PROPAGATION, FORAGE PRODUCTION AND FORAGE QUALITY OF SOME GHANAIAN BROWSE PLANTS

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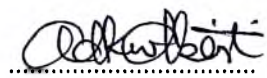
DECLARATION

I hereby declare that this is an original Research work carried out and completed by Albert Addo-Kwafo with exception of other people's work which has been duly cited, and that this Thesis either in whole or in part, has not been presented for another degree anywhere else.



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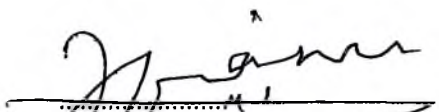

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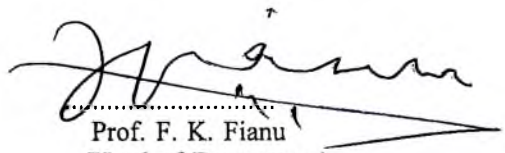

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DEDICATION

Dedicated to my lovely Wife, Mrs. Evelyn Adubea Addo-Kwafo, and my children: Chief Kwaasi Addo-Kwafo, Akua Kyekye Addo-kwafo and Nana Akornobea Addo-Kwafo for toiling day and night to sustain me during the course of the study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Experiments were carried out to examine the ease of establishment of some native browse species through both seed and stem cuttings, the forage production from these browse species and the nutritive quality of the forage produced as livestock feed. Five experiments were therefore conducted to address the problem.

Experiment I: The objective of this experiment was to test *in vitro* techniques for breaking the dormancy of the seed of some native browse plants. Germination tests were performed, after no treatment (control) soaking in warm water, immersion in hot water and mechanical scarification, on the seed of ten browse plants namely: *Cajanus cajan, Dialium guineense, Afzelia africana, Khaya senegalensis, Grewia carpinifolia, Pithecellobium dulce, Albizia lebbek, Milettia thonningii, Baphia nitida* and *Griffonia simplicifolia.* The experimental design was 10 x 4 factorial arranged in a completely randomised design with four replicates. The factors were the ten browse species and the four seed treatment methods.

Percentage germination was high (54-98%) with mechanical scarification for all the species except *Grewia carpinifolia* and *Khaya senegalensis* (11-16%). The other treatments also gave high percentage germination (above 48%) with the exception of *Grewia carpinifolia, Khaya senegalensis* and *Dialium guineense* which were very low (5-41%). Number of days taken to germinate in the different browse species was significantly shorter ($P<0.05$) for the scarified seed than the other treatments. Regardless of the type of treatment adopted *Cajanus cajan* and *Milettia thonningii* took the same time to germinate for all the treatments (3 and 4 days respectively). Mechanical scarification reduced the number of days to germination from 13.8 to 2.3 and 12.7 to 6.3 in *Albizia lebbek* and

Afzelia africana respectively. For *Grewia carpinifolia* and *Dialium guineense* both warm and hot water treatments increased the number of days to germination. The control and mechanical scarification were similar. Species differed significantly ($P<0.05$) in the rate of germination. Mechanical scarification increased the rate of germination of the species more than the other treatments.

Experiment II: The objective of this experiment was to study the changes in plant height with time, the relative growth rate (RGR), net assimilation rate (NAR) and Leaf area ratio (LAR) of the browse plants. The seed of the browse plants used in Experiment I were planted in polybags and their RGR, NAR, LAR and dry matter accumulation were noted. The experimental design was a completely randomised design with 8 replicates. The RGR was highest (0.052 g g^{-1} d^{-1}) in *Cajanus cajan* and lowest (0.021 g g^{-1} d^{-1}) in *Afzelia africana.* The NAR ranged between (153 and 491) x 10^{-6} g cm^{-2} d^{-1} with *Cajanus cajan* and *Albizia lebbek* accounting for the lowest and highest values respectively. LAR values ranged between 60 and 339 cm^2 g^{-1} being lowest and highest in *Pithecellobium dulce* and *Cajanus cajan* respectively. Dry matter accumulation was highest in *Cajanus cajan* (280g) and lowest in *Afzelia africana* (4g). The NAR value of *Cajanus cajan* suggests that it was very poor in putting on dry material contrary to actual observation. Thus care should be taken when comparing species using their NAR values.

Experiment III: The objective of this experiment was to study the sprouting ability as well as the growth rate of these native browse plants, using hardwood stem cuttings treated with a rooting hormone. Cuttings of all the browse plants mentioned in experiment I in addition to those of *Spondias mombin and Ficus exasperata* were planted in polybags with the aid of a rooting hormone. It was observed that, the establishment of the browse plants

studied. The percentage seedling emergence was over 80% for all the species while the percentage plant survival to 16 weeks was over 78% for all the species reaching 100% in *Cajanus cajan.*

Experiment V: The objective of this experiment was to study the feed quality of the forage produced in Experiment IV in the laboratory. The dry matter content of the species ranged between 302-703 g/kg. The dry matter yield of *Afzelia africana* (0.08 t/ha) was so low that enough was not available for the determination of NDF, ADF cellulose, hemicellulose and lignin. Average crude protein (CP) content for the six, seven and eight months period were 21.52%, 19.67% and 19.36% respectively and ranged between 14.76 - 25.00%. The calcium (Ca) content of the species ranged between 2.2-5.6% while the phosphorus (P) content ranged between 0.15 and 0.23% for all the species over the three periods.

The *In vitro* dry matter digestibility (IVDMD) ranged from 44-63% with *Cajanus cajan,* the lowest value and *Afzelia africana* having the highest. The *in situ* disappearance after 48 hours of incubation for both DM and CP was in the range of 40-70% and 29-68% respectively. The most promising species for dry season supplementary feeding of ruminants from these studies were *Albizia lebbek, Cajanus cajan, Milettia thonningii* and *Pithecellobium dulce.* These forages when supplemented to ruminants especially during the dry season could play a vital role in the improvement of animal production. It is therefore suggested that very efficient management practices should be adopted in the propagation agronomy of these browse species so that enough would be available for dry season supplementary feeding. The work done so far should be extended to include studies with

animals so as to ascertain the voluntary intake and *in vivo* dry matter digestibility and animal preference.

CHAPTER ONE

1.0 INTRODUCTION

Ghana, according to the Medium Term Agricultural Development Programme (1990) is producing only 22-25% of its total meat requirement. Chief among the several reasons for this low level of output, is the inadequate supply of good quality feed. There is plenty of green forage available for ruminant livestock during the rainy season which may even be underutilized. However, the grasses become wiry and parched during the dry season, resulting in their poor nutritive value. Thus, animals gain weight during the rainy season only to lose it during the dry season. Liveweight losses of up to 11% for cattle Rose Innes, 1961 and 15% for sheep Otchere *et al.* 1977 have been reported in the country.

Comparative studies of sheep and goats in Nigeria's forest zone showed that sheep and goats spent over 90% of their total feeding time browsing (Carew *et al.* 1980). In the semi-arid and arid regions, shrub and tree fodder become even more important as feed resources due to the harsh environment which makes feed supply uncertain. The role of leguminous shrubs in integrated farming systems has been highlighted by various workers (Kang *et al.* 1984, Atta-Krah and Francis, 1986, Atta-Krah, 1989). Browse plants, especially leguminous trees and shrubs, beside providing feed for livestock, supply other needs of man.

It has been suggested that woody leguminous browse species of high nutritive value if established in the subhumid and semi-arid savanna zones would alleviate the

problem of slow growth of livestock (Rose Innes and Mabey 1964a). This would ensure adequate high quality feed for livestock throughout the year and hence increase production of meat in the country. Studies on germinability, establishment, yield and quality of native/introduced browse plants used by stockmen in the country seem not to have been conducted. This knowledge gap needs to be filled. A successful establishment of such plants will require efficient means of propagation. Those that establish quickly, have high growth rate and produce high yield of nutritious forage would then be selected for production.

The main objectives of this work were to study the seed germination, ease of establishment, forage yield potential and nutritive value of some indigenous browse plants.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 FORAGE PRODUCTION AND NUTRIENT RECYCLING

Multipurpose trees have been used in various cropping practices for the maintenance of soil nitrogen and other nutrient elements. In this regard, *Leucaena leucocephala* has been one of the most highly studied species (N.A.S. 1977, Guevarra *et al.* 1978). Reports from field trials in Hawaii indicate that under favourable growing conditions, 500-600kg N/ha/yr. is possible if the foliage harvested from this plant were incorporated into the soil. The herbage produced is also a potential feed for livestock and constitutes a very important nitrogen source to the animal.

Kang *et al;* (1984) reported that a well established hedgerow of Leucaena leucocephala variety K-28, grown in a sandy Entisol in Nigeria at 4m interrow spacing, produced between 15-20 tonnes of fresh prunings per year (5.0 - 6.5 t DM/ha with five prunings per year). These prunings, excluding stakes, yielded over 160kg N, 15kg P, 150kg K, 40 kg Ca and 15kg Mg/ha/yr. In Colombia, Rachie (1983) reported that 127kg N/ha was obtained from four months old *leucaena* plants.

A comparison of biomass and nutrient yield of *Leucaena leucocephala*, *Acioa barterii, Alchornea cordifolia* and *Gliricidia sepium* planted in an alley farming system in Nigeria indicated that biomass yield ranged between 3.0 - 7.4 t DM/ha/yr while the nutrient yields were as follows: 40.5 - 246.5 Kg N/ha/yr., 3.6-19.9 kg. P/ha/yr., 20.4 - 184.0 kg K/ha/yr, 14.7 - 104.3 kg Ca/ha/yr. and 5.4 - 17.6 kg

Mg/ha/yr. (Kang and Reynolds 1986).

Nye and Stephens (1962) reported that *Acioa barterii* used as planted fallow accumulated more calcium and magnesium than natural secondary forest. Nye (1958) observed that in the savanna region of Northern Ghana, *Cajanus cajan* planted at close spacing, accumulated larger quantities of nutrients than *Adropogon sp.*

Supplementing poor quality diets to a protein level of at least 7% will increase feed intake and animal production (Minson and Milford 1967). Since browse maintains a high nutritive value throughout the year it is valuable for supplementation (Reynolds and Adeoye, 1986).

Reynolds and Adeoye (1986) reported that a mixed *Leucaena/Gliricidia* browse fed in a cut and carry system of feeding increased the productivity index (Kg of offspring weaned/ewe/year) by 55% over those receiving only a basal diet of *Panicum maximum*. Parturition interval in sheep reduced in year round continuous breeding when supplementary *Leucaena* and *Gliricidia* were made available (International Livestock Centre for Africa (ILCA), 1986). Similarly supplementation with tree legume foliage was shown by van Eys *et al.* (1986) to improve goat growth rates.

Reynolds and Adediran (1988) showed that supplementation of a grass and cassava peel based diet with a mixed *Leucaena/Gliricidia* feed, significantly increased both growth rate and survival (up to 24 weeks) of lambs. Reynolds (1989) fed West African dwarf goats at four levels of *Leucaena* and *Gliricidia* with a basal

diet of *Panicum maximum* and dried cassava peel to study its effect on growth and survival rates of the offspring in two breeding seasons. Productivity, (calculated as weight of kids weaned/doe/year) increased by 0.64kg for each 100g of browse DM consumed by the does. Dry matter intake also increased as the level of supplementation rose from 200-800g DM/hd/day, reaching 180g/$kg^{0.75}$/day for lactating adults.

