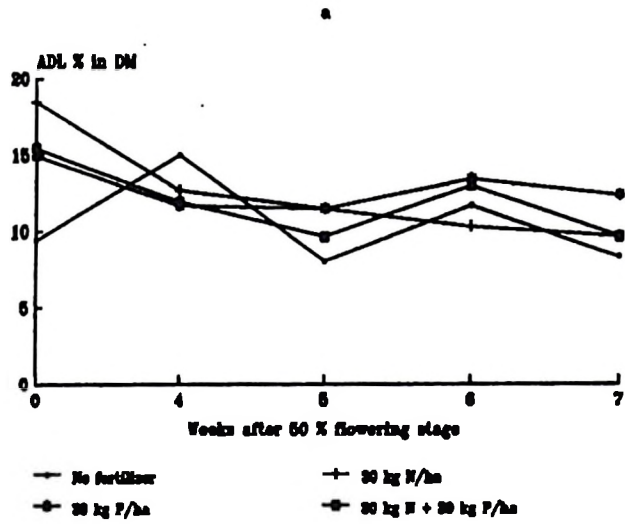


Figure 12: ADL % in DM of *S. guianensis* as affected by time of harvest and (a) different level of P fertilizer application and (b) two levels of N and P fertilizer application.

#### 4.4 *In vitro* digestibility, digestible crude protein and metabolizable energy of *S.hamata* and *S.guianensis*

##### 4.4.1 Effect of N fertilizer application on *in vitro* digestibility, DCP and ME

Results of *in vitro* digestibility, DCP(g/kg DM) and ME (MJ/kg DM) content of *S.hamata* and *S.guianensis* as affected by N fertilizer application are given in Table 28. Nitrogen application did not affect ( $p>0.05$ ) both IVDMD and IVOMD % of *S.hamata*, and IVDMD % of *S.guianensis* (Table 28). However, regardless of statistical insignificance both IVDMD and IVOMD of *S.hamata* showed slight increment with N application. Nitrogen application significantly increased ( $p<0.05$ ) the DCP content of *S.hamata* (Table 28). ME content of both *S.guianensis* and *S.hamata* was unaffected by initial N application ( $p>0.05$ ).

##### 4.4.2 Effect of P fertilizer application on *In vitro* digestibility, DCP and ME

Phosphorus application in experiment I did not affect ( $p>0.05$ ) both the IVDMD and IVOMD % of *S.hamata* and *S.guianensis* (Table 29 and 30). However, in both *S.hamata* and *S.guianensis* though statistically not significant, a reduction in IVDMD and IVOMD % were observed for P applied plots (Table 29). In experiment II, P application significantly reduced ( $p<0.05$ ) the IVOMD % of *S.guianensis*

(Table 30). The highest value , 56.31 % , in terms of IVOMD for *S.guianensis* was recorded for the control followed by 56.01 % , 56.2 % and 52.84 % for 30, 60 and 90 kg P/ha fertilized plots, respectively. A similar decreasing trend in IVDMD % of *S.hamata* with P application was observed (Table 30). The lowest value being recorded for plots receiving 90 kg P/ha.

Phosphorus application in experiment I did not affect the DCP and ME contents of both *S.hamata* and *S.guianensis* (Table 29). In experiment II, the DCP content was slightly decreasing with increasing level of P, but, the difference was insignificant ( $p>0.05$ ) in *S.hamata*. On the other hand in experiment II, ME content was not affected by P fertilizer application in *S.hamata*. However, it showed a significant decrease in *S.guianensis* as levels of P increased (Table 30).

#### 4.4.3 Effect of time of harvest on *in vitro* digestibility, DCP and ME

Both IVDMD and IVOMD % declined significantly ( $p<0.01$ ) for *S.hamata* as the time of harvest was increased from 50 % flowering stage to 7<sup>th</sup> week post 50 % flowering (Table 31). The highest IVDMD and IVOMD %, 59.52 % and 63.88 %, respectively were observed for *S.hamata* at 50 % flowering stage. The IVDMD and IVOMD % of *S.guianensis* were also significantly affected ( $P<0.01$ ) by the different times of

Table 28: Effect of nitrogen application on *in vitro* digestibility, DCP and ME of *Stylosanthes* species (Experiment I).

Species/N-level	IVDMD %	IVOMD %	DCP (g/kgDM)	ME (MJ/kgDM)
<i>S. hamata</i>				
0 kg N/ha	52.29	53.89	73.50	7.36
30 kg N/ha	53.97	55.48	85.05	7.26
SEM	1.11	0.921	2.29	0.254
p	ns	ns	ns	ns
<i>S. guianensis</i>				
0 kg N/ha	54.71	54.19 <sup>b</sup>	94.87	7.79
30 kg N/ha	57.95	56.16 <sup>a</sup>	100.69	8.07
SEM	0.793	0.646	1.86	0.095
p	ns	*	ns	ns

Means within the same column followed by different superscripts for each species are significantly different ( $p < 0.05$ ).

Table 29: Effect of phosphorus application on *in vitro* digestibility, DCP and ME of *Stylosanthes* species (Experiment I).

Species/P-level	IVDMD %	IVOMD %	DCP (g/kgDM)	ME (MJ/kgDM)
<i>S.hamata</i>				
0 kg P/ha	53.61	54.82	81.87	7.46
30 kg P/ha	52.65	54.56	76.68	7.15
SEM	1.11	0.921	2.29	0.254
p	ns	ns	ns	ns
<i>S.guianensis</i>				
0 kg P/ha	57.78	56.08	99.37	8.06
30 kg P/ha	54.89	54.27	96.08	7.78
SEM	0.793	0.646	1.86	0.095
p	ns	ns	ns	ns

Means within the same column followed by different superscripts for each species are significantly different ( $p < 0.05$ ).

Table 30: Effect of phosphorus application on *in vitro* digestibility and DCP and ME of *Stylosanthes* species (Experiment II).

Species/P-level	IVDMD %	IVOMD %	DCP (g/kgDM)	ME (MJ/kgDM)
<i>S. hamata</i>				
0 kg P/ha	54.27 <sup>a</sup>	55.28	84.81	7.95
30 kg P/ha	53.69 <sup>ab</sup>	55.69	85.32	8.01
60 kg P/ha	52.11 <sup>ab</sup>	53.56	70.13	7.69
90 kg P/ha	49.86 <sup>b</sup>	52.89	79.79	7.59
SEM	1.34	1.10	3.06	0.160
p	*	ns	ns	ns
<i>S. guianensis</i>				
0 kg P/ha	58.22	56.31 <sup>a</sup>	100.6	8.1 <sup>a</sup>
30 kg P/ha	57.69	56.01 <sup>a</sup>	100.8	8.05 <sup>a</sup>
60 kg P/ha	58.60	56.2 <sup>a</sup>	94.4	8.08 <sup>a</sup>
90 kg P/ha	54.57	52.84 <sup>b</sup>	91.7	7.59 <sup>b</sup>
SEM	1.20	0.939	3.40	0.138
p	ns	*	ns	ns

Means within the same column having different superscripts for each species are significantly different ( $p < 0.05$ ).

Table 31: *In vitro* digestibility, DCP and ME of *Stylosanthes* species as affected by time of harvest (Combined analysis over experiment I and II).