Smith *et al.* (1990) using the leaves of *Cajanus cajan* as supplement to maize stover, observed that the total intake of *Cajanus* increased significantly whilst that of maize stover fell. Both nitrogen intake and retention were increased by the *Cajanus*. Again, Biru *et al.* (1990) fed milking cows with freshly cut *Sesbania sesban or Leucaena leucocephala* to replace part of the concentrate ration normally given to cows during dry season grazing of natural pastures. They observed that milk yield of the browse fed group was significantly higher than the control. Hashim (1990) supplementing the feeding of range forage sheep with the seed pods of *Dicrostachys cinera* and *Acacia albida* during the dry season, reported that dry matter intake was 814g/head/day for sheep supplemented with seed pods of *Dicrostachys*, 855.9 g/head/day for sheep supplemented with *Acacia albida* and 908.6 g/head/day for the control. The sheep supplemented with *Acacia albida* gained significantly more liveweight than those on *Dicrostachys cinera.* The controls lost weight during the experiment.

Fodder from trees and shrubs form the bulk of the feed of ruminant animals in confinement in most towns and villages in Ghana. Fodder trees and shrubs are

therefore very important, for without them, ruminant production especially in the semi-arid areas would have been near impossible.

2.2 IMPORTANCE OF BROWSE PLANTS

Browse has been defined as the leaves, shoots and sprouts including tender twigs and stems of woody plants and vines, flowers, pods, and seeds which are eaten to varying extent by both domestic and wild animals (Rose Innes 1977, Devendra 1989, Gutteridge and Shelton 1994).

Browse forms an important component of the diet of ruminant animals especially goats, sheep and camels and to a lesser extent buffaloes and cattle (Devendra 1989).

This appears to be the most important use of browse plants in arid lands. According to Le Houerou (1978), nearly one-third of the world's land surface is natural grassland with varying degrees of shrub components which serve as an important source of feed for both domestic animals and wildlife. The feed includes leaves, flowers, fruits, seeds which are rich in protein, vitamins and minerals even in the dry season. Adegbola (1985) found that the major advantage of browse in the feeding of ruminants is that, they maintain a fairly good quality foliage all the year round. In the absence of this forage, animals during the dry season have only straw from native grasses which are poor in quality and may result in avitaminoses, mineral deficiency and severe debilitations. The trees and shrubs enable standing feed reserves to be built up so that herds can survive critical periods of shortfall or

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prolonged drought without losses (Rose Innes and Mabey 1964a; NAS, 1979; Le Houerou 1980a).

Le Houerou (1980a) stressed that browse species are often an effective means of utilising marginal land on which normal crop production is poor owing to climatic, topographic and edaphic constraints. Leguminous browse plants are included in the group of plants known as multipurpose trees (MPT'S) as they have many other uses apart from their use as feed for ruminants (McKell, 1974). Multipurpose trees provide several needs of man. According to Le Houerou (1980a) and Nitis (1992) these needs include wood for fuel, building and fencing. In addition they provide various foodstuffs such as fruits and spices as well as medicine, dyes and fibre for clothing, ropes, bags and shade. Multipurpose trees also serve as a means to prevent soil erosion, increase or maintain soil fertility and productivity and in the long term help the balance of highly sensitive ecosystems (Fianu, 1992a,b).

2.3 FACTORS INFLUENCING PRODUCTIVITY AND SURVIVAL OF BROWSE PLANTS

2.3.1 Climatic factors

Climatic factors such as rainfall, temperature, daylength, humidity, wind and light are known to affect the productivity of browse plants. Brewbaker *et al.* (1985) reported that *Leucaena leucocephala* performs well in areas of rainfall between 650mm and 3000mm. *Calliandra calothyrsus* is known to be adapted to altitudes

ranging from sea level to 1860m and annual precipitation ranges from 700mm - 3000mm (Lowry and Macklin, 1989) while *Albizia lebbek* grows well under rainfall regimes ranging from 400 mm to 2500 mm (Lowry *et al*, 1994). Similarly *Erythrina bacteroana* grows from sea level to elevations of 2000 m in South America with rainfall ranging from 800 - 5000 mm per annum (Kass, 1994). On the other hand, *Prosopis* spp. are very drought tolerant, and have been found in areas receiving less than 100 mm (Gutteridge, 1994).

Tropical species such as *Leucaena* require warm temperatures of 25 to 30°C during the day for optimum growth (Brewbaker *et al.* 1985). Whiteman *et al.* (1986), in south east Queensland, found that *Gliricidia sepium* became leafless when night temperatures fell below 15°C. Again, Wood and Larkens (1987) reported that *Sesbania glandiflora* is well adapted to hot humid environments and it does not grow well in the subtropics particularly in areas with cool season minimum temperatures below 10°C.

Little is known about the effect of day length on growth and yield of tropical browse plants. However Hammerton (1976) reported that long daylength increased the herbage yield and depressed the seed yield of pigeon pea (*Cajanus cajan*) in the West Indies. In *Leucaena* and others shading reduced growth but the legumes tolerated reduced light better than non-legumes (Benjamin *et al.,* 1991).

2.3.2 Biotic factors

Le Houerou (1980a) and Adegbola (1985) reported that one of the factors that threaten the survival of browse plants is their overexploitation. Due to the high human population growth rate, there is increased pressure on land. Trees are being cleared at a fast rate as cultivated and urban areas expand. This has consequently reduced the area occupied by browse plants (Fianu 1975, 1990). On the Accra plains alone, Fianu (1990) estimated the loss of grazing land and thickets (in which browse abounds) to real estate to be about 2500 hectares yearly.

Bray and Woodroffe (1991) have reported that the psyllid (*Heteropsylla cubana*) reduced the production of edible material of *Leucaena* spp by 52% and that of the stem by 79% in south east Queensland. The establishment of *Albizia lebbek* can be affected by mice, rabbits and domestic ruminants which attack the young plant. Mature leaves are largely unaffected by insects but young leaves may be subjected to heavy predation by the grass yellow butterfly (*Eurema hecoba*) (Lowry *et al.* 1994). Recently, a psyllid has been reported to attack seedlings of *Albizia* in India (Lowry *et al.* 1994). Diseases of browse plants are not widely documented in the literature. However, Brewbaker *et al,* (1985) have reported that damping off in moist soils caused by the fungus *Phythium or Rhizoctonia* Spp. is a very serious *Leucaena disease* in the nursery. It is probable that other species of browse may encounter similar problems. Damage by wildlife can be a serious hazard to the establishment of browse plants. In Australia, marsupials, hares, cockatoos and ducks have been reported to chew *Leucaena* seedlings to the ground level (Shelton 1994b).

2.4 METHODS OF PROPAGATING BROWSE PLANTS

Browse plants have either been propagated by seed or vegetative means (Le Houerou 1980a, Adegbola 1985).

2.4.1 Seed propagation and factors affecting germination

The establishment of browse plants by seed is the most common method for sowing (Shelton 1994a). Most tree legumes are readily established from transplanted seedlings. The seedlings are first raised in polythene bags until they reach a height of about 30-50cm, and after a short period of "hardness" in the open air are directly transplanted into the field in moist soils. Various factors have been found to affect germination. These include seed viability, moisture, temperature, light, gases especially oxygen, speed (rate) of germination and seed dormancy. Among these factors, dormancy is seen to be a potential problem which must be overcome in order to ensure adequate germination. A rapid rate of seed germination is often beneficial to field establishment. Competition with fast germinating weeds or survival before soil drying are both favoured if the seed germinate quickly (Humphreys, 1987).

2.4.1.1 Dormancy as a factor affecting seed germination

Dormancy is a condition in a viable seed which prevents it from germinating when supplied with conditions normally adequate for germination (Greulach, 1973; Mayer and Poljakoff-Mayber, 1975; Harper, 1977; Ellis *et al.* 1985) Dormancy has an important survival value particularly in regions with marked seasonal changes in

environmental factors such as rainfall and temperature (Tybirk, 1991). Different types of dormancy are encountered in nature. One type is due to impermeable seed coat to water or oxygen. This type of dormancy results from the impregnation of the seed coat with waxes or other water proofing substances. Many legumes including clovers, alfalfa and locust beans have this type of dormancy (Ellis *et al.* 1985; Tybirk, 1991). Another type of dormancy is innate dormancy which is associated with rudimentary embryos or physiologically immature embryo. A number of plant species have seeds that contain only partially developed embryos at the time of seed dispersal. Such seeds therefore need time to ripen. Enforced dormancy is the condition where viable seeds do not germinate because of some limitation in the environment such as the absence of light and reduced temperature (Greulach 1973, Mayer and Poljakoff-Mayber 1975, Ellis *et. al.,*1985, Tybirk 1991). For a dormant seed to germinate, there is the need to break or remove the dormancy.

2.4.1.2 Methods of breaking seed dormancy

Various methods have been used to break dormancy in order to obtain fast and homogenous germination either in the laboratory or nursery. These include mechanical and chemical scarification, heat treatment and "after ripening" in dry storage.

2.4.1.2.1 Mechanical scarification

This involves the nicking, filing, drilling or shaking the seed in a container lined with emery paper or containing gravel (Hartman and Kester 1959, Quinlivan 1966, Mayer and Poljakoff-Mayber 1975, Ellis *et al.* 1975, Tybirk 1991). These treatments may be detrimental to the seed (Tybrik 1991) as they can crack the seed. However when properly done it is efficient, raising germination percentages close to hundred within a few days in most species such as *Albizia lebbek* (Tybirk 1991).

2.4.1.2.2. Chemical scarification

Concentrated H_2S0_4 or NaOH may be used to soak the seed for some time before sowing (Greulach 1973, Mayer and Poljakoff-Mayber 1975, Ellis *et al.* 1985, Tybirk 1991). Soaking time varies according to the plant species. For example with *Acacia albida* 5 minutes; *Acacia nilotica* 20-120 minutes, *Cassia siamea* 10-30 minutes. Often good results are obtained with 50-90% germination within one day to two weeks when the seeds are thoroughly watered (Tybirk 1991). Other chemical compounds that have also been used to remove seed dormancy and which have been reported to promote germination of dormant seed include hydrogen peroxide, ethyl alcohol, sodium hypochlorite, thiourea, marcaptoethanol, nitrates, nitrites, cynides, azide, gibbrellins, cytokinin (for example kinetin) and hydroxyl amine (Ellis *et al.*1985).

2.4.1.2.3 Heat treatment

Heat application methods that have been used to remove seed dormancy include hot water treatment, dry (oven heat) heat, temperature fluctuations and warm water treatment.

2.4.1.2.3.1 Hot water treatment

Seeds can be soaked in boiling water for sometime to break dormancy before sowing. Soaking time varies from five seconds for *Acacia senegal* to one hour for *Acacia sieberiana*. This method has often given varied results. For example soaking in boiling water resulted in no effect on *Pterocarpus lucens*, 2% germination in *Acacia nilotica,* 60% germination in *Acacia sieberiana* and 90% germination in *Prosopis juliflora* (Tybirk, 1991). Instead of boiling water, seeds can be immersed in hot water at 60-80°C for one to ten minutes to soften the seed coat of *Leucaena leucocephala* and *Centrosema pubescens* (Tybirk, 1991). Soaking seeds in warm water for 24 hours enhances germination of *Pithecellobium dulce* (Fianu, personal communications).

2.4.1.2.3.2 Dry heat treatment

Heating the seed in an oven with temperatures ranging between 80-250°C from a few seconds to several minutes, helps to break seed dormancy in some species. Heating for ten minutes at 110°C has been used to break dormancy in *Acacia hockii* (Tybirk, 1991).

Temperature fluctuations with an amplitude of 15°C has been found to hasten germination of hard seeded legumes such as *Acacia nilotica* (Tybirk, 1991). Microwave oven has also been used to break seed dormancy. This treatment depends on the moisture content of the seed as well as the species. Microwave treatment cracks the seed coat as happens in Australian *Acacias* (Tybirk, 1991).

2.4.1.2.4 "After ripening" in dry storage

"After ripening" is post harvest maturation. It is the loss of dormancy that gradually occurs when seeds are stored in an air dry state (Hartmann and Kester, 1959; Greulach, 1973; Mayer and Poljakoff-Mayber, 1975; Grant, 1979; Ellis *et al.*, 1985; Tybirk, 1991).

2.4.2 Vegetative propagation

In some plant species, vegetative propagation is the only means by which the plant can be established. This may be due to the fact that few or no viable seeds are produced by such species. For some species propagation through the seed is so slow that the best way possible is to use vegetative propagation. Vegetative propagation can be done in many ways. The three common methods used are either by planting with stem cuttings, rootstock or by grafting (Kempana and Chandrasekharia, 1959, Kempana *et al.* 1961, Greulach 1973, Le Houerou 1980c, Adegbola 1985).

Raising stem cuttings in the nursery improves survival rates (Le Houerou 1980c, Adegbola 1985). Application of growth regulators such as 2, 4-dichlorophenoxy acetic acid (2, 4-D) and Naphthalene acetic acid (NAA) may

improve root development (Kempana and Chandrasekharia 1959, Kempana *et al.* 1961, Chaudhuri 1965) and thus enhance the survival rates of the cuttings. Browse plants can also be propagated by air layering with the aid of growth regulators (Kempana *et al.* 1961). Age of stem cuttings, diameter and length of the cuttings, the position of the cutting on the parent tree, the type of cut, length of the storage time and depth of planting are important factors affecting vegetative propagation. Falvey (1982) conducted some studies into these aspects and reported that gliricidia cuttings should be taken from stems that are at least 6 months old, 0.5 - 2 m in length and from the lower part of the tree. Stem sections should also be planted as soon as possible after cutting. Glover (1989), as cited by Shelton (1994a), reported that cuttings should be mature branches, greater than 7 cm in diameter and which are brownish green in bark colour. The cut is normally made obliquely at both ends, discarding the younger tips, and the base inserted 20-50cm into the soil. Cuttings for live fences may be up to 200cm while those for hedgerows may be 30-50 cm in length.

2.5 MANAGEMENT OF BROWSE PLANTS

Plant spacing and density adopted depend on the size of the browse plant and the management procedure to be adopted and its utilisation such as in intensive feed gardens, hedgerow browse, and alley farming (Le Houerou, 1980c; Adegbola, 1985). Browse plants can be planted on millet, groundnut or sorghum fields. If a browse plant such as *Faidherbia albida* is planted on such fields, a planting density

of fifty trees per hectare in rows of 10m x 20m could be adopted (Le Houerou, 1980c; Adegbola, 1985). Generally, for all species of browse plants, wide spacing encourages fruit production while higher stocking densities promote the production of leaf biomass per unit area.

A compound fertilizer providing N, P and K applied at the rate of 25-50 kg/ha encourages early growth. Watering after planting is beneficial especially in arid zones. Watering on two or three subsequent occasions may be necessary depending on local and seasonal conditions (Le Houerou, 1980c; Adegbola, 1985).

A major problem encountered during the establishment of shrubs and trees is competition with weeds. The growth rate of shrub/tree seedlings is often very slow, thus competition from weeds may result in high plant mortality (Maasdorp and Gutteridge, 1986; Ivory, 1989). Therefore, considerable advantages are gained if the seeds are germinated and the young plants raised in a nursery before transplanting to the field. If the shoots and roots are trimmed, at the time of transplanting, it reduces transpiration and stimulates root development (Pound and Martinez - Cairo, 1983). Such seedlings are better able to compete with weeds after transplanting.

Le Houerou (1980c) and later Adegbola (1985) have enumerated the following procedures as essential in the management of browse plants. During the first year after planting, it is always good to reduce or eliminate competition from weeds and this could be achieved by ploughing a strip 1 to 2m wide on each side of the planted row. This ensures higher survival of the plant and more rapid growth. Species

which are normally bushy, for instance *Faidherbia albida*, should be pruned and protected from browsing until they are strong enough to survive. Certain species like *Leucaena leucocephala*, need to be cut back to keep them within the reach of some of the animals. Finally, the plantation should be enclosed to prevent uncontrolled grazing and subsequent damages to the plantation.

2.6 PLANT GROWTH ANALYSIS

Growth analysis is a useful tool in studying the complex interaction between plant growth and the environment (Noggle and Fritz 1986). Two basic measurements are normally required to carry out a simple growth analysis. These include a measure of the plant material present (W) and a measure of the magnitude of the assimilatory system (A) of that plant material (Watson 1947a, Radford 1967). In practice, the most common measures of W and A are the total weight of the individual plant and the total leaf area of the plant. For plants that form a continuous canopy cover such as a sward, W is the total dry weight of the plant material per unit area of the ground. Other measures of W that have been used are the total dry weight of the plant material above ground level, above harvest cutting height and some distinctive plant fractions (Watson 1947 a,b.; Blackman *et al.* 1955, Radford, 1967). The measure of A has been taken as the total photosynthesising area, leaf weight, leaf protein, leaf chrolophyll (Williams 1946, Watson 1952).

Common measures of growth include:

- **Crop growth rate (CGR).** The CGR of a canopy is defined here as the increase in total foliar dry matter per unit area per unit time.

  CGR = dw/dt. It helps to determine the rate of foliar dry matter accumulation of a crop.

- **Relative Growth Rate (RGR).** The RGR of a plant in this study refers to increase in total folia dry matter per unit plant present per unit time.

  $RGR = 1/W \cdot dw/dt \quad (g\ g^{-1}\ d^{-1})$.

  RGR helps to assess the efficiency of herbage production over a time period.

- **Net Assimilation Rate (NAR).** The NAR is defined as the increase in weight of leaves per unit of assimilatory surface per unit time.

  $NAR = 1/A \cdot dw/dt\ (g\ cm^{-2}\ wk^{-1})$.

  The NAR is a measure of the amount of photosynthetic product going into the forage, thus it is an estimate of net photosynthesis harvested in the forage.

- **Leaf Area Ratio (LAR).** The LAR of a plant is defined as the ratio of the assimilatory surface per unit leaf weight. $LAR = A/W\ (cm^2\ g^{-1})$. It reflects the density of photosynthetic material in the leaf.

It follows from the above definitions that RGR = NAR x LAR (Williams 1946; Watson 1952, 1956; Thorne 1960, Radford 1967, Leopold and Kriedman 1975).

These measurements are relevant to the present study in that they throw light on the rate and efficiency of dry matter formation in these plants and contributes to

the understanding of their genetic potential for photosynthesis.

2.7 EVALUATION OF FEED QUALITY OF BROWSE PLANTS

2.7.1 Percentage crude protein

The minimum level of crude protein (CP) which is normally considered adequate for moderate level of production for ruminants is reported to be 11-12% (ARC, 1980). Various workers have reported that browse plants in general have higher CP content (8-30%) than natural or native grasses (2-10%) in the same area (Rose Innes and Mabey, 1964b; Mecha and Adegbola, 1980; Norton, 1994).

Mohamed-Saleem *et al.* (1979) found that the CP content of browse species ranged from 12.3-21.8%, 5.3-15.6% and 5.5-16.6% respectively for the heavily browsed, moderately browsed and occasionally browsed species. The CP content of browse plants also depends on the location. For example, Mecha and Adegbola (1980) found the protein content of Nigerian browse to be different from that of Australia as reported by Wilson (1977). The report by Pellow (1980) showed that there were differences in the CP composition of six *Acacia* species studied. Old leaves were shown to have lower protein content than young leaves and this confirms the fact that CP content decreases as the plant ages. The average protein content of browses in Tropical West Africa was 12.5% (Le Houerou, 1980b). Rose Innes and Mabey (1964 a,b) identified a number of browse species palatable to local cattle and performed digestibility trials on some of them. The recommended species included *Griffonia simplicifolia, Baphia nitida* and *Antiaris africana*. The results

showed that *Baphia nitida* had the highest CP among the three. The CP content of the species were 21.2%, 18.6% and 11.4% for *Baphia nitida, Griffonia simplicifilia* and *Antiaris africana* respectively.

Research at the Animal Research Institute (ARI) in Ghana in the late 1960's showed that the crude protein content of seeds of such browse plants as *Samanea saman, Albizia lebbek, Bauhinia monandra, Khaya senegalensis, Caesalpinia pulcherrima* and *Cassia occidentalis* varied (ARI, 1968). At the University of Ghana, Adjei and Fianu (1985) worked on *Aeschynomene americana* and *Cajanus cajan* cut at 60, 90 and 120 days to assess regrowth and yield of the plants. They reported a mean dry matter yield of 4.7 t ha^{-1} and 4.9t ha^{-1} and mean crude protein content of 25.2% and 21.4% for *Aeschynomene* and *Cajanus* respectively. Karbo and Barnes (1993) studied the preference by sheep and goats of four browse plants - *Gliricidia sepium, Leucaena leucocephala, Sesbania sesban* and *Cajanus cajan.* They reported that the crude protein content of the browse ranged from 19 to 26% and when offered a forage choice of the browse species Djallonke sheep selected *Cajanus cajan* whilst the West African dwarf goat preferred *Leucaena leucocephala.*

2.7.2 Cell wall constituents

Van Soest (1966, 1967) separated the plant material into soluble and various components using detergent solutions. The cell wall components which represent the neutral-detergent fibre (NDF) is the residue after extraction with boiling neutral detergent solutions of sodium lauryl sulphate and ethylenediminotetraacetic acid

(EDTA). It consists mainly of hemicellulose, cellulose, lignin and silica.

The acid-detergent fibre (ADF) is the residue after refluxing with 0.5M sulphuric acid and cetyltrimethylammonium bromide (CTAB) and represents essentially the crude cellulose, lignin and silica. Therefore, it is commonly accepted that the hemicellulose content is determined as a result of the difference between NDF and ADF.

Cellulose and hemicellulose account for a large proportion of energy obtained from forages, but they differ in their yield of useful energy due to differences in digestibilities and to a lesser extent to the end product they yield on breakdown in the digestive tract (Crampton, 1956). This difference is attributed to the cellulase enzyme of the microbes which readily ferments cellulose to a greater extent than the hemicellulose. The lignin is highly indigestible and reduces the digestibility of other components possibly because of encrustation.

McDonald *et al.* (1988) reported that the extent to which cellulose is digested in the rumen depends particularly on the degree of lignification of the plant material. Lignin and also the related substance, cutin, is resistant to attack by anaerobic bacteria probably because of its low oxygen content and its condensed structure which inhibits hydrolysis. Lignin therefore appears to hinder the breakdown of cellulose with which it is associated (McDonald *et al.* 1988).

Norton (1994) reported that the digestibility of plant material in the rumen is related to the proportion and lignification of plant cell walls (NDF), and that tree forages with low NDF content (20-35%) are usually of high digestibility, while

species with high lignin contents are often low in digestibility. Stems have been reported to have higher lignin contents than leaves and hence are less digestible than leaves (Norton, 1994). There are a few exception now, according to available literature.

2.7.3 Mineral content

The dietary requirements of livestock for minerals have been reported to vary with the species, breed of the animal, its age and rate of growth or production and with the biological availability of the mineral in the diet (Underwood, 1981). The minimum requirement of ruminants for P varies from 0.12 - 0.24% (dry matter basis) depending on the physiological function of the animal (Norton 1994). The minimum requirement of sodium for ruminants for satisfactory growth, and lactation and maintenance are estimated to be 0.07 - 0.1% of the dry diet (Hagsten *et al.* 1975, Morris and Peterson 1975, Norton 1994). Le Houerou (1980b) and Norton (1994) have lamented that there is inadequate information on the mineral content of browse plants.

Le Houerou (1980b) reported that the P and Mg content of browse in Africa is generally adequate for stock feeding P(0.15%) and Mg (0.60%) but is a little high in Ca (1.7%) and K (1.5%). However, the Ca/P ratio is usually too high (11) as against the optimum figure of 1-2. Although calcium is rarely limiting in forage trees as it is true for forages generally, high concentrations of oxalic acid in leaves may decrease Ca availability during digestion (Norton 1994).