Species/Time of harvest	IVDMD %	IVOMD %	DCP (g/kg DM)	ME (MJ/kg DM)	Microbial N requirement (CP g/kgDM)
<i>S.hamata</i>					
50 % flowering stage	59.52 <sup>a</sup>	63.88 <sup>a</sup>	135.0 <sup>a</sup>	9.21 <sup>a</sup>	64.76 <sup>a</sup>
4 week post 50 % flowering	53.89 <sup>b</sup>	55.16 <sup>b</sup>	73.6 <sup>b</sup>	7.93 <sup>b</sup>	55.76 <sup>b</sup>
5 week post 50 % flowering	51.47 <sup>bc</sup>	52.57 <sup>bc</sup>	65.2 <sup>bc</sup>	7.55 <sup>b</sup>	53.09 <sup>b</sup>
6 week post 50 % flowering	48.04 <sup>c</sup>	49.1 <sup>d</sup>	61.4 <sup>c</sup>	7.04 <sup>c</sup>	49.50 <sup>c</sup>
7 week post 50 % flowering	49.17 <sup>c</sup>	50.3 <sup>cd</sup>	53.9 <sup>c</sup>	7.19 <sup>bc</sup>	50.55 <sup>bc</sup>
SEM	1.29	1.02	3.11	0.150	
p	***	***	***	***	***
<i>S.guianensis</i>					
50 % flowering stage	58.62 <sup>a</sup>	57.1 <sup>a</sup>	106.8 <sup>a</sup>	8.21 <sup>a</sup>	57.74 <sup>a</sup>
4 week post 50 % flowering	54.89 <sup>b</sup>	53.46 <sup>c</sup>	93.1 <sup>b</sup>	7.68 <sup>c</sup>	53.98 <sup>c</sup>
5 week post 50 % flowering	54.22 <sup>b</sup>	53.36 <sup>c</sup>	95.9 <sup>b</sup>	7.66 <sup>c</sup>	53.88 <sup>c</sup>
6 week post 50 % flowering	55.86 <sup>ab</sup>	54.19 <sup>bc</sup>	94.5 <sup>b</sup>	7.79 <sup>bc</sup>	54.73 <sup>bc</sup>
7 week post 50 % flowering	58.49 <sup>a</sup>	56.62 <sup>ab</sup>	90.7 <sup>b</sup>	8.15 <sup>ab</sup>	57.29 <sup>ab</sup>
SEM	1.19	0.892	2.79	0.131	0.923
p	*	**	**	**	**

Means within the same column followed by different superscripts for each species are significantly different ( $p < 0.05$ ).

harvest considered (Table 31). However, the trend observed for *S.guianensis* was different from *S.hamata* in that both IVDM % and IVOMD % decreased up to the 5<sup>th</sup> week followed by an increase beyond the 5<sup>th</sup> week (Table 31).

DCP and ME content of *S.hamata* significantly decreased as the time of harvest increased (Table 31). A similar trend was observed for *S.guianensis* in DCP content; whereas the ME content significantly decreased as the time of harvest increased up to the 5<sup>th</sup> week, followed by an increase in ME content thereafter (Table 31).

#### 4.5 Economics of fertilizer application

##### 4.5.1 Nitrogen and phosphorus application (Experiment I)

Application of N and P fertilizer at 30 kg/ha of each maximized profit from *S.hamata* kept for both seed and fodder production (190 231.5 Tsh/ha). However, the maximum additional profit per Tsh invested on N or P fertilizer in experiment I was observed from application of N at the rate of 30 kg N/ha to *S.hamata* meant for both seed and fodder production (12.02). This was followed by the one meant for sole seed production (9.75). In contrast, application of N fertilizer to *S.guianensis* was not economical (Table 32).

On the other hand, application of P at the rate of 30 kg P/ha gave additional profit from *S.guianensis* meant for seed production (150 290 Tsh/ha) (Table 32). The maximum

additional profit per Tsh of investment on P fertilizer was also observed when it was used for seed production (8.02) than for production of both seed and fodder (5.05). The use of P fertilizer for *S.hamata* was found to be in any case uneconomical (Table 32).

#### 4.5.2 Different levels of P application (Experiment II)

The result of partial budget analysis done for the different levels of P fertilizer application in *S.hamata* and *S.guianensis* is given in Table 33. *S.hamata* benefited from additional profit in terms of Tsh/ha when P was added at the level of 30 kg P/ha, and the maximum profit per Tsh invested on P fertilizer was observed when the crop was used for both seed and fodder production. On the other hand application of P at different levels to *S.guianensis* seed production gave maximum Tsh/ha when P was applied at the rate of 60 kg P/ha (164 867.8 Tsh) from crop kept for both seed and fodder production. However, the maximum profit per Tsh investment on P fertilizer was observed when it was invested for seed production (4.9 Tsh) followed by both seed and fodder production (3.3 Tsh).

Table 32: Economics of nitrogen and phosphorus fertilizer application in *S.hamata* and *S.guianensis*: Additional profit (Tsh/ha) and additional profit per Tsh of investment on N and/or P fertilizer (parenthesis) (Experiment I).

Type of out put	Species	Nitrogen level (kg/ha)	Phosphorus level (kg/ha)	
			0	30
Seed	<i>S.hamata</i>	0	-	-45 510 (-2.42)
		30	121 902 (9.75)	150 832 (4.83)
	<i>S.guianensis</i>	0	-	150 290 (8.02)
		30	-76 618 (-6.13)	-49 328 (-15.78)
Fodder	<i>S.hamata</i>	0	-	-32 048.6 (-1.71)
		30	15 884 (1.27)	8 151.5 (0.26)
	<i>S.guianensis</i>	0	-	-74 396.2 (-3.97)
		30	-5 202.4 (-0.42)	-2 084.0 (-0.70)
Seed + Fodder	<i>S.hamata</i>	0	-	-61 808.6 (-3.30)
		30	150 284 (12.02)	190 231.5 (6.09)
	<i>S.guianensis</i>	0	-	94 643.8 (5.05)
		30	-69 322.4 (-5.55)	-20 164 (-0.65)

Table 33: Economics of different levels of phosphorus fertilizer application in *S.hamata* and *S.guianensis*: Additional profit (Tsh/ha) and additional profit per Tsh of investment on P fertilizer (parenthesis) (Experiment I).

Type of out put	Species	Phosphorus level (kg/ha)			
		0	30	60	90
Seed	<i>S.hamata</i>	-	28 930 (0.93)	-20 140 (-0.40)	-81 810 (-1.19)
	<i>S.guianensis</i>	-	27 290 (0.87)	244 940 (4.90)	45 910 (0.67)
Fodder	<i>S.hamata</i>	-	8 151.5 (0.26)	-26 832.6 (-0.54)	-56 815.8 (-0.83)
	<i>S.guianensis</i>	-	3 118.4 (0.10)	-117 572.2 (-2.35)	-11 376.8 (-1.65)
Seed + Fodder	<i>S.hamata</i>	-	69 947.5 (1.28)	-9 472.6 (-0.19)	-82 375.8 (-1.20)
	<i>S.guianensis</i>	-	49 158.4 (1.57)	164 867.8 (3.30)	-11 603.8 (-0.17)

## CHAPTER V

## 5.0 DISCUSSION

5.1 Seed production of *S.hamata* and *S.guianensis*

## 5.1.1 Seed production response to N application

There were large differences in seed yield of both *S.hamata* and *S.guianensis* for plots with and without N. However, there was a distinct difference in the type of response. Seed production from *S.hamata* benefited from N application while that of *S.guianensis* did not. The positive effect of N application observed in seed yield of *S.hamata* in the present study is in agreement with the results of other workers who found and reviewed increased seed yield in other forage legumes such as *Desmodium* in Australia (Gibson and Humphreys, 1973; Nichollas et al., 1973; Skerman, 1988). Positive effect of N application to legumes depend on other factors such as adequate moisture availability in the soil, whether symbiotic N fixation provides rates of N supply which do not limit seed production. Minimum effects of grass and seed invasion may also affect seed yield response to N application (Humphreys, 1979). In the present study, the positive effect of N to *S.hamata* is speculated to be associated with indirect effect of N on rapid development of the sward. This could have assisted the seed crop of *S.hamata*, which has a short growing period to

complete its growth before the soil moisture was exhausted. Nitrogen on the other hand makes the seed crop of *S.guianensis* vulnerable to moisture stress at the time of seed setting and filling as it has a relatively long growing period. According to Humphreys (1979), N application will increase vegetative growth and cause more utilization of soil moisture and subsequent loss through transpiration. The important implication of the present finding is that, N application may improve seed production in semi-arid areas by assisting the seed crop to complete its growth before moisture becomes more limiting for seed production. However, this seems to be specific for those forage legumes which have short growing periods.

#### **5.1.2 Seed production response to P application**

Analysis of soil samples from the experimental site showed low P (about 2.22 ppm of Bray-P) content. According to Miller et al.(1991) soils which contain P levels under 8 ppm are inadequate for optimum growth of plant and positive response to P fertilizer application is expected. The present finding tend to show slight increase in seed yield of *S.hamata* only up to 30 kg P/ha. For *S.guianensis* seed yield increased continuously up to 60 kg P/ha level followed by a decline thereafter. Similar to the present finding Quinlivan et al.(1973) and Kanodia et al.(1985) reported higher seed yield response in the same species at

moderate levels than higher levels of P application. The lower response observed in this study may have been masked by inherent adaptation of *Stylosanthes* to soils with low levels of available P. The general implication of the current finding is that *S.guianensis* will respond better than *S.hamata* to P application. The biological optimum level was found to be at 60 kg P/ha for *S.guianensis* while for *S.hamata* it was between 0 to 30 kg P/ha. However, the latter result need further investigation to determine the optimum P level to be applied.