Vercoe (1987) working on the foliage of 23 tree species used for livestock feeding in Australia found considerable variation in their chemical composition. P(0.5 - 0.18%), K (0.41 - 1.78%) Ca (0.29 - 3.52%), S (0.21 - 1.13%), Na (≤0.01 - 0.41%), Mg (0.21 - 0.62%), Cu 4 - 152 ppm), Al (26 - 325 ppm) and B (16 - 59 ppm).

The minimum needs of sheep and cattle for Mg for growth can generally be met by pastures or rations containing 0.07% Mg on dry basis (Underwood 1981).

2.7.4 In vitro dry matter digestibility

Lignin in grasses and other plants is frequently assumed to be completely indigestible by ruminants, although many examples to the contrary exist in the literature (Sullivan, 1959; Ahn *et al.* 1989). Sullivan (1959) reported that within a plant species, an increase in lignin content almost invariably resulted in a decrease in digestibility. Ahn *et al.* (1989) also reported that lignin and condensed tannins are responsible for low digestibilities in forages.

Dry matter digestibility values for some browse plants have been determined by several workers in different ecological zones (Adegbola, 1985). These include the summaries of Mabey and Rose Innes (1964 a, b) for Ghana which averaged 53.69% and that of Barnes (1979) as cited by Adegbola (1985) for southern Africa which ranged between 41 - 53.5%. Dry matter digestibility values range widely from 60% for species like *Gliricidia sepium* and *Leucaena leucocephala* down to about 30% for fibrous species (Brewbaker, 1986).

The form in which the leaves are fed (fresh, wilted or dry) is known to affect both feed intake and digestibility in some species (Palmer and Schlink, 1992). The dry matter digestibility (DMD) of forages is known to decrease with advancing plant growth. Tilley and Terry (1963) showed that the *in vitro* digestibility of lucerne stems declined from 85% when young to 56% at maturity.

2.7.5 *In sacco* degradability

In sacco degradability of DM and N involves placing samples of ground forage in nylon bags and suspending them in the rumen of fistulated animals by the help of steel weights. The rates of the digestion of dry matter can then be determined by removing the bags at varying intervals. The technique provides a powerful tool for the initial evaluation of feedstuffs and for improving our understanding of the processes of degradation which occur within the rumen (Ørskov *et al.* 1980).

The pore size of the nylon bags is very important since it is known to regulate the passage of solid particles from the bags. Uden *et al.* (1974) as cited by (Ørskov *et al.*, 1980) reported that material with pore size of 20μ and 35μ have been found to give smaller dry matter losses than from bags with 5μ pores. Van Miellan and Ellis (1977) considered 10μ to be the maximum pore size if loss of solids was to be prevented. Rodriguez (1968) as cited by Kempton (1980) reported that the pore size of the material used for the manufacture of the nylon bags apparently has no significant effect on dry matter disappearance from bags during a 72 hour incubation.

The optimum size of the bag has been investigated by a number of workers (Rodriquez 1968, as cited by Kempton 1980; Mehrez 1976 as cited by Ørskov *et al.,* 1980). The optimum size of the bag is essentially a compromise between two opposing factors. On one hand, it is necessary to have the bag large enough relative to the sample size used so as to ensure that rumen fluid can easily enter the bag and mix with the sample. On the other hand, it is necessary to have the bag small enough for ease of withdrawal through the rumen canular.

Preparation of the feed samples for incubation is very critical, as they should represent as far as possible the material as they would appear in the rumen had they been consumed by the animal (Bailey 1962 as cited by Ørskov *et al,* 1980). Ideally, masticated ingesta from animals fitted with an oesophageal cannula can be collected but in practice the use of a laboratory hammer mill fitted with 2.5 3.0 mm screen for dry feed is adequate. Erwin and Ellison (1959) as cited by Ørskov *et al,* (1980) found out that the fineness of grinding of the sample had less effect on the disappearance of dry matter as the period of incubation was increased. Mohammed and Smith (1977) as cited by Kempton (1980) found out that with grains however, cracking of the glumes increases degradability and with protein meals, degradability increases with reduction in particle size.

The basal diet of cannulated animals has major effect on dry matter disappearance. Kempton (1980) found out that the half time for dry matter disappearance from rice hulls is considerably less in sheep given a diet of chopped lucerne chaff in comparison with sheep given a diet of liquid molasses and 100g

wheatened chaff. Ørskov and Hovell (1978) found out that dry matter disappearance was 18% lower in bags incubated in the rumen of zebu cattle given chopped sugar cane diet after 40h incubation than animals given pangola hay. It is therefore important that cannulated animals be given standard ration when used to assess the rates of degradation of most feed material.

It has been suggested that the position of the nylon bag in the rumen affects the dry matter disappearance of feed from the bag. Balch and Johnson (1950) as cited by Ørskov *et al.* (1980) showed that the position of the bag in the rumen had little or no effect on the degradation of the various feeds.

Ørskov *et al.* (1980) reported that the total time for complete or partial degradation varies with the material being incubated. As a rough guide, concentrates require 12-36 hours, good quality forages 24-60 hours, and poor quality roughages 48-72 hours. These are the times required to reach the asymptote (potential degradation). Mehrez and Ørskov (1977) found that the greatest source of variation in the dry matter disappearance from the bags was between (animal) component (6.2% of the mean) followed by that of between days (4.9%). The least variation was found between the bags (3.3%) incubated together and withdrawn at the same time. They suggested that the use of one bag, two days (that is a repeat measurement, and three sheep was a reasonable combination). The number of bags incubated is affected by the type of animal used. In cattle, which generally can have much larger rumen cannulae than sheep, the number of bags incubated at one time can be greater than with sheep, 12 in Balch and Johnson (1950) and 20 in Miles

(1951) as cited by Ørskov *et al.* 1980). With sheep, Mehrez and Ørskov (1977) found it preferable to incubate no more than five bags in the rumen at the same time in order to avoid the difficulties in their removal from the rumen.

2.8 TOXIC PRINCIPLES IN BROWSE PLANTS

Apart from being low in digestibility, some tree species have low acceptability to livestock or contain deleterious principles (Duke 1981, Maslin *et al.* 1987; Ivory, 1989). High levels of phenolic compounds such as tannins in many tree species have been implicated as reducing acceptability (Hegarty *et al.* 1986; Brewbaker, 1986). Duke (1981) listed ninety-seven toxic substances found in some browse legumes. These principles limit the use of the browse plants as livestock feed (Hegarty *et al.* 1964).

Hegarty *et al.* (1964) reported that it is not possible to add *Leucaena* at more than 30% of the diet of goat due directly or indirectly to its mimosine content. Mimosine is degraded by the action of saliva and above all by rumen microbial action to 3,4-dihydroxypyridine (DHP) and thence to 2,3 - DHP which have anti thyroid effects (Hegarty *et al.,* 1986; Christie *et al.,*1979; Jones, 1979). However, in Indonesia a solution to the mimosine problem has been found in the presence of a gram negative bacterium capable of metabolising DHP to innocuous substances (Jones, 1986). This microbe is transferable from ruminant to ruminant both artificially and by contact (Jones *et al.* 1985; Jones and Megarrity, 1986). Although low mimosine lines of *Leucaena* have been bred, their low dry matter yield makes

them undesirable. Some *Acacia* species contain linamarine, a cyanogenetic glycoside that can kill instantly by disrupting the electron transport system. If small doses of linamarine are taken in, thiocynate is rather formed and this is goitrogenous as it inhibits the formation of thyroxine (Jones 1986). There are various ways by which the toxicity of these browse plants can be reduced. Kang and Reynolds (1986) reported that a combination of these tree/shrub fodder planted in alley farms and intensive feed gardens (IFG's) could allow mixed foliage to be offered to livestock and this would minimise the possibility of toxicity from high levels of intake of only one species. This idea has also been expressed by Lowry (1989) who reported that a simple approach to reducing toxicity is to feed the toxic plant in a mixture with other plants, thus diluting the effective level of each compound. Toxicity can also be minimised through management practices as in many plants, the level of secondary compounds is higher in new or developing leaves than in matured leaves (Lowry 1989). Detoxification by rumen microbial activities is also a possibility (Jones 1986).

CHAPTER THREE

EXPERIMENT ONE

TITLE: Seed germination in some browse plants.

3.1 INTRODUCTION

Throughout the developing tropical world, shrub and tree fodders are traditionally used in feeding livestock. This practice calls for studies into sustainable propagation and establishment to enhance their exploitation for the benefit of the livestock industry. Humphreys and Riveros (1986) advocated that successful pasture establishment occurs when good quality seed or cutting is given the right conditions to germinate or sprout and grow.

The objective of the study was to test *in vitro*, the most appropriate technique for breaking the dormancy of the seed of one adapted and nine native browse plants.

3.2 MATERIALS AND METHODS

The study was carried out on the seed of the following 10 browse species in the laboratory of the Department of Animal Science, University of Ghana, Legon (Lat. 5° 38'N and 60° O'N, Long. 0° 12'W and 0° 5'E)

i. *Cajanus cajan* (L) Millsp.

ii. *Dialium guineense* Willd.

iii. *Afzelia africana* Sm.

iv. *Khaya senegalensis* (Desr) A. Juss.

v. *Grewia carpinifolia*

vi. *Pithecellobium dulce* (Roxb) Benth

vii. *Albizia lebbek* L (Benth)

viii. *Milettia thonningii* (Schum & Thonn)

ix. *Baphia nitida* Lodd.

x. *Griffonia simplicifolia* (Vahl ex DC) Baill

The seeds were given the following treatments.

(a) Sowing without any treatment (control) (T_1).

(b) Soaking in water at room temperature for 14 hours before sowing (T_2).

(c) Immersing in hot water at 80°C for five minutes before sowing (T_3).

(d) Scarifying with sand paper until their testa broke before sowing (T_4).

The experiment, was a 10 x 4 factorial arranged in a completely randomised design with four replicates, the factors being the ten browse species and the four treatment methods. Cotton wool was placed in petri dishes and the seeds were placed on the cotton wool in the dishes. There were five petri dishes per treatment and twenty seeds per dish for all the species with the exception of *Afzelia africana* and *Khaya senegalensis* where there were ten petri dishes and ten seeds per dish as their seeds were so big that twenty could not be contained in one petri dish. Each treatment was replicated four times. The petri dishes were covered but occasionally, the lids were removed to flush in fresh air. Water was sprinkled on the seeds daily when necessary and germination counts made daily for each treatment over a period of 18 days. The appearance of the radicle was used as an index of germination. The

rate of germination was calculated using the method of Maguire (1962). This was done by dividing the number of normal seedlings per 100 seeds obtained at each counting in the standard germination test by the number of days seeds have been in the germinator. The values obtained at each count were then summed at the end of the germination test to obtain the germination rate. This is expressed as follows:

$$\frac{\text{Number of normal seedings}}{\text{Days to first count}} + \cdots + \frac{\text{Number of normal seedlings}}{\text{Days to final count}}$$

Data obtained for the germination percentage were subjected to the arcsin percentage transformation after which analysis of variance was performed on the data. The treatment means were compared, using the LSD procedure according to Steel and Torrie (1980).

3.3 RESULTS

Table 3.1 shows the percentage germination of the seed of the browse species given different treatments. Seeds of *Baphia nitida* and *Griffonia simplicifolia* did not germinate over the study period. The species differed significantly ($P<0.05$) in percentage seed germination. *Cajanus cajan* , *Afzelia africana* and *Milettia thonningii* had 83.8, 85.8 and 93.8% respectively which were significantly higher ($P<0.05$) than the rest of the species for the control. *Grewia carpinifolia* and *Dialium guineense* had very low germination (10.8% and 12.1% respectively).