#### 5.1.3 Effect of time of harvest on Seed production

Seed production of *Stylosanthes* species is affected by many factors including time of harvest (Humphreys, 1979; Crowder and Chheda, 1982). In the present study, the general trend was for seed yield to increase with increasing time of harvest after the 4<sup>th</sup> week post 50 % flowering stage in both *S.hamata* and *S.guianensis*. However, there was distinct species difference. The response for *S.hamata* was linear throughout the study period while for *S.guianensis* the yield increased and reached a peak at the 6<sup>th</sup> week and thereafter declined gently. A similar trend was observed in harvesting index of both *Stylosanthes* species.

In the present study, as stated above, seed yield declined after the 6<sup>th</sup> week in *S.guianensis* by 30 percent. This has an important implication as reviewed by Humphreys

(1979) in the efficiency of seed recovery. Loch et al. (1976) similarly found that delay in harvesting just by a week could lead to loss of seed yield by about 25 percent. Interestingly, seed germination percentage declined continuously with increasing time of harvest. This finding disagrees with the trend reported by Crowder and Chheda (1982) which showed increase in germination percentage of seeds with increasing time of harvest as a result of reduction in the proportion of immature seeds, followed by a decline thereafter which might be accounted by inadequate nutrients stored in the seed at later stages. The difference between the trend observed in the present study might arise from the difficulties encountered in determining the germination percentage because of hard seed effect. Therefore, the present results on germination should be taken with caution. Further research is recommended to verify the findings of this study.

## **5.2 Dry matter yield of *S.hamata* and *S.guianensis***

### **5.2.1 Dry matter yield response to N application**

Herbage DM yield response to initial N application in the two species was different. *S.hamata* benefited from N application while the effect of initial N application on *S.guianensis* was negative. Positive effect of N application to *S.hamata* may be associated with its short growing

period. Most of its growth was realized during the period of high rainfall compared to *S.guianensis* which extended its growth towards the beginning of the dry season. Similar benefits of N application to other forage legumes were documented else where (Gill and Patil, 1985b; Tang et al., 1990). Other results discourage the use of N fertilizer application for legume DM production because of insignificant DM yield response (Rai and Kanodia, 1980). According to Raggio and Raggio (1966) and Lopez et al. (1974) lack of response to DM yield may be attributed by N fertilizer depressive effect on the number and dry weight of nodules which subsequently leads to low efficiency of N fixation. Dry matter yield response is also known to be associated with favourable environmental conditions such as rainfall and high temperatures (Frame and Newbound, 1986).

On average N fertilizer application did not affect the leaf:stem ratio of *S.hamata*. However, its effect on *S.guianensis* was associated more with time of harvest. The highest leaf DM accumulation was observed at an earlier age for N fertilized plots compared to unfertilized plots. The implication of this finding is that N application may promote rapid vegetative growth in terms of leaf which subsequently leads to higher photosynthetic ability of the crop and hence maturity within a short period of time. Thus, optimum time of herbage utilization, which is a compromise between yield and quality, becomes more critical

with application of fertilizer.

#### 5.2.2 Dry matter yield response to P application

There was no DM yield response to P fertilizer application in this study for both *S.hamata* and *S.guianensis*. The finding for *S.hamata* support that of Mohammed-Saleem and Von-Kaufmann (1986), McIvor et al. (1988) and Kanodia et al. (1985). In contrast, other researchers found increased DM yield response to P fertilizer application for both *S.hamata* and *S.guianensis* (Rai and Kanodia, 1980; Dowling and Bouma, 1985; Winter and Chapman, 1986; Impithuksa and Rungrattanakasin, 1986; Mohammed-Saleem and Von-Kaufmann, 1986). Although statistically not significant there was a tendency of getting higher DM yields from both *S.hamata* and *S.guianensis* at moderate (30 kg P/ha) than higher levels (60 kg P/ha). Similar response was obtained by Kanodia et al. (1985) using the same species in India. In another study, however, Chisholm and Blair (1988) showed that DM production of *Trifolium repens* was higher than *S.hamata* at moderate levels of P deficiency but the reverse applied at more severe levels of P deficiency. Mohammed-Saleem and Von-Kaufmann showed slight reduction in the productivity of *S.hamata* compared to *S.guianensis* in the absence of maintenance P in the second year of production. All these findings indicate the capacity of these species to grow in soil with low P. The relative high requirement of

*S.guianensis* might be attributed to its higher levels of P uptake by the plant compared to *S.hamata*. Therefore, one can infer that the tested legumes may respond to P fertilizer application in terms of DM yield but the level should be between 0 and 30 kg P/ha. Higher DM yields from *Stylosanthes* species were also observed elsewhere (Bruce and Teitzel, 1978; Crespo and Curbelo, 1990; Miller et al, 1991) in the range of 0 to 30 kg P/ha.

#### 5.2.3 Effect of time of harvest on DM yield

DM yield produced from both *S.hamata* and *S.guianensis* at 50 % flowering stage was far lower than the one harvested at post 50 % flowering stage. This finding supports the one reviewed by Crowder and Chheda (1982) which indicates increased DM accumulation with advancing maturity. In another study, Brolmann and Boman (1988) reported higher DM accumulation from a single harvest at the end of the growing season than frequent cutting in *S.guianensis*. The important implication of the present finding is that it is possible to harvest both seeds and large amounts of fodder from the same stand of *S.hamata* and *S.guianensis*. However, this needs to be further verified especially in semi-arid Morogoro where regrowth of perennial species after cutting is limited by erratic rainfall experienced during the dry season. In contrast to the present finding, other results by Tudsri, et al. (1989) have indicated higher DM yield for

*S.hamata* harvested at first flowering than harvested at full flowering. This may be attributed to better distribution of rainfall that allows higher DM production and distribution from plants harvested at early flowering stages. Therefore, correct judgement of optimum time of harvest for high DM production should take into account the rainfall distribution of the locality and the need for high quality and/or quantity of the feed to be produced.

### 5.3 Chemical composition of *S.hamata* and *S.guianensis*

#### 5.3.1 Effect of N fertilizer application on chemical composition

Ash content of *S.guianensis* increased by N application while that of *S.hamata* declined. Low ash content observed for *S.hamata* disagrees with the results of Raymond (1966), who found higher ash content in heavily fertilized pasture.

Average CP % of the DM tend to increase with N fertilizer application in both *S.hamata* and *S.guianensis*. This is in agreement with the finding of Vicente-Chandler *et al.* (1974), Chheda and Akinola (1971), Crespo (1974) and Olsen (1975) who reported higher figures of CP % in DM for N applied plots regardless of stage of growth considered. An increase in CP % is an advantage as most of the feed in semi-arid Morogoro are low in CP % during the dry season (Mtenga and Madsen, 1992).

ADL content was unaffected by N application in both *S.hamata* and *S.guianensis*, and these results disagrees with other reports (Vicente-Chandler, 1974). The important implication of this finding is that it indicates the advantage of N fertilizer application on *Stylosanthes* crop from the animal nutrition point of view as it may ensure higher DM yield without affecting the lignin content which subsequently leads to better digestible DM.

#### 5.3.2 Effect of P fertilizer application on chemical composition

The general trend observed in the present study was that P application tend to reduce slightly the CP % in DM of both *S.hamata* and *S.guianensis* beyond 30 kg P/ha. Application of P fertilizer to legumes is expected to increase nodulation of forage legumes and hence increase in N or CP content. (Mohammed-Saleem and Von-Kaufmann, 1986; Impithuksa and Rungrattanakasin, 1986). However, increase in nodulation due to P application may vary depending on the species. Mohammed-Saleem and Von-Kaufmann (1986) reported no effect of P application on nodulation of *S.hamata* but there was a marked increase in nodulation in *S.guianensis*. Although data were not available on nodulation, similar effect of P observed on nodulation of *S.hamata* by Mohammed-Saleem and Von-Kaufmann (1986) might also have contributed for the lack of response observed in the present study.