For the warm water treatment, *Milettia thonningii, Afzelia africana* and *Cajanus cajan* had germination value of 90.4%, 77.5% and 69.6% and these were

significantly higher (P<0.05) than the rest of the species. Germination was lowest for *Grewia carpinifolia and Dialium guineense.*

For mechanical scarification, *Milettia thonningii,* together with *Albizia lebbek, Afzelia africana* and *Cajanus cajan* were superior to the rest of the species (P<0.05). *Grewia carpinifolia* and *Khaya senegalensis* were significantly very low (P<0.05).

Mechanical scarification did not affect the % germination but warm and hot water slightly depressed the germinability of *Cajanus cajan.*

Table 3.1: Percentage germination of browse plants under different seed treatments

SPECIES	TREATMENT				LSD (5%)
	Control (T_1)	Warm water (T_2)	Hot water (T_3)	Mechanical scarification (T_4)	
Cajanus	83.8	69.6	74.6	86.3	9.6
Albizia	26.7	30.4	86.3	94.6	9.1
Milettia	93.8	90.4	90.4	98.3	NS
Afzelia	85.8	77.5	94.2	97.5	NS
Pithecellobium	65.4	47.5	65.4	65.8	NS
Grewia	10.8	10.4	2.9	15.5	5.0
Khaya	44.2	40.8	28.3	10.8	13.7
Dialium	12.1	5.0	8.8	53.8	5.7
LSD (5%)	15.0	10.2	11.4	17.5	

NS = Not significant
LSD , Species x treatment = 9.1

Table 3.2: Effect of seed treatment on germination time of browse plants (Days)

SPECIES	TREATMENT				LSD (5%)
	Control (T_1)	Warm water (T_2)	Hot water (T_3)	Mechanical scarification (T_4)	
Cajanus	3.5	3.4	3.4	3.4	NS
Albizia	13.8	14.3	12.8	2.3	4.2
Milettia	4.3	5.4	4.6	3.8	0.7
Afzelia	12.7	12.7	12.0	6.3	2.6
Pithecellobium	7.0	4.3	5.5	3.7	1.0
Grewia	6.7	8.8	9.6	6.4	NS
Khaya	9.0	8.4	7.8	6.8	2.0
Dialium	4.4	7.5	5.8	3.3	1.0
LSD (5%)	3.0	1.8	2.4	2.8	

NS = Not significant
LSD, Species x treatment = 1.5

For *Albizia lebbek* hot water treatment or mechanical scarification significantly ($P<0.05$) improved the germinability while warm water only slightly influenced it. There were no significant differences ($P>0.05$) among treatments for *Milettia thonningii, Afzelia africana* and *Pithecellobium dulce.* With regard to *Grewia carpinifolia* hot water treatment depressed % germination ($P<0.05$) while mechanical scarification increased it slightly. Warm water treatment did not affect it.

In *Khaya senegalensis*, whereas warm water treatment did not affect the % germination hot water treatment and mechanical scarification actually decreased the % germination ($P<0.05$). In *Dialium guineense,* hot water treatment did not affect the germination percentage, whereas warm water depressed it ($P<0.05$) and mechanical scarification increased it ($P<0.05$). There was a significant ($P<0.05$) species x treatment effect on percentage germination.

Table 3.2 shows the effect of seed treatment on germination time of the browse plants in days. Significant differences ($P<0.05$) were observed among the species under all treatments. No matter what treatment method was adopted, *Cajanus cajan* and *Milettia thonningii* took the same time to germinate for all the treatments (3 and 4 days respectively). Mechanical scarification reduced the number of days to germination from 13.8 to 2.3 and 12.7 to 6.3 in *Albzia lebbek* and *Afzelia africana* respectively. For *Grewia carpinifolia* and *Dialium guineense,* warm and hot water treatments increased the number of days to germination. The control and mechanical scarification were similar. There was a significant ($P<0.05$) species x treatment effect on days to germination.

The rate of germination of the eight species of browse plants under different treatments is presented in Table 3.3. The species differed significantly ($P<0.05$) in the rate of germination. Significantly higher ($P<0.05$) germination rates were recorded by *Pithecellobium dulce, Milettia thonningii* and *Albizia lebbek* in T_4 (15.5, 31.1 and 42.0 respectively). With the exception of *Khaya senegalensis* in which the germination rate in T_4 was significantly lower ($P<0.05$), (0.9) than in the others.

Mechanical scarification significantly increased ($P<0.05$) the germination rate in all other species more than the other treatments.

There was a significant ($P<0.05$) species x treatment effect on rate of germination.

Table 3.3: Rate of germination of browse plants under different seed treatments

Species	Treatment				LSD 5%
	Control (T_1)	Warm water (T_2)	Hot water (T_3)	Mechanical scarification (T_4)	
Cajanus	2.3	1.0	1.4	4.8	0.13
Albizia	2.1	2.7	8.3	42.0	0.43
Milettia	22.0	11.9	22.8	31.1	0.36
Afzelia	6.4	6.0	6.7	7.8	0.16
Pithecellobium	7.1	11.0	8.1	15.5	0.36
Grewia	1.8	1.6	0.3	4.8	0.13
Khaya	3.6	3.9	3.0	0.9	0.45
Dialium	3.9	0.8	1.6	18.5	0.32
LSD (5%)	0.92	0.13	0.17	0.52	

LSD Species x treatment = 0.19

3.4 DISCUSSION

The differences in the germination of the browse species as influenced by the different treatments adopted seem to agree with the findings of other workers (Whiteman, 1980; Grant and Clatworthy 1984). Although seed treatment generally promotes germination, the actual method used would depend on the browse species and the feasibility of the seed treatment method. The high germination obtained in the scarified seed agree with the findings of other workers (Viliers, 1972; Ellis *et al.* 1985). Such treatments are known to improve germination by enhancing permeability to moisture and gases (Milthorpe and Moorby, 1986; Tybirk 1991). It may also increase the seeds sensitivity to temperature and light as well as result in the removal or destruction of some of the inhibitory substances (Ellis *et al.* 1985) thus improving germination. On the contrary, comparatively lower germination with scarification have also been reported in other studies (Clark *et al.* 1968; Bewley and Black, 1978). Scarification damaged the seed coat of such seeds and led to the loss of cell contents stimulating the growth of fungal pathogens. The low germination given by the scarified seeds of *Khaya senegalensis* might be attributed to the fact that mechanical scarification led to the peeling off of a greater part of the embryo and subsequent build up of fungal pathogens..

Dell (1980) reported that different treatments gave different water uptake curves for *Albizia lophanta.* This gives an indication that the various treatments adopted in the trial might have affected the imbibition of water by the seeds differently hence some of the species recording higher germination than others.

Tybirk (1991) reported that seed coat dormancy of legumes in semi-arid climate has many important ecological advantages such as endozooic dispersal, recolonisation after fire and escape in terms of time. This is seen in the differential germination of hard seeded legumes of a population under the same stimulus.

Seeds with no pretreatments have been found to germinate in spurts if kept moist over long periods of time (Halevy, 1974; Coe and Coe, 1987). This explains why appreciable germination was recorded in some of the untreated species. Even though most of the species obtained their lowest germination in the untreated groups, some of them germinated after long periods as was exhibited by *Albizia lebbek* and *Afzelia africana.*

Freshly harvested seeds have been reported to germinate differently from seeds that have been stored for some period. For example, fresh seeds of *Cassia siberiana, Albizia gummifera, Acacia hockii, Acacia milifera* and *Acacia tortilis* had germination of 67-100% after hot water treatment, whilst the same treatment gave germination of 3-31% for old stored seeds (Schmidt 1988 as cited by Tybirk, 1991). This might explain the differences found in the various treatments as some of the seeds for the study were collected after their dispersal from the plant whilst other seeds were collected whilst still on the plant.

Ellis *et al.*, (1985) have observed imbibition injury and subsequent destruction of the embryo of forage sorghum (*Sorghum vulgare*) when immersed in warm water. In the same way Rudrapel and Basu (1980) also observed soaking injury resulting from rapid imbibition when soybean was immersed in warm water. These findings

might explain why *Dialium guineense* seeds for both warm and hot water treatments were very low. Tybirk, (1991) reported that the kind of treatment and the duration of the treatment is very important and this should be considered in each case and depends mainly on species, duration of storage of the seed and moisture content of the seed.

Maguire (1962) reported that seedlots with similar total gemination often vary in the rate of seedling emergence and rate of growth. This finding seems to explain the differences that were observed in both the percentage germination as well as the rate of germination. For example, *Milettia thonningii* and *Afzelia africana* had similar germination percentages (98.3 and 97.5) respectively for mechanical scarification, their rates of germination were 31.1 and 7.8 respectively. Also *Cajanus cajan* recorded a high % germination (86.3) for mechanical scarification but a low rate of germination of 3.4. This might also be explained by varietal differences (Craddock and Vogel, 1960 as cited by Allen *et al.*, 1961) who reported that large varietal differences in rate of seedling emergence occur in nature. The rate of germination has also been found to decrease with decreasing available moisture but the rate of decline varies with species (Evans and Stickler, 1961; Nyborg 1961).

The reason why *Baphia nitida* and *Griffonia simplicifolia* failed to germinate is not quite clear. However, it was observed that the seeds got mouldy within 24 hours after sowing in the petri dishes and some greenish liquid was found in them especially in *Griffonia simplicifolia.* This greenish liquid may contain inhibitors to

germination and the seed may as well need "after ripening" period since they were freshly collected from the plants.

CHAPTER FOUR

EXPERIMENT TWO

TITLE: GROWTH AND DEVELOPMENT OF SELECTED BROWSE PLANTS OF GHANA

4.1 INTRODUCTION

According to Noggle and Fritz (1986) the term growth in the broad sense is used to denote an increase in size by cell enlargement and cell division together with the synthesis of new cellular material and the organisation of sub cellular organells. Development however is used to encompass the activities resulting from growth and differentiation.

Growth can be measured in many different ways. These include plant height measurement, individual leaf size (length, width, area), plant fresh weight and dry weight partitioned among organs such as roots, stems, leaves and fruits, cell numbers in tissues and organs, and concentration of specific chemical constituents (nucleic acid, soluble nitrogen, protein nitrogen, lipids, carbohydrate) in tissues and organs.

The growth and development of browse plants is affected by genetic, nutritional, environmental and hormonal factors. How these factors affect the growth and development of the plant would ultimately determine its yield. The leaf with its axilliary bud is the smallest module of organised structure in higher plants and it plays a vital role in the construction of the crown structure of the tree (Harper and White, 1974). Many strategies of leaf display and variation in leaf life span have

been evolved to maximize production in higher plants (Chabot and Hicks, 1982). Thus total leaf area is primarily determined by the pattern of production, leaf fall and longevity of leaves (Watson, 1956) along with seasonal variation in leaf size (Kozlowski, 1971). Many investigations related to plant growth processes such as photosynthesis, net assimilation rate (NAR), transpiration and response to management practices require an estimation of leaf area (Ndawula-Senyimba, 1972).

The objective of this experiment was to study the changes in plant height with time, the relative growth rate (RGR), net assimilation rate (NAR) and leaf area ratio (LAR) of the browse plants.

4.2. MATERIALS AND METHODS

Soil collected from Pokoase Agricultural Station, 15km from Legon, was autoclaved at 2.11 kg/cm^2 pressure and put into perforated polythene bags of size 18cm x 25cm. The bags were then put under a 2½ m high shed behind the Animal Science Department, University of Ghana, Legon, and planted with the following eight browse species.