Furthermore, in the present study beneficial effect of P was associated with time of harvest. Phosphorus has increased the CP content of herbage at 50 % flowering stage than late time of harvest considered. However, the marginal decline in CP content of *S.guianensis* observed with application of P in both experiment I and II disagrees with the finding of Mohammed-Saleem and Von-Kaufmann (1986) who reported positive effect of P application on CP content of the same species. Lack of positive response in terms of CP content of the herbage to P application was found to be against documented literature (Mohammed-Saleem and Von-Kaufmann, 1986; Haque et al., 1986), and deserves further investigation as there might be other nutrients which are most limiting than P. This might also be further complicated by the moisture situation of the soil. However, one can speculate from the current finding that *S.hamata* seems to be adaptable to soils low in P content than *S.guianensis*. On the other hand a declining CP content of *S.guianensis* beyond application rate of 30 kg P/ha might be attributed by the dilution effect of corresponding increase in DM yield observed.

Phosphorus application slightly increased the ADL % in DM for *S.hamata* and inconsistently for *S.guianensis*, indicating that this practice may not be beneficial to improve the quality of the herbage DM. The effect of P fertilizer in both ADF and ADL content was inconsistent.

However, its effect on ADF was more associated with time of harvest considered in *S.guianensis*. P application increased ADF content of the herbage at 50 % flowering stage while its effect was insignificant thereafter. This might also contribute for high ADL estimated which indirectly may affect digestibility of the feed.

### 5.3.3 Effect of time of harvest on chemical composition

Changes in total ash content of both *Stylosanthes* species were observed as time of harvest increased from 50 % flowering stage. This finding is in agreement with other results (McDonald et al., 1988) which indicated a similar trend for other forage crops. In addition to change in ash content, change also occurred in CP content of both *Stylosanthes* species. The CP content declined continuously as time of harvest increased post 50 % flowering stage. A decline in CP content has also been observed elsewhere with increasing age of forage plants (Grof et al., 1970; Murugan et al., 1986; Mariyappan et al., 1987; Xande et al., 1989). The lower CP content observed from non-seed residue harvested at the 7<sup>th</sup> week post 50 % flowering stage in both *S.hamata* and *S.guianensis* in the present study is comparable to the one reported by Barnes and Addo-Kwafo (1996) in Ghana for *S.hamata* (10.6 %) and *S.guianensis* (13.1 %) cut during the dry season at 12 weeks regrowth. However, the lowest CP % observed at post 50 % flowering in

the present study were quite adequate and higher than that of improved grasses in Tanzania, such as *Cenchrus ciliaris* cv *Gayndah* (7.8 %), *Bothriocloa insculpta* cv *Hatch* (8.4 %), *Cenchrus ciliaris* cv *Bioloela* (9.4 %), *Panicum coloratum* cv *Bambatsi* and *Chloris gayana* cv *Mpwapwa* (9.5 %) (Shem and Kimambo, 1994). Adequate N is necessary for optimum digestion in vivo (Donefer, 1968), and this was estimated by different workers more or less in the same way using different factors such as: 1.25 g N/ME (ARC, 1980), 7.8 g/MJ ME (Ray et al., 1977). Pigden and Bender (1972), in general suggested 1 % N in the diet to be adequate for the digestion of cellulose in the reticulo-rumen for feeds with up to 50 % digestibility.

ADF and ADL % in DM significantly increased with increasing time of harvest in *S.hamata*. A similar trend has been reported for other forages (Crowder and Chheda, 1982). However, a declining trend in ADF % and ADL % observed in this study for *S.guianensis* with advanced stage of maturity disagrees with documented literature (Chatterjee and Das, 1989; McDonald, 1989; Van Soest, 1994). Initially possible analytical errors were suspected to cause such effect. However, reanalysis of 15 samples from the control plots for fertilizer treatment (with no fertilizer application) confirmed the following:

a) There was a slight variation in the magnitude of ADF % determined between the first and rerun analysis of the same

sample material (App.Fig. 2).

b) Time of harvest affected the ADL and ADF % of the sample in the same way in both analysis (App.Fig. 2).

c) There was no observed interaction effect between analysing the sample more than once and time of harvest effect, indicating that the trend observed in the first analysis for time of harvest would be considered as free from analytical errors as it has repeated itself in the rerun analysis (App.Table 9).

Therefore, there might be a systematic error which may arise from lignin methodologies which are comparatively crude procedures (Van Soest, 1994). In this method determination of ADL assumes difference in weight between indigestible ADF after treating with  $H_2SO_4$  and ash content of the ADF. Traditional methods that use much drying, heating and boiling may generate maillard products. This may bias correct estimation of both ADF and ADL. According to Van Soest (1994) maillard products has most of the physical and chemical properties of lignin. It is soluble in alkali and insoluble in acid. Indigestible protein formed through the maillard reaction is quantitatively recoverable in lignin and ADF. Hence exaggerates the ADF and ADL estimation. In the present study, the oven used for drying did not have ventilation to ensure rapid moisture removal. There might be high possibility of maillard reaction to occur especially for those samples which were

harvested at 50 % flowering than post 50 % flowering stage by virtue of having high moisture content. This may subsequently account for high ADF and ADL content at early harvested samples than the late harvested. In the absence of difficulty with maillard reaction one may associate high ADF and ADL content of *S.guianensis* at early stage of growth which declined with age as a characteristic of *S.guianensis* species. One can speculate in different ways as to how this happens: large proportion of the N in *S.guianensis* may be available in the form of lignified N which may account for high crude lignin estimation at early stage of growth. Advance in plant maturity in *S.guianensis* was associated with decline in N content of the plant which may subsequently lead to lower percentage of lignified N. Hence lower crude lignin estimation at late stage of growth. In another way, perenniality nature of the crop may also contribute for low ADF and ADL content at later harvested samples because of the dilution effect that arise from continuous plant growth. An increase in leaf:stem ratio observed after the 5<sup>th</sup> week may seem to support this argument and be considered as a reflection of continuous growth of the plant. However, this effect seems to be controversial in semi-arid Morogoro as moisture *per se* can check growth of *S.guianensis* at the late stage of growth. There seems to be also some sort of interaction effect between time of harvest and fertilizer application in terms

of ADF and ADL content of *S.guianensis*. Both ADF and ADL % showed increment from 50 % flowering stage up to the 4<sup>th</sup> week for the control ,with no N and P, fertilizer treatment. However, it followed the same declining trend observed for other plots which received fertilizer after the 4<sup>th</sup> week. This could be taken as an interesting point which deserves glass house experiment in the future to investigate further the effect of fertilizer and time of harvest association in *S.guianensis*.

At the moment it seems difficult to accept the observed decline in ADF and ADL content of *S.guianensis* with aging, and this result has to be taken with caution. However, it deserves further research in the future to confirm the result in Morogoro. This includes determination of ADF nitrogen which enables to estimate the N accounted in the crude lignin, preparation of the sample material following sun drying, etc. If research confirms repeatability of the trend in the future this should be considered as part of new knowledge which assists better understanding of the species characteristics. This characteristics of *S.guianensis* makes it advantageous from both agronomical and nutritional point of view in that higher DM accumulation were observed at seed setting stage than 50 % flowering stages. A decline in lignin content with increasing time of harvest post 50 % flowering was advantageous to maintain the quality of the herbage as

lignin acts as a physiological barrier between cellulose and rumen microbes (Dehority and Johnson, 1961) thus affecting the digestibility of the non-seed residue produced from these crops.

#### **5.4 *In vitro* digestibility, digestible crude protein and metabolizable energy of *S.hamata* and *S.guianensis***

##### **5.4.1 Effect of N fertilizer application on *in vitro* digestibility, DCP and ME**

*In vitro* digestibility of the DM increased as a result of N fertilizer application in the present experiment for *S.guianensis*. Similar effect of N was observed in *S.hamata* in the present study though statistically not significant. Effect of N application on digestibility was reviewed by Van Soest (1994). Positive and negative effect have been reported by the same author and this was attributed to the effect of N fertilizer application on CP and lignin content of the DM. In the present study the relative increase in CP content of DM seems to be slightly higher than that of ADL content and hence the slight increase in digestibility value observed for both *S.hamata* and *S.guianensis*.

##### **5.4.2 Effect of P fertilizer application on *in vitro* digestibility, DCP and ME**

Positive effect of P fertilizer application was reported by

Mohammed-Saleem and Von-Kaufmann (1986) and Haque *et al.* (1986) in terms of digestibility for both *S.hamata* and *S.guianensis*. This was not supported by the findings of the present study where lower digestibility values were found for P fertilized plots. This might be attributed by the observed negative P effect on CP content of both *S.hamata* and *S.guianensis* (see section 5.3.2). Increased lignin content due to P fertilizer application could also be attributed to lower digestibility values observed in the present study.

#### 5.4.3 Effect of time of harvest on *in vitro* digestibility, DCP and ME

*In vitro* digestibility of forage legumes generally decreases with maturity as a result of increasing lignin content (Christian *et al.*, 1970; Minson, 1990). This was supported by the findings of the present study in both *S.hamata* and *S.guianensis*. Digestibility declined as the time of harvest extended beyond 50 % flowering stage. Differences between the two species in rate of digestibility decline was observed. The rate of decline was higher for *S.hamata* compared to *S.guianensis*. This might be associated with longer vegetative growth period of *S.guianensis* compared to *S.hamata*. A similar trend was reported by Van Soest (1994) who found that plants that remain vegetative over longer periods may not decline in

quality. Another possible reason for species differences in rate of digestibility decline could be due to differences in plant parts especially leaf:stem ratio. In the present study leaf:stem ratio in *S.guianensis* was almost the same (ranged 1:1.64 to 1:1.45) over the different time of harvest while that of *S.hamata* showed a larger variation (ranged 1:1.20 to 1:0.60). Leaves are more digestible than stems (Van Soest, 1994). The implication of these results are that by virtue of having this quality *S.guianensis* may be more suitable for fodder banks than *S.hamata*. Fertilizer effects on increasing herbage yield was also different between the two species which may dilute the various nutrients.

Increase in digestibility value observed for *S.guianensis* after the 5<sup>th</sup> week post 50 % flowering is conflicting against the common trend reported elsewhere (Chatterjee and Das, 1989; McDonald et al., 1988; Van Soest, 1994) with advanced maturity of forage crops. Further more the same authors emphasised that digestibility of forage crops is positively correlated with CP content and negatively correlated with lignin content of the forage. However, the decline in digestibility value of *S.guianensis* observed up to the 5<sup>th</sup> week post 50 % flowering was speculated to be more associated with decline in CP content; whereas an increase in digestibility observed after the 5<sup>th</sup> week might be a reflection of the decline in

the lignin content of *S.guianensis*. However, this speculation needs to be further investigated in the future.

The decline in *in vitro* DM digestibility of *S.hamata* and *S.guianensis* with increasing time of harvest was also reflected on the low DCP, ME and microbial N requirement. The calculated values in the present study showed that CP content of DM at each time of harvest was higher than the microbial N requirement even at the late harvest time considered (Table 27). One can, therefore, speculate that *S.hamata* and *S.guianensis* non-seed residue could be used for feeding animals to meet maintenance and production requirement. However, at higher levels of animal production, energy rather than CP may be limiting. With the exception of *S.hamata* harvested at 50 % flowering stage, ME content of DM produced at all stages of growth in the present study were less than a minimum level likely to meet maintenance requirement as most of them were below 8.368 MJ/kgDM (NRC, 1979). The observed low ME content may have been attributed partly to lower organic matter digestibility and partly due to high concentration of lignin. A similar trend was reported for other forage legumes by McDonald *et al.*(1988). Thus it is important to look for other feed resources which supplement the energy deficit encountered in non-seed residues of *S.hamata* and *S.guianensis* seed crops, as levels of energy in the diet were found to be the major limitations for livestock

production in semi-arid Morogoro (Mtenga and Madsen, 1992).

### 5.5 Economics of fertilizer application

The biological merits and demerits of N and P fertilizer application were discussed from both agronomic and nutrition point of view in the previous sections (5.1-5.4). However, the partial budget analysis done in the present study indicates the following:

a. Application of N fertilizer in *S.hamata* kept for production of both seed and fodder was profitable followed by the same crop meant for seed production. However, the benefit of N application in *S.hamata* kept for fodder production in the present study was not economical.

b. Application of P fertilizer in *S.guianensis* kept for seed production was the most profitable followed by the same crop meant for both seed and fodder production. Out of the different rates of P fertilizer tested, application of P at 60 kg/ha was found to be the most economical. This was followed by application rate of 30 kg P/ha. Application of P fertilizer for fodder production was not economical and, therefore, is not recommended.

c. Starter dose of N application to *S.guianensis* was found to be uneconomical.

d. Application of P fertilizer in *S.hamata* in any case was not economical.

The present study also showed some advantages and disadvantages of applying both N and P fertilizer together. However, the economic benefit observed by this practice was out yielded by sole application of these fertilizers as stated earlier.

## CHAPTER VI

## 6.0 CONCLUSIONS AND RECOMMENDATIONS

The present study conducted in semi-arid area in Morogoro on N and P application to *S.hamata* and *S.guianensis* indicates that:-

1. The two *Stylosanthes* species studied responded differently to N application in terms of DM yield. Starter dose of N application at the rate of 30 kg N/ha increased the DM yield and seed yield of *S.hamata*. *S.guianensis*, however, did not benefit from starter dose of N application in terms of increased DM and seed yield. This practice may be adopted for *S.hamata* to increase both DM and seed yield. However, its effect on production in subsequent years need further investigation.
2. The overall quality of the two *Stylosanthes* species was improved as a result of a starter dose of N application. CP and DCP content of *S.hamata* and *S.guianensis* increased as compared to the control. Starter dose of N application also improved the ME content of *S.guianensis*.
3. Phosphorus application to *S.hamata* did not benefit the crop in terms of increased seed yield, DM yield or quality of the herbage. The use of higher P levels beyond 30 kg

P/ha for *S.hamata* may, therefore, not be beneficial.

4. *S.guianensis* responded to higher levels of P application up to 60 kg/ha in terms of seed yield and leaf:stem ratio. However, higher levels of P beyond 60 kg P/ha reduced the IVOMD % and subsequently ME content of the herbage. It is therefore, recommended that application of P fertilizer for *S.guianensis* be at 60 kg P/ha for establishment.

5. Starter dose of N and P application was found to be economical in *S.hamata* and *S.guianensis* respectively kept for sole seed production and the production of both seed and fodder. In both *Stylosanthes* species it was uneconomical to apply fertilizer for sole fodder production.

6. Harvesting at 4<sup>th</sup> week post 50 % flowering stage allowed seed production in both *S.hamata* and *S.guianensis*. However, seed yield was low and this was increased at later harvests in both species. Therefore, harvesting at the 7<sup>th</sup> week for *S.hamata* and 6<sup>th</sup> week for *S.guianensis* have distinct advantage in seed production over other times of harvest. However, peak seed yield for *S.hamata* was not reached in the present study and, therefore, there is a need for further research to identify the best time of harvest for sole seed production beyond the 7<sup>th</sup> week post 50 %

flowering.

7. Harvesting of the crop at different seed setting stages increased DM yield of *S.hamata* and *S.guianensis* compared to the ones harvested at 50 % stage. The quality of herbage produced at post 50 % flowering stage were low, with the exception of declining ADF and ADL % observed in DM of *S.guianensis*. This, needs further investigation in the future.

8. The result of the present study indicated that CP content of both species, regardless of stage of harvest, was not limiting at least for maintenance requirement of animals. But, the ME content is not likely to meet maintenance requirement. This suggests that there is a need to look for other feed resources which can supplement the energy deficit encountered in *S.hamata* and *S.guianensis* crops.

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## 8.0 APPENDICES

Appendix Figure 1.1: Experimental field lay out

S  
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a) *S. hamata*

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Rep.	
D	D	D	D	D	A	A	A	A	A	C	C	C	C	C	B	B	B	B	B	F	F	F	F	F	F	E	E	E	E	E	I
31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	II	
F	F	F	F	F	D	D	D	D	D	A	A	A	A	A	B	B	B	B	B	E	E	E	E	E	C	C	C	C	C	II	
61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	III	
D	D	D	D	D	A	A	A	A	A	B	B	B	B	B	B	B	B	B	B	E	E	E	E	E	F	F	F	F	F	III	

b) *S. guianensis*

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Rep.
B	B	B	B	B	F	F	F	F	F	A	A	A	A	A	D	D	D	D	D	E	E	E	E	E	C	C	C	C	C	I
31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	II
F	F	F	F	F	D	D	D	D	D	E	E	E	E	E	B	B	B	B	B	A	A	A	A	A	C	C	C	C	C	II
61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	III
A	A	A	A	A	C	C	C	C	C	D	D	D	D	D	B	B	B	B	B	E	E	E	E	E	F	F	F	F	F	III

Appendix Table 1.2: Experimental treatment allocation for *S.hamata* and *S.guianensis*.