1. *Cajanus cajan (L)* Millsp.
2. *Dialium guineense* willd.
3. *Afzelia africana* sm.
4. *Khaya senegalensis* (Desr) A Juss
5. *Grewia carpinifolia*
6. *Pithecellobium dulce* (Roxb) Benth.

7. *Albizia lebbek* (L) Benth.

8. *Milettia thonningii* (Schum and Thonn).

The experimental design was a completely randomised design with 8 replicates. Four seeds of each species were planted in each of the polythene bags. After emergence, the plants in the polythene bags were thinned to one plant per bag. Data collected included weekly height of the plant from the soil surface to the tip of the terminal bud. The leaf area of the plants was determined every five weeks by using the cork borer method (Edje and Osiru, 1987). Two plants were used at a time for the leaf area determination. One of the two plants (A) was used to get the cork bored leaves and the leaves from the remaining plant (B) was bulked together with the leaves from (A) that was left after the cork bored leaves had been taken. The cork bored leaves as well as the other bulked leaves were dried in an oven to constant weight, and used to estimate the leaf area. The leaf area of the leaf discs is related to the bulk leaf area as follows.

$$\frac{\text{Area of leaf discs } (cm^2)}{\text{weight (g) of leaf discs}} = \frac{\text{leaf area of the bulk leaves } (cm^2)}{\text{weight (g) of the bulk leaves}}$$

From this relationship, the leaf area of the bulked leaves was calculated.

For the determination of the growth rates of the browse plants, the graphical method as described by Noggle and Fritz (1986) was used. Growth curves (Fig. 4.1) were plotted, a straight line, touching the curves at approximately 30 and 60 days after planting were drawn. Triangles were then constructed and the growth rates

calculated from the units of the coordinates of the graph. The calculated leaf area for the plants together with their dry matter accumulation for, 5, 10, 15 and 20 weeks were used to calculate Net assimilation rate (NAR) and leaf area ratio (LAR) while the dry matter accumulation alone was used to calculate the relative growth rate (RGR) by using the following formulae (Noggle and Fritz, 1986).

$$RGR = \frac{2.303\ (\log_{10} W_2 - \log_{10} W_1)}{t_2 - t_1}$$

$$NAR = \frac{(W_2 - W_1)\ 2.303\ (\log_{10} A_2 - \log_{10} A_1)}{(t_2 - t_1)\ (A_2\ \ A_1)}$$

$$LAR = \frac{(A_2 - A_1)\ 2.303\ (\log_{10} W_2 - \log_{10} W_1)}{2.303\ (\log_{10} A_2\ \ \log_{10} A_1)\ W_2\ \ W_1)}$$

where W_1, A_1, W_2, A_2 represent dry weights and leaf areas at time intervals t_1 and t_2 respectively.

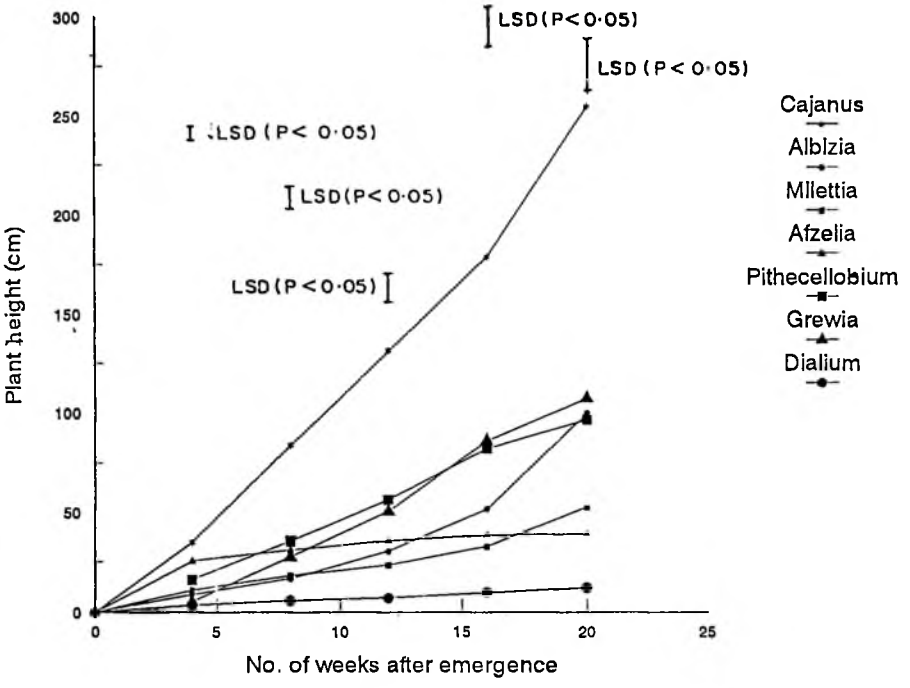

Figure 4.1: Height (cm) of seven browse species during 20 weeks of growth

4.3 RESULTS

Khaya senegalensis seeds did not emerge in the test and *Dialium guineense* and *Grewia carpinifolia* had very poor emergence (Table 4.1).

Table 4.1: Number of seeds of browse species that emerged from the soil

Species	Replicates								Total Emergence	% Emergence
	1	2	3	4	5	6	7	8		
Cajanus	4	4	3	4	4	4	3	2	28	87.5
Albizia	4	4	4	3	4	3	2	3	27	84.4
Milettia	4	4	3	4	3	3	4	4	29	90.6
Afzelia	3	3	4	4	4	2	3	3	26	81.3
Pithecellobium	2	3	2	2	2	1	2	2	16	50.0
Grewia	1	0	0	1	1	0	0	0	3	9.4
Khaya	0	0	0	0	0	0	0	0	0	0
Dialium	2	0	0	1	0	1	0	1	5	15.6

In view of this, after taking the height measurements of these two species subsequent measurement on them were discarded hence the species that were used to continue the study were, *Cajanus cajan, Afzelia africana, Pithecellobium dulce, Albizia lebbek* and *Milettia thonningii.*

The growth rates of the plants are shown in Table 4.2. The growth rate of *Cajanus cajan* was the highest at both 30 and 60 days of growth. This was followed by *Grewia carpinifolia, Albizia lebbek* and *Pithecellobium dulce* in that order. These also had increases in growth rates at 30 and 60 days of growth. On the contrary, *Afzelia africana, Millettia thonningii* and *Dialium guineense* had low growth rates

and their growth rates fell at 30 and 60 days of growth.

Table 4.2: Growth rates (cm d^{-1}) of browse plants to 30 and 60 days after planting

Species	30 days	60 days
Cajanus cajan	2.80	4.20
Grewia carpinifolia	1.75	1.86
Albizia lebbek	1.63	1.75
Pithecellobium dulce	1.40	1.75
Afzelia africana	0.70	0.20
Milettia thonningii	0.46	0.07
Dialium guineanse	0.35	0.11

The leaf area development of browse plants for 5, 10, 15 and 20 weeks of growth is presented in Table 4.3.

Table 4.3: Leaf area development of browse to 20 weeks of growth (cm^2)

Species	Weeks				$\bar{x}$	SE
	5	10	15	20		
Pithecellobium	744.4	1486.7	1211.7	1982.8	1356.4[a]	259.0
Cajanus	4768.6	37562.7	39854.7	128660.8	52711.7[a]	26554.3
Afzelia	461.0	2481.0	2362.3	2022.4	1831.7[a]	467.1
Albizia	586.7	1811.8	4450.2	6160.6	3252.3[a]	1260.7
Milettia	568.9	1524.2	2125.9	3429.6	1912.2[a]	598.8
$\bar{x}$	1425.9[A]	8973.3[A]	10001.0[A]	28451.3[A]		
SE	836.9	7149.6	7482.2	25063.9		

Means bearing the same superscript are not significantly different (P>0.05).

Table 4.3 shows that the leaf area of *Cajanus cajan, Albizia lebbek* and *Milettia thonningii* continuously increased from week 5 through to week 20.

Table 4.4: Dry matter yield of browse plants to 20 weeks of growth (g)

Species	Weeks				$\bar{X}$	SE
	5	10	15	20		
Pithecellobium	0.30	6.2	2.9	5.1	3.6^{a}	1.3
Cajanus	5.5	38.3	65.6	279.9	97.3^{a}	62.1
Afzelia	0.8	4.2	4.8	4.3	3.5^{a}	0.9
Albizia	0.5	8.3	10.3	13.4	8.1^{a}	2.6
Milettia	0.3	6.4	8.5	9.2	6.1^{a}	2.0
$\bar{X}$	1.5^{A}	12.7^{A}	18.4^{A}	62.4^{A}		
SE	1.0	6.4	11.9	54.4		

Means bearing the same superscript are not significantly different (P>0.05).

The highest yield of dry matter was recorded by *Cajanus cajan* from week 5 through to week 20 (Table 4.4). Similarly *Albizia lebbek and Milettia thonningii* also increased in dry matter accumulation from week 5 through week 20 but these increases were not as large as in *Cajanus cajan. Pithecellobium dulce* increased in dry matter accumulation from week 5 till week 10, decreased in week 15 and rose again in week 20. *Afzelia africana* on the other hand, had increases in dry matter from week 5 till week 15 and then decreased in week 20.

Relative growth rate (RGR), Net assimilation (NAR) and Leaf area ratio (LAR) of 5 browse plants to 70 days of growth are presented in table 4.5.

Table 4.5: RGR, NAR and LAR of five browse plants to 70 days of growth

Species	RGR ($g\ g^{-1}d^{-1}$)	NAR ($g\ cm^{-2}d^{-1}$)	LAR (cm^2g^{-1})
Pithecellobium dulce	0.026	435.24×10^{-6}	59.89
Cajanus cajan	0.052	153.46×10^{-6}	339.40
Afzelia africana	0.021	189.06×10^{-6}	108.45
Albizia lebbek	0.030	491.05×10^{-6}	61.58
Milettia thonningii	0.027	439.72×10^{-6}	60.32

Values of RGR and LAR were highest in *Cajanus cajan* whilst its value for NAR was the lowest. *Pithecellobium dulce* had the fourth highest value in RGR, third in NAR and lowest in LAR. *Afzelia africana* had the lowest value for RGR and fourth value for NAR and and second in LAR. *Albizia lebbek* had the highest value in NAR, second in RGR and third in LAR. *Milettia thonningii* was second in NAR, third in RGR and fourth in LAR.

4.4 DISCUSSION

Based on the results of the RGR, NAR and LAR, it was obvious that *Cajanus cajan* was able to increase its dry weight at a faster rate than the rest of the species. That *Albizia lebbek* had the highest value for NAR could be explained in terms of species differences. Watson (1952) explained that the NAR measures the net result of photosynthetic gain over respiratory loss and this may vary according to the magnitude of respiration. For example, if the total respiration of an entire plant is expressed in terms of leaf area, then NAR is likely to increase with age but LAR will decrease, as an older plant is not as leafy so that NAR could fall irrespective of

change in photosynthetic activity.

The lowest NAR value obtained from *Cajanus cajan* suggests that it was the poorest in putting up dry material. This was not the case since *Cajanus cajan* accumulated the highest dry matter. This discrepancy could be explained by the findings of Watson (1952) that precautions should be taken when comparing species by using their NAR values. Watson (1952) noted that because NAR gives no direct indication of respiratory losses, it does not necessarily serve as a direct measure of inherent photosynthetic capacities. Watson (1952) reported that while NAR indicates a plant efficiency at producing dry matter, economic yield is subject to additional controls and it is not necessarily related to photosynthetic efficiency. The differences in NAR observed in the species agree with the findings of Hunt (1978) that wide variation in NAR may occur between species.

CHAPTER FIVE

EXPERIMENT THREE

TITLE: PROPAGATING NATIVE BROWSE PLANTS USING STEM CUTTINGS.