Plot No.	Replicati on	Treatment allocation for <i>S.hamata</i>		Treatment allocation for <i>S.guianensis</i>	
		Main-plot treat.	Sub-plot treat.	Main-plot treat.	Sub-plot treat.
1	1	D	5	B	5
2	1	D	3	B	3
3	1	D	1	B	1
4	1	D	4	B	4
5	1	D	2	B	2
6	1	A	2	F	2
7	1	A	3	F	3
8	1	A	4	F	4
9	1	A	5	F	5
10	1	A	1	F	1
11	1	C	3	A	5
12	1	C	4	A	3
13	1	C	1	A	4
14	1	C	5	A	2
15	1	C	2	A	1
16	1	B	3	D	3
17	1	B	4	D	4
18	1	B	2	D	1
19	1	B	1	D	5
20	1	B	5	D	2
21	1	F	5	E	5
22	1	F	3	E	2
23	1	F	4	E	1
24	1	F	2	E	3
25	1	F	1	E	4
26	1	E	5	C	3
27	1	E	2	C	4
28	1	E	1	C	2
29	1	E	3	C	1

Continued...

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30	1	F	4	C	5
31	2	F	2	F	2
32	2	F	1	F	1
33	2	F	5	F	5
34	2	F	3	F	3
35	2	F	4	F	4
36	2	D	4	D	4
37	2	D	3	D	3
38	2	D	5	D	5
39	2	D	2	D	2
40	2	D	1	D	1
41	2	A	4	E	5
42	2	A	5	E	4
43	2	A	2	E	3
44	2	A	1	E	1
45	2	A	3	E	2
46	2	B	1	B	3
47	2	B	5	B	1
48	2	B	2	B	4
49	2	B	3	B	5
50	2	B	4	B	2
51	2	E	5	A	2
52	2	E	4	A	4
53	2	E	3	A	1
54	2	E	1	A	3
55	2	E	2	A	5
56	2	C	2	C	1
57	2	C	4	C	5
58	2	C	1	C	2
59	2	C	3	C	3
60	2	C	5	C	4
61	3	D	3	A	3
62	3	D	2	A	2

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Continued...

63	3	D	4	A	4
64	3	D	5	A	5
65	3	D	1	A	1
66	3	A	5	C	1
67	3	A	1	C	2
68	3	A	2	C	3
69	3	A	3	C	4
70	3	A	4	C	5
71	3	C	3	C	2
72	3	C	4	D	5
73	3	C	5	D	1
74	3	C	1	D	4
75	3	C	2	D	3
76	3	B	4	B	3
77	3	B	5	B	4
78	3	B	1	B	5
79	3	B	2	B	1
80	3	B	3	B	2
81	3	E	5	E	1
82	3	E	2	E	5
83	3	E	1	E	2
84	3	E	4	E	4
85	3	E	3	E	3
86	3	F	1	F	4
87	3	F	5	F	5
88	3	F	2	F	1
89	3	F	4	F	2
90	3	F	3	F	3

Label coding: Species name/plot number/rep M-plot treat and  
S-plot treat code

Example for plot number 1 SH/1/1D5 for *S.hamata*, and  
SG/1/1B5 for *S.guianensis*  
for plot number 90 SH/90/3F3 for *S.hamata*, and  
SG/90/3F3 for *S.guianensis*

Appendix Table 2.1: Summary of mean square for N, P and time of harvest effect and their interaction on different studied parameter for *S.hamata* under experiment I.

parameter	Source of variation										
	Rep	N	P	N*P	Error a	HT	N*HT	P*HT	N*P*HT	Error b	
Index	0.579	2.393	0.009	0.049	0.867	37.614	1.147	1.443	0.740	0.575	
Syld	1746.1	17832.1	47.8	891.5	3643.1	32225.3	681.4	642.8	1815.3	2192.6	
Germ	-	108.9	0.225	129.6	-	132.8	-	-	-	233.2	
LSR	0.167	0.112	0.003	0.00001	0.062	1.931	0.049	0.142	0.110	0.069	
DMyld	1160054.3	11297183.9	8907.6	1016075.8	1895701.3	11208837.0	679751.3	125771.7	523402.5	813126.	
Ash %	1.405	2.108	0.0001	5.847	0.535	112.6	1.567	3.582	1.464	2.433	
CP %	9.176	22.68	4.577	5.463	11.369	155.55	3.249	4.982	2.101	1.787	
ADF %	10.807	23.989	152.732	16.806	88.125	685.69	90.66	38.767	66.764	115.89	
ADL %	0.701	1.986	13.016	0.187	9.924	77.643	1.873	5.474	7.626	8.368	
IVDMD	940.42	39.78	13.046	1.96	24.011	294.80	9.421	52.0937	14.0639	34.959	
IVOMD	158.653	36.888	.989	6.468	33.575	445.679	5.454	18.734	18.374	24.697	
DCP	760.61385	1886.87761	397.950	454.68768	944.11208	1290.13804	269.824	414.8640	174.50754	148.464	
ME	0.599	0.158	1.394	0.332	2.008	5.880	0.902	.914	2.937	1.880	

Appendix Table 2.2: Summary of degrees of freedom and levels of significance for N, P and time of harvest effect and their interaction on different studied parameters for *S.hamata* under experiment I.

parameter	Source of variation											R-square
	Rep	N	P	N*P	Error a	HT	N*HT	P*HT	N*P*HT	Error b	Mean	
Index	2	1 ns	1 ns	1 ns	6	3 ***	3 ns	3 ns	3 ns	23	2.68	0.91
Syld	2	1 ns	1 ns	1 ns	6	3 ***	3 ns	3 ns	3 ns	23	80.6	0.75
Germ	-	1 ns	1 ns	1 ns	-	3 ns	-	-	-	8	39.8	0.27
LSR	2	1 ns	1 ns	1 *	6	4 ***	4 ns	4 ns	4 ns	31	1.04	0.82
Dmyld	2	1 *	1 ns	1 ns	6	4 ***	4 ns	4 ns	4 ns	31	2467.1	0.75
Ash ‡	2	1 ns	1 ns	1 ns	6	4 **	4 ns	4 ns	4 ns	31	9.18	0.87
CP ‡	2	1 ns	1 ns	1 ns	6	4 ***	4 ns	4 *	4 ns	30	12.86	0.93
ADF ‡	2	1 ns	1 ns	1 ns	6	4 **	4 ns	4 ns	4 ns	31	47.35	0.55
ADL ‡	2	1 ns	1 ns	1 ns	6	4 ***	4 ns	4 ns	4 ns	14	10.75	0.83
IVDMD	2	1 ns	1 ns	1 ns	6	4 ***	4 ns	4 ns	4 ns	30	53.22	0.78
IVOMD	2	1 ns	1 ns	1 ns	6	4 ***	4 ns	4 ns	4 ns	31	54.71	0.77
DCP	2	1 ns	1 ns	1 ns	6	4 **	4 ns	4 ns	4 ns	31	80.52	0.93
ME	2	1 ns	1 ns	1 ns	6	4 *	4 ns	4 ns	4 ns	31	7.31	0.50

Appendix Table 3.1: Summary of mean squares for N, P and time of harvest effect and their interaction on different studied parameters for *S.guianensis* under experiment I.

parameter	Source of variation										
	Rep	N	P	N*P	Error a	HT	N*HT	P*HT	N*P*HT	Error b	
Index	0.753	1.751	1.553	1.887	0.498	1.220	0.693	0.9050	0.1085	0.3048	
Sy1d	94.564	4765.855	7181.0	2927.158	2268.602	8844.910	2002.319	4916.882	1299.168	2935.1374	
Germ	77.744	33.354	29.468	20.735	544.605	351.562	249.739	813.477	701.9847	251.1664	
LSR	0.020	0.003	0.0032	0.149	0.0202	0.0107	0.0825	0.0342	0.0445	0.00811	
DMY1d	283692944	631313.6	15311027.8	10517914.5	18098393.3	40280136.7	6385405.7	597688.2	5714191.8	5253215.4	
Ash %	2.276	10.102	3.370	1.405	0.713	11.315	0.107	0.6205	0.4984	0.4717	
CP %	0.107	6.118	1.973	2.189	1.456	4.719	1.285	2.1155	2.5323	1.24716	
ADF %	6.209	22.965	12.568	29.793	13.180	77.159	12.248	61.283	57.4957	22.0128	
ADL %	4.133	4.137	0.313	10.299	9.862	32.188	8.183	7.649	10.0054	5.5435	
IVDMD	504.507	157.367	125.657	84.040	36.133	73.518	7.045	15.592	17.9035	18.8741	
IVOMD	134.014	58.214	49.323	34.020	9.788	64.269	4.927	6.825	24.0713	12.5145	
DCP	8.864	508.669	163.680	181.308	121.050	393.864	106.104	175.473	209.810	103.613	
ME	2.899	1.259	1.075	0.741	0.213	1.392	0.107	0.148	0.5190	0.2708	

Appendix Table 3.2: Summary of degrees of freedom and levels of significance for N, P and time of harvest effect and their interaction on different studied parameters for *S. guianensis* under experiment I.

parameter	Source of variation											Error b	Mean	R- square
	Rep	N	P	N*P	Error a	HT	N*HT	P*HT	N*P*HT	Error b	R- square			
Index	2	1 ns	1 ns	1 ns	6	3 *	3 ns	3 ns	3 ns	21	0.64	0.75		
Syld	2	1 ns	1 ns	1 ns	6	3 ns	3 ns	3 ns	3 ns	20	51.65	0.59		
Germ	2	1 ns	1 ns	1 ns	6	3 ns	3 ns	3 *	3 *	20	57.44	0.68		
LSR	2	1 ns	1 ns	1 *	6	4 ***	4 ***	4 **	4 **	30	0.57	0.79		
DMyld	2	1 ns	1 ns	1 ns	6	4 ***	4 ns	4 ns	4 ns	31	8368.7	0.77		
Ash %	2	1 *	1 ns	1 ns	6	4 *	4 ns	4 ns	4 ns	32	9.58	0.83		
CP %	2	1 ns	1 ns	1 ns	6	4 *	4 ns	4 *	4 ns	32	14.75	0.61		
ADF %	2	1 ns	1 ns	1 ns	6	4 *	4 ns	4 ns	4 ns	32	47.96	0.58		
ADL %	2	1 ns	1 ns	1 ns	6	4 *	4 ns	4 ns	4 ns	27	12.42	0.75		
IVDMD	2	1 ns	1 ns	1 ns	6	4 *	4 ns	4 ns	4 ns	32	56.33	0.77		
IVOMD	2	1 *	1 ns	1 ns	6	4 *	4 ns	4 ns	4 ns	32	55.17	0.61		
DCP	2	1 ns	1 ns	1 ns	6	4 ?	4 ns	4 ns	4 ns	32	97.74	0.68		
ME	2	1 ns	1 ns	1 ns	6	4 *	4 ns	4 ns	4 ns	32	7.93	.50		

Appendix Table 4.1: Summary of mean squares of P and time of harvest and their interaction effect on different studied parameters for *S.hamata* under experiment II.

Param eter	Source of variation					
	Rep	P	Error a	HT	P*HT	Error b
Index	1.9480	0.3795	1.2522	37.1866	1.10817	0.51448
Syld	13899.85	586.067	3182.01	53654.33	2519.689	2871.958
Germ	-	72.24861	-	67.571759	-	68.51736
LSR	0.2237	0.1771	0.0235	1.1737	0.02612	0.0723
DMyld	3683536.4	293072.0	2209532.9	16799760.5	456038.7	787358.1
Ash %	2.2164	1.58278	2.11564	9885430	1.1844	1.66867
CP %	10.8247	8.9430	7.1227	172.0455	1.9379	1.6898
ADF %	41.2905	49.387	40.0571	533.0987	42.5697	69.195
ADL %	6.3404	7.04768	9.9246	83.9562	8.4792	7.4376
IVDMD	1011.559	57.2121	11.3919	266.0984	35.2967	25.9367
IVOMD	167.159	26.9678	17.0744	396.223	10.097	17.806
DCP	898.161	742.687	592.08	14293.869	161.0207	140.287
ME	3.617	0.5853	0.3699	8.5928	0.2187	0.38568

Appendix Table 4.2: Summary of degrees of freedom and levels of significance of P and time of harvest and their interaction effect on different studied parameters for *S.hamata* under experiment II.

Parameter	Source of variation							
	Rep	P	Error	HT	P*HT	Error	MEAN	R-square
			a			b		
Index	2	3 ns	6	3 ***	9 ns	24	2.83	0.92
Syld	2	3 ns	6	3 ***	9 ns	24	98.99	0.77
Germ	-	3 ns	-	3 ns	-	8	40.9	0.43
LSR	2	3 *	6	4 ***	12 ns	31	1.07	0.73
DMyld	2	3 ns	6	4 ***	12 ns	32	2918.4	0.79
Ash %	2	3 ns	6	4 ***	12 ns	32	8.79	0.89
CP %	2	3 ns	6	4 ***	12 ns	32	12.8	0.94
ADF %	2	3 ns	6	4 ***	12 ns	32	48.51	0.58
ADL %	2	3 ns	6	4 ***	12 ns	19	11.12	0.80
IVDMD	2	3 *	6	4 ***	12 ns	31	52.50	0.82
IVOMD	2	3 ns	6	4 ***	12 ns	32	54.36	0.80
DCP	2	3 ns	6	4 ***	12 ns	32	80.01	0.94
ME	2	3 ns	6	4 ***	12 ns	32	7.81	0.80

Appendix Table 5.1: Summary of mean squares of P and time of harvest and their interaction effect on different studied parameters for *S.guianensis* under experiment II.

Parameter	Source of variation					
	Rep	P	Error a	HT	P*HT	Error b
Index	0.14589	1.88410	0.08907	0.19618	0.44433	0.358054
Syld	993.465	7997.086	126.4039	3158.475	3578.973	2931.5802
Germ	64.7925	133.161148	538.1664	196.3883	543.5805	300.58777
LSR	0.04228	0.24833	0.053819	0.030989	0.028557	0.0200812
DMyld	12489864	12398965.4	12315215	265671.1	6641702.	7675170.6
Ash %	4.23239	4.58677	0.63976	5.58579	1.47536	0.558690
CP %	4.6996	3.677287	3.47262	5.623918	1.49076	2.020385
ADF %	13.14734	22.60253	17.02272	53.9325	29.46108	17.151567
ADL %	4.76184	6.24328	7.332269	24.07304	7.0845	5.38755
IVDMD	504.2782	49.687886	9.689198	34.3346	6.8061	20.9353
IVOMD	63.91613	41.40394	8.66932	28.4375	8.35595	12.8207
DCP	390.589	306.0321	288.6427	467.581	123.8557	167.8218
ME	1.38033	0.895757	0.18957	0.615927	0.180659	0.277912

Appendix Table 5.2: Summary of degrees of freedom and levels of significance of P and time of harvest and their interaction effect on different studied parameters for *S.guianensis* under experiment II.

Paramete r	Source of variation							MEAN	R- square
	Rep	P	Error a	HT	P*HT	Error b			
Index	2	3 **	6	3 ns	9 ns	21	0.75	0.63	
Syld	2	3 *	6	3 ns	9 ns	20	56.41	0.62	
Germ	2	3 ns	6	3 ns	9 ns	18	60.99	0.66	
LSR	2	3 **	6	4 ns	12 ns	30	0.67	0.73	
DMyld	2	3 ns	6	4 *	12 ns	30	-	0.70	
Ash %	2	3 *	6	4 ***	12 *	31	9.65	0.80	
CP %	2	3 ns	6	4 *	12 ns	27	14.64	0.57	
ADF %	2	3 ns	6	4 *	12 ns	30	48.80	0.60	
ADL %	2	3 ns	6	4 *	12 ns	17	12.74	0.70	
IVDMD	2	3 *	6	4 ns	12 ns	31	57.27	0.69	
IVOMD	2	3 *	6	4 ns	12 ns	31	55.30	0.57	
DCP	2	3 ns	6	4 *	12 ns	31	96.72	0.57	
ME	2	3 ns	6	4 ns	12 ns	31	7.95	0.57	

Appendix Table 6.1: Summary of mean squares of N and P fertilizer combination (NP) and time of harvest and their interaction effect on different studied parameters for *S.hamata* under combined analysis over experiment I and II.