5.1 INTRODUCTION

Propagation by stem cuttings is one of the means of establishing browse plants (Le Houerou 1980c, Adegbola 1985, Ivory 1989). In some plant species, this is the surest way of their establishment as the seeds produced by these plants may not be viable, or seedling growth from germinated seeds may be very slow.

Establishing cuttings in the nursery improves the survival rates of stem cuttings: Growth regulators such as hormones are very important in the establishment of stem cuttings as they may help to improve root development so that the cuttings could easily be established.

The objective of this experiment was to study the sprouting ability as well as the growth rate of some native browse plants using hardwood stem cuttings and with the help of a rooting hormone.

5.2 MATERIALS AND METHODS

Soil collected from Pokoase and treated as in Chapter 4 was used. The polythene bags were put under a two and half metre high shed to provide shade for the cuttings. The browse species used in the study were *Cajanus cajan, Dialium guineense, Afzelia africana, Khaya senegalensis,*

Grewia carpinifolia, Pithecellobium dulce, Albizia lebbek, Milettia thonningii, Baphia nitida, Griffonia simplicifolia, Ficus exasperata and *Spondias mombin.* These were treated with a rooting hormone before planting.

The hormone, Biozyme TS (manufactured by Bioenzymas S.A. De Cu of Mexico) was used together with an adherent - Bionex (manufactured by the same company).

There were four treatments as follows:

1. No hormone application (control treatment) (T_1).
2. Application of the hormone and adherent based on the manufacturer's recommendation (i.e. 5cc Biozyme TS plus 1cc Bionex in one litre of water) (T_2).
3. Twice the normal concentration of the hormone (i.e., 10cc Biozyme TS plus 2cc Bionex in one liter of water) (T_3).
4. Three times the normal concentration of the hormone (ie 15cc Biozyme TS plus 3cc Bionex in one litre of water) (T_4).

Mean diameter and length of the cuttings were 15mm and 30cm respectively. The base of the cuttings were dipped in the hormone solution for 10-15 minutes before planting. The experiment was a 12 x 4 factorial arranged in a completely randomised design with four replicates, the factors being the twelve browse plants and the four treatment methods.

Data were collected on the number of sprouts on every cutting at two and four weeks after planting. The plant height (cm) taken from the base to the tip of the

sprout from each cutting was recorded at monthly intervals for a period of six months.

5.3 RESULTS

Table 5.1 shows the sprout check on cuttings 2 and 4 weeks after planting. Sprouting did not occur in *Griffonia simplicifolia, Afzelia africana, Dialium guineense* and *Albizia lebbek* in any of the treatments while *Cajanus cajan, Grewia carpinifolia, Khaya senegalensis* and *Spondias mombin* sprouted in all the four treatments but died within 2 to 4 weeks after sprouting. A close look at the base of the cuttings which died after sprouting as well as those that never sprouted indicated that no roots developed in them. Thus the species that actually survived were: *Baphia nitida, Milettia thonningii, Pithecellobium dulce* and *Ficus exasperata.*

Figure 5.1 shows the effect of hormone application on the growth of the browse species during 6 months of growth. The species differed significantly ($P<0.05$) in the growth of the sprouts.

Pithecellobium dulce gave significantly higher ($P<0.05$) growth than the rest of the species for all the treatments. For T_1 *Pithecellobium dulce* was highest (15.5 cm), followed by *Baphia nitida* (7.3 cm) with *Ficus exasperata* being the lowest (2.3 cm).

For T_2, *Pithecellobium dulce* was the highest (53.9cm) followed by *Baphia nitida* (6.5 cm), then *Ficus exasperata* (2.5 cm) with *Milettia thonningii* being the lowest (1.0 cm). In T_3, *Pithecellobium dulce* was again the highest (31.2 cm)

followed by *Milettia thonningii* (22.3 cm). *Ficus exasperata* and *Baphia nitida* were similar (2.9 cm and 2.3 cm respectively). In T_4, *Pithecellobium dulce* was highest (33.1 cm) followed by *Ficus exasperata* (20.0 cm) then *Milettia thonningii* (11.1 cm) and then *Baphia nitida* (2.8 cm).

Baphia nitida in T_1 was the highest (7.3 cm) whilst that in T_3 was the lowest (2.3 cm). For *Milettia thonningii* T_3 was the highest (22.3 cm). This was followed by T_4 (11.1 cm) whilst T_2 was the lowest (1.0 cm). With regards to *Pithecellobium dulce,* T_2 was the highest (53.9cm). This was followed by T4 (33.1cm) whilst T_1 was lowest (15.5cm). *Ficus exasperata* had a significantly higher ($P<0.05$) growth (20.0cm) for T_4 compared to all the other treatments.

Table 5.1: Sprout check on cuttings 2 and 4 weeks after planting

Species	Period 1 (2 weeks)				Period 2 (4 weeks)			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
Cajanus cajan	+	+	+	+	-	-	-	-
Albizia lebbek	-	-		-		-	-	
Pithecellobium dulce	+	+	+	+	+	+	+	+
Milettia thonningii	+	+	+	+	+	+	+	+
Afzelia africana	-	-	-	-	-	-	-	-
Grewia carpinifolia	+	+	+	+	-	-	-	-
Khaya senegalensis	+	+	+	+	-	-	-	
Baphia nitida	+	+	+	+	+	+	+	+
Griffonia simplicifolia	-	-	-	-	-	-	-	-
Dialium guineense	-	-	-	-	-	-	-	-
Ficus exasperata	+	+	+	+	+	+	+	+
Spondias mombin	+	+	+	+	-	-	-	-

T_1 = Control
T_2 = Normal concentration of hormone
T_3 = Twice the normal concentration of hormone
T_4 = Thrice the normal concentration of hormone
\+ = Presence of sprouts (roots or buds)
\- = Absence of sprouts (roots or buds)

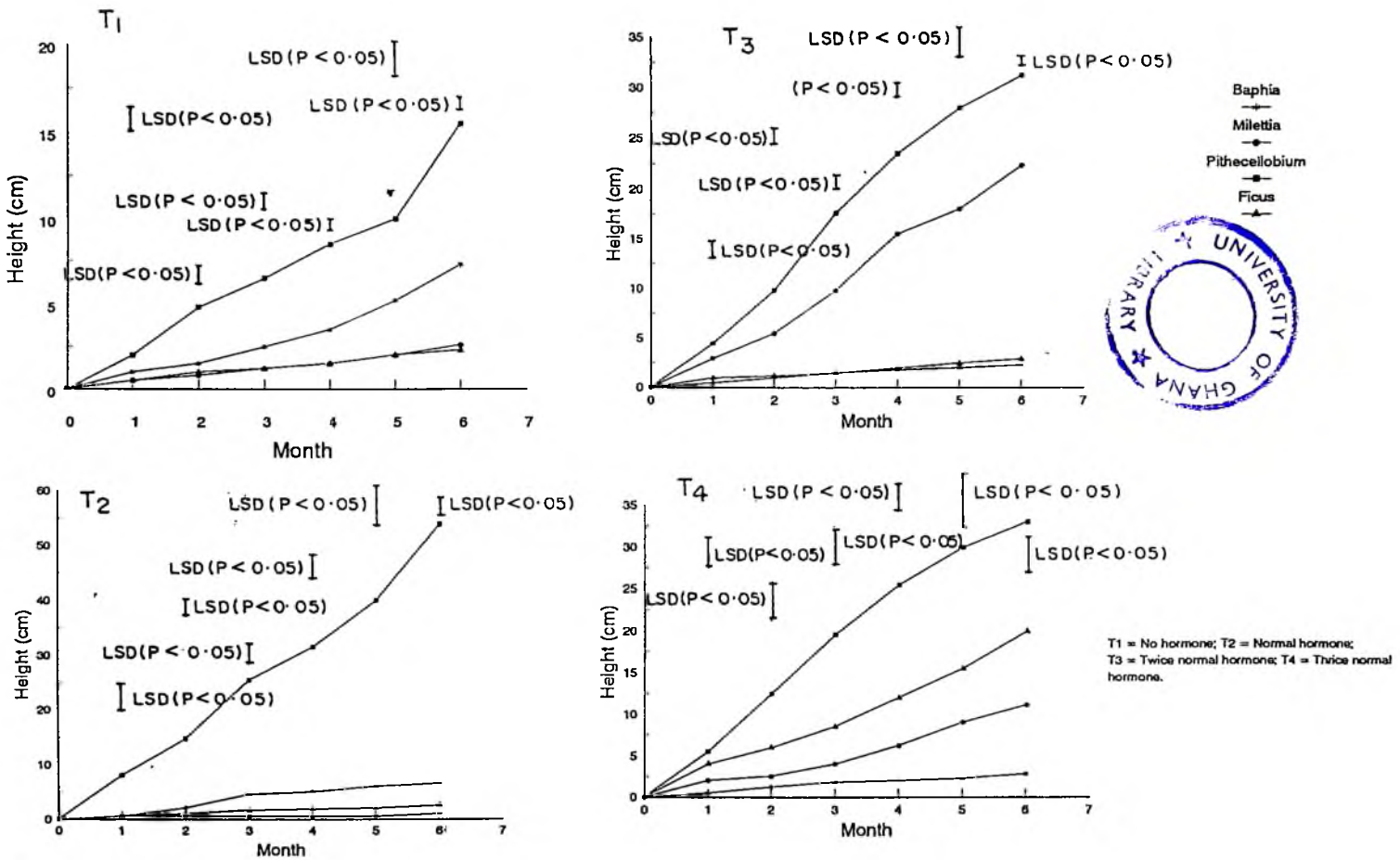

Figure 5.1: Effect of Hormone Application on the Growth of 4 browse plants

5.4 DISCUSSION

The differences in growth among the browse species is in agreement with the findings of Larbi *et al* (1993) who classified *Baphia nitida* together with *Dialium guineense* as very slow growth rate types of browse plants and *Leucaena leucocephala* together with *Alchornea cordifolia* as fast growth rate types. These differences may also have been influenced by the age, diameter and length as well as the depth of planting. Since stem cuttings were taken from plants whose ages could not be determined, it could be that the cuttings were taken from plants of different ages, resulting in the differences in growth. Falvey, (1982) has recommended that cuttings should be taken from stems which are at least six months old and from the lower part of the tree, and should be matured. They should be of diameter of 7.0cm and of length 0.5-2m. The diameter and length of the cuttings used in the study were 15mm and 30cm respectively which is in contrast with the 7cm in diameter and 0.5-2m in length as recommended by Falvey (1982) and Glover (1989) as cited by Shelton (1994a).

It was not clear why some of the cuttings failed to develop roots since the basis of choosing the hormone was to help the cuttings to develop roots quickly so that the sprouts could easily survive. Here, it could be said that the hormone is likely to be effective for some species and not others. The failure of some of the cuttings to develop roots may also be attributed to the depth of planting. Glover (1989) as cited by Shelton (1994a) recommended that cuttings should be planted 20-50cm deep into the soil and since a planting depth of less than 6cm was adopted in

the study it might be possible that the shallow depth of planting affected the root development of some of the species.

Environmental conditions have been found to modify the pattern of shoot development in stem cuttings (Noggle and Fritz, 1986) and it is possible that the ambient temperature and relative humidity provided during the study period were not all that conducive for the development of the shoot system, hence the differences in growth.

CHAPTER SIX

EXPERIMENT FOUR

TITLE: FORAGE YIELD OF SOME NATIVE BROWSE PLANTS ESTABLISHED ON THE FIELD

6.1 INTRODUCTION

The importance of browse trees and shrubs is acknowledged throughout the world and much work is being carried out under various disciplines (Le Houerou 1980a). The major value of such plants is that they provide protein, vitamins and mineral elements which are lacking in grass pastures especially during the dry and/or cold seasons. They also provide feed reserves so that herds or flocks are able to survive critical periods of feed shortages and prolonged drought without losses. Browse species are often an effective aid to the utilisation of marginal lands on which normal crop production is not possible owing to climatic, topographic and edaphic constraints. There is therefore a need for studies into the establishment of browse plants so as to derive the maximum potential from them for the benefit of man and his animals.