Param eter	Source of variation					
	Rep	NP	Error a	HT	NP*HT	Error b
Index	0.68723	0.526549	1.137908	55.98279	1.045762	0.592233
Syld	9583.90	5374.520	4658.742	75872.09	2748.716	3029.4012
Germ	-	67.015	-	80.195833	-	174.04583
LSR	0.17033	0.129989	0.070404	2.314823	0.080642	0.0738698
DMyld	2479376	3307315.	2145874.	19244298.	473445.5	768966.7
Ash %	2.23498	2.736437	1.362091	156.6829	1.894283	2.295001
CP %	2.53929	9.141913	13.29348	226.8011	2.420599	2.00565
ADF %	8.39907	47.56626	57.04562	903.8159	51.84115	80.708226
ADL %	1.71061	5.966670	8.084867	110.3626	6.390434	6.7092931
IVDMD	1484.90	36.9774	18.22888	368.7381	33.50515	29.294979
IVOMD	232.724	18.32713	21.56082	616.6220	14.44295	18.288622
DCP	210.824	759.7584	1103.854	18841.72	201.1693	166.57315
ME	5.04263	0.397109	0.467176	13.36086	0.312947	0.3962749

Appendix Table 6.2: Summary of degrees of freedom and levels of significance of N and P fertilizer combination and time of harvest and their interaction effect on different studied parameters for *S.hamata* under combined analysis over experiment I and II.

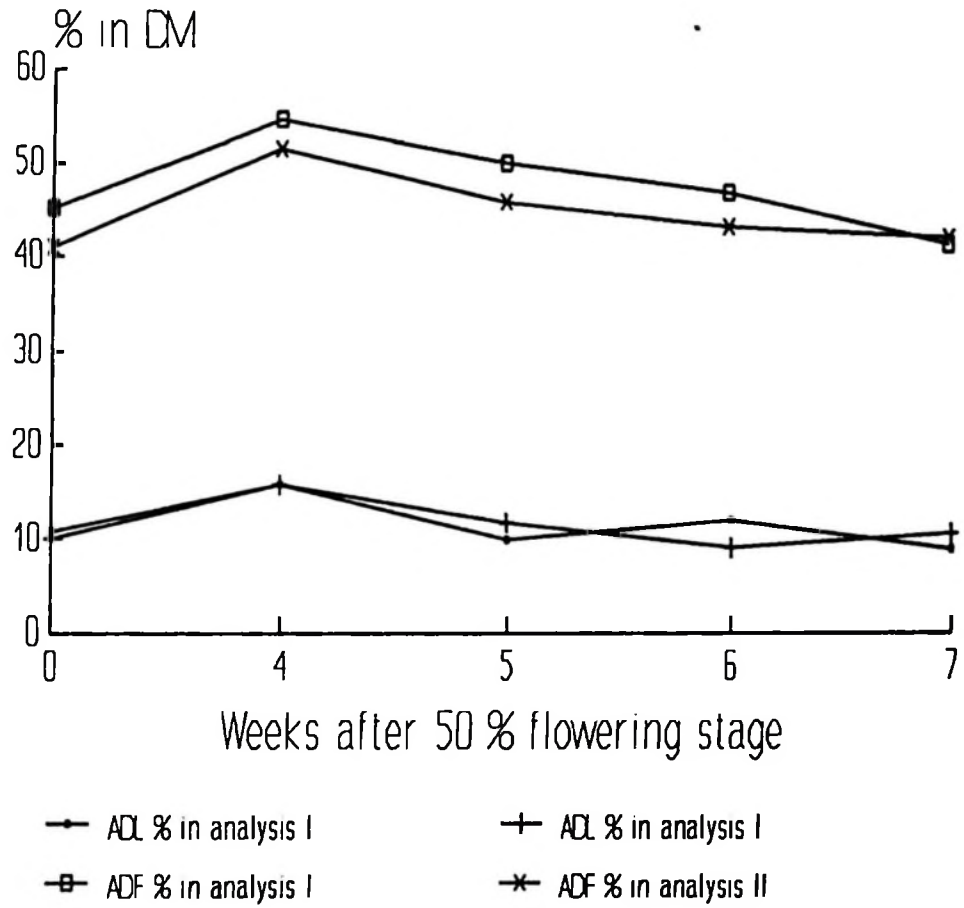
Param eter	Source of variation							
	Rep	NP	Error	HT	NP*HT	Error	MEAN	R- square
			a			b		
Index	2	5 ns	10	3 ***	15 ns	35	2.68	0.77
Syld	2	5 ns	10	3 ***	15 ns	35	94.33	0.91
Germ	-	5 ns	-	3 ns	-	14	39.91	0.19
LSR	2	5 ns	10	4 ***	20 ns	46	1.05	0.78
DMyld	2	5 ns	10	4 ***	20 ns	47	2617.5	0.78
Ash %	2	5 ns	10	4 ***	20 ns	47	8.99	0.87
CP %	2	5 ns	10	4 ***	20 ns	46	12.65	0.92
ADF %	2	5 ns	10	4 ***	20 ns	47	47.86	0.59
ADL %	2	5 ns	10	4 ***	20 ns	24	11.02	0.83
IVDMD	2	5 ns	10	4 ***	20 ns	46	52.46	0.81
IVOMD	2	5 ns	10	4 ***	20 ns	47	54.21	0.81
DCP	2	5 ns	10	4 ***	20 ns	46	78.63	0.92
ME	2	5 ns	10	4 ***	20 ns	47	7.79	0.81

Appendix Table 7.1: Summary of mean squares of N and P fertilizer combination (NP) and time of harvest and their interaction effect on different studied parameters for *S.guianensis* under combined analysis over experiment I and II.

Parameter	Source of variation					
	Rep	NP	Error a	HT	NP*HT	Error b
Index	0.344415	1.88369	0.440729	1.147041	0.543144	0.402989
Syld	50.298	7134.37	1617.86	10210.32	2931.47	3306.129
Germ	10.66661	155.72281	425.0479	304.97817	737.4039	244.3918
LSR	0.011397	0.19739	0.048480	0.015100	0.033238	0.016504
DMyld	17463696.	11228546.	19556661.	35111293.	5035850.	6058968.
Ash %	4.6671011	3.813009	0.849457	10.24758	1.116391	0.518566
CP %	1.590733	3.24391	3.065526	8.22374	1.679379	1.654881
ADF %	11.56794	21.3812	16.22116	102.0992	40.0468	20.67502
ADL %	2.30535	6.33812	10.33071	38.2807	9.14093	5.4610
IVDMD	682.14009	96.41352	29.0587	72.9199	11.31988	24.7761
IVOMD	130.4058	46.328	11.58301	56.76426	11.47897	14.0358
DCP	132.1842	269.727	254.9256	683.873	139.5247	137.4127
ME	2.81875	1.00515	0.252619	1.228979	0.247999	0.304190

Appendix Table 7.2: Summary of degrees of freedom and levels of significance of N and P fertilizer combination and time of harvest and their interaction effect on different studied parameters for *S.guianensis* under combined analysis over experiment I and II.

Parameter	Source of variation							MEAN	R-square
	Rep	NP	Error	HT	NP*HT	Error			
			a			b			
Index	2	5 *	10	3 ns	15 ns	32	0.78	0.68	
Syld	2	5 *	10	3 *	15 ns	31	57.35	0.59	
Germ	2	5 ns	10	3 ns	15 ns	29	59.56	0.72	
LSR	2	5 *	10	4 ns	20 *	44	0.64	0.77	
DMyld	2	5 ns	10	4 ***	20 ns	46	7715.8	0.76	
Ash %	2	5 *	10	4 **	20 *	47	9.49	0.81	
CP %	2	5 ns	10	4 **	20 ns	47	14.57	0.60	
ADF %	2	5 ns	10	4 **	20 *	46	48.3	0.62	
ADL %	2	5 ns	10	4 ***	20 ns	28	11.91	0.76	
IVDMD	2	5 ns	10	4 *	20 ns	47	56.4	0.70	
IVOMD	2	5 *	10	4 **	20 ns	47	54.92	0.62	
DCP	2	5 ns	10	4 **	20 ns	47	96.09	0.60	
ME	2	5 *	10	4 **	20 ns	47	7.89	0.62	



Appendix Figure 8.1: ADF and ADL % in DM of *S. guianensis* as affected by time of harvest and reanalysis at DASP, SUA.

Appendix Table 9: Summaries of level of significance of *S.guianensis* herbage sample analyzed for ADF and ADL content determination at two separate analysis conducted at DASP (SUA) and time of harvest effect.

Parameter	Source of variation					
	Analysis	Rep	HT	Analysis*HT	CV(%)	R-square
ADF %	0.019	ns	0.0001	ns	6.7	0.78
ADL %	ns	ns	0.0057	ns	22.2	0.66