No published studies on the establishment of native browse plants seem to have been conducted in Ghana. Indeed yield studies are yet to be done on the wide range of browse plants used by stockmen in the country. The objective of the experiment therefore was to conduct studies into the field establishment and forage yield of some native browse plants.

6.2 MATERIALS AND METHODS

Location: The experiment was carried out at the Animal Science Department, University of Ghana which is located on the Accra plains (Lat. 5° 38'N and 60° 0'N, Long 0° 12'W and 0° 5'E).

Soil: The soil of the area belongs to the savanna ochrosol of the Adentan series. They are light textured, free draining but inherently low in nitrogen and phosphorus (Nye and Betheux, 1957).

Climate: Precipitation in Legon which has two peaks in the major and minor seasons in June and September respectively varies from 650mm to 1000mm per year with a long term average of 821mm per year (Walker, 1962). Maximum and minimum mean monthly temperatures range between 28°C - 30°C and 22°C - 25°C respectively. The climatic data for the experimental period for Legon is shown in Table 6.1.

Plant species: The species studied were: *Cajanus cajan, Albizia lebbek, Pithecellobium dulce, Milettia thonningii* and *Afzelia africana.* These were planted on the field after scarification by rubbing the seeds on emery paper.

Experimental design and method of planting: The experimental design was a split plot design with the browse as the main plots and three harvest dates as the subplots. There were four replicates. Each main plot was 5m x 3m whilst each subplot was 1m x 1m. Four seeds were sown per hole and thinned to one plant per

hole after emergence. The planting space was 1m x 1m. There were thus eight plants per sub plot giving an estimated plant density of 16,000 plants per hectare. A compound fertilizer (15% N, 15% $P_2 0_5$ and 15% $K_2 0$) was applied at the rate of 50kg/ha, three weeks after planting. Weeding was done, when necessary, by hand hoeing. The field was irrigated by a nearby stand pipe when necessary. Observations were made on the four plants in the central row of each subplot leaving four border plants.

Table 6.1: Climatic data for Legon for the experimental period, January 1993-February, 1994

	1993												1994	
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb
Monthly rainfall (mm)	17.3	7.8	28.2	52.4	66.8	91.6	9.0	18.6	118.3	47.6	69.9	28.8	12.7	5.2
Mean monthly temperature (Min)	22.7	24.4	24.3	24.4	24.7	23.4	23.1	22.3	22.8	23.3	23.8	24.1	23.2	24.5
Mean monthly temperature (Max)	32.9	33.2	33.1	33.0	32.9	29.9	28.1	28.9	30.4	31.7	32.3	32.3	32.8	33.3
Mean monthly relative humidity % (0600hrs)	84	93	86	91	93	94	92	93	94	95	94	93	87	NA
Mean monthly relative humidity % (1500hrs)	84	90	86	89	90	93	92	92	93	94	93	92	87	NA
Mean monthly duration of sunshine (hrs.)	5.9	7.8	7.2	7.4	7.7	6.4	3.3	4.3	6.5	8.6	8.5	8.5	NA	NA
Mean monthly rainfall for the decade 1984-1993	5.7	13.3	59.2	80.2	168.4	106.0	70.3	27.3	72.1	66.4	38.9	27.8	NA	NA

NA = Not available
Source: Ghana Meteorological Services Department (1994).

The following data were taken:

1. Percentage seedling emergence within fourteen days of sowing.
2. Percentage plant survival up to sixteen weeks (4 months) after sowing.
3. Weekly height (cm) of the plants.
4. Number of primary branches at four-weekly intervals.
5. Stem girth at ground level, sixteen and twenty four weeks after sowing by the use of a thread and a ruler.

The three subplots were harvested at 24 weeks (6 months), 28 weeks (7 months) and 32 weeks (8 months) respectively. Harvesting was done by cutting the stem 15cm above the ground. The harvested material was separated into the foliage (i.e. leaves plus twigs less than 5mm in diameter) and stem fractions. Fresh weight of both the leaf and stem fractions were taken to give fresh leaf and wood yield. The leaf fraction at each harvest was oven dried at 60°C for 72 hours for dry matter determination.

Statistical analysis

Percentage seedling emergence and plant survival 16 weeks after emergence were tranformed by the arcsin percentage transformation and these together with leaf dry matter yield were subjected to analysis of variance (ANOVA). The Student-Newman-Keuls' test (SNK) was used to separate the mean of significant difference according to Steel and Torrie (1980).

6.3 RESULTS

Table 6.2 shows the percentage seedling emergence and survival to 16 weeks of the 5 browse plants.

Table 6.2: Percentage seedling emergence and survival to 16 weeks of 5 browse plants

	Cajanus cajan	*Albizia lebbek*	*Pithecellobium dulce*	*Milettia thonningii*	*Afzelia africana*
% Seedling emergence	98.5[a]	87.5[a]	88.0[a]	82.8[b]	87.5[a]
% Survival to 16 weeks	100.0[a]	91.9[b]	84.4[b]	78.7[b]	90.6[b]

Figures in a row with the same superscripts are not significantly different at 5% level.

The percentage seedling emergence was high (above 80%) for all the species. *Cajanus cajan* had the highest percentage (98.5) while the value for *Milettia thonningii* (82.8) was significantly lower ($P<0.05$) than that of any other species. The percentage of plants surviving up to 16 weeks after planting ranged between 79% and 100%. *Cajanus cajan*, which had the highest percentage survival was significantly different ($P<0.05$) from the others. *Milettia thonningii* scored the lowest percentage survival but was similar to the others.

Table 6.3 shows the dry matter yield of the 5 browse plants as influenced by age.

Table 6.3: Herbage dry matter yield of 5 browse plants as influenced by age (t/ha)

Species	Harvesting date (Months)			$\bar{X}$	S.E
	6	7	8		
Cajanus cajan	6.60	7.83	8.05	7.49^{a}	0.45
Albizia lebbek	1.55	3.52	6.88	3.98^{b}	1.56
Pithecellobium dulce	0.34	2.12	3.92	2.13^{b}	1.03
Milettia thonningii	0.25	0.55	1.57	0.79^{b}	0.40
Afzelia africana	0.07	0.10	0.07	0.08^{c}	0.01
$\bar{X}$	1.76^{B}	2.82^{B}	4.10^{A}		
SE	1.24	1.39	1.52		

Means with the same superscripts are not significantly different at 5% level.

The dry matter yield of the plants ranged between 0.1 t/ha to 7.5t/ha. *Cajanus cajan,* which had the highest DM yield (7.5 t/ha) was significantly different ($P<0.05$) from all the others (0.1-4.0 t/ha). No significant difference ($P>0.05$) was observed among *Albizia lebbek, Pithecellobium dulce, Milletia thonningii.* The 0.1 t/ha yield produced by *Afzelia africana* was significantly ($P<0.05$) the lowest.

The date of harvest had a significant effect ($P<0.05$) on the DM yield of the browse plants (Table 6.3). The DM yield at 8 months for all the species (4.10t/ha) was significantly higher ($P<0.05$) than the DM yield at either 6 or 7 months (1.76 and 2.82 t/ha respectively).

Figure 6.1 represents the changes in plant height (cm) of the browse plants with age. *Cajanus cajan* grew highest (225.7 cm) and was significantly different ($P<0.05$) from the others. It was followed by *Albizia lebbek* (155.5 cm), *Pithecellobium dulce*

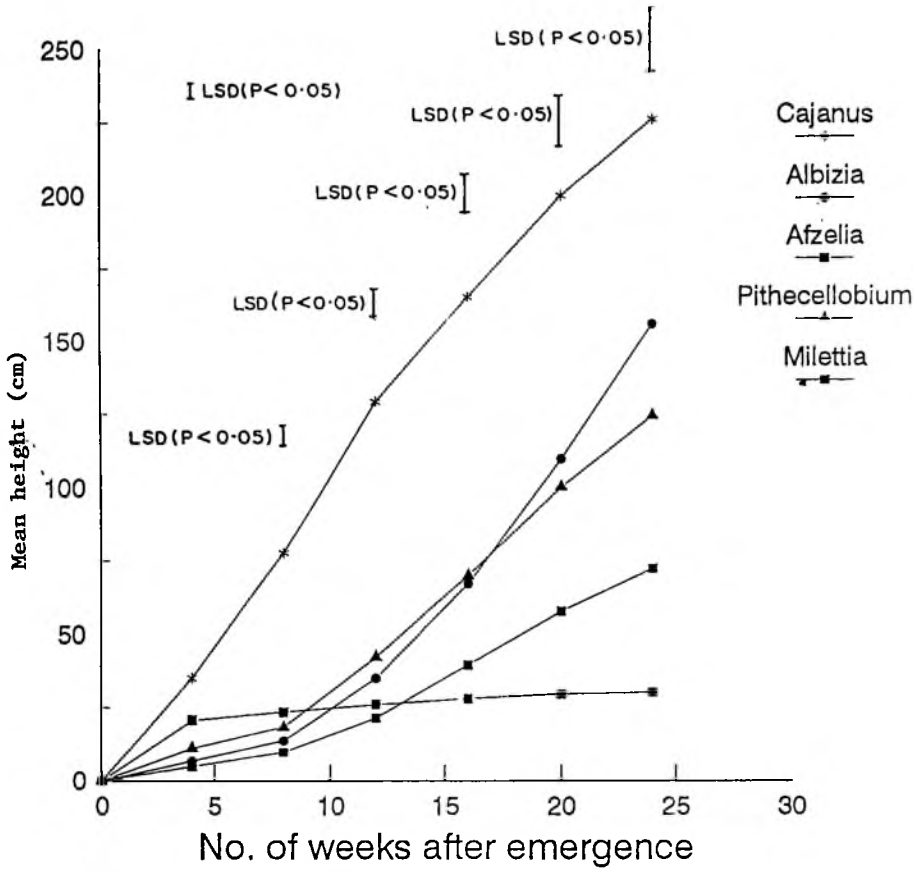

Figure 6.1: Height of five browse species during growth

(124.3 cm), Milettia thonningii (72.0 cm) and *Afzelia africana* (30.3 cm). *Albizia lebbek and* Pithecellobium dulce were similar ($P>0.05$). *Afzelia africana* was significantly ($P<0.05$) the shortest.

Stem girth (cm) of the browse plants at 16 and 24 weeks of growth are presented in Table 6.4. Stem girth increased with advancing growth period for all species. *Cajanus cajan* recorded the greatest stem girth for both 16 and 24 weeks of growth. A similar trend was followed by *Albizia lebbek* which ranked next to *Cajanus cajan. Milettia thonningii* recorded the lowest stem girth (1.5cm) at 16 weeks of growth whilst *Afzelia africana* had the lowest stem girth at 24 weeks of growth.

Figure 6.2 represents the development of primary branches of four browse plants with age. It was noted that *Afzelia africana* never developed a single primary branch for the 24 weeks of growth. *Cajanus cajan* developed the highest number of primary branches (27.4) and this was significantly different ($P<0.05$) from the others. It was followed by *Pithecellobium dulce, Albizia lebbek and Milettia thonningii* in that order. The development of primary branches for *Albizia lebbek and Milettia thonningii* were similar.

Table 6.4: Stem girth (cm) of 5 browse plants at 16 and 24 weeks of growth

	Cajanus cajan	*Albizia lebbek*	*Pithecellobium dulce*	*Milettia thonningii*	*Afzelia africana*
16 Weeks	5.3	2.6	1.8	1.5	1.9
24 Weeks	8.9	6.5	4.5	3.7	3.1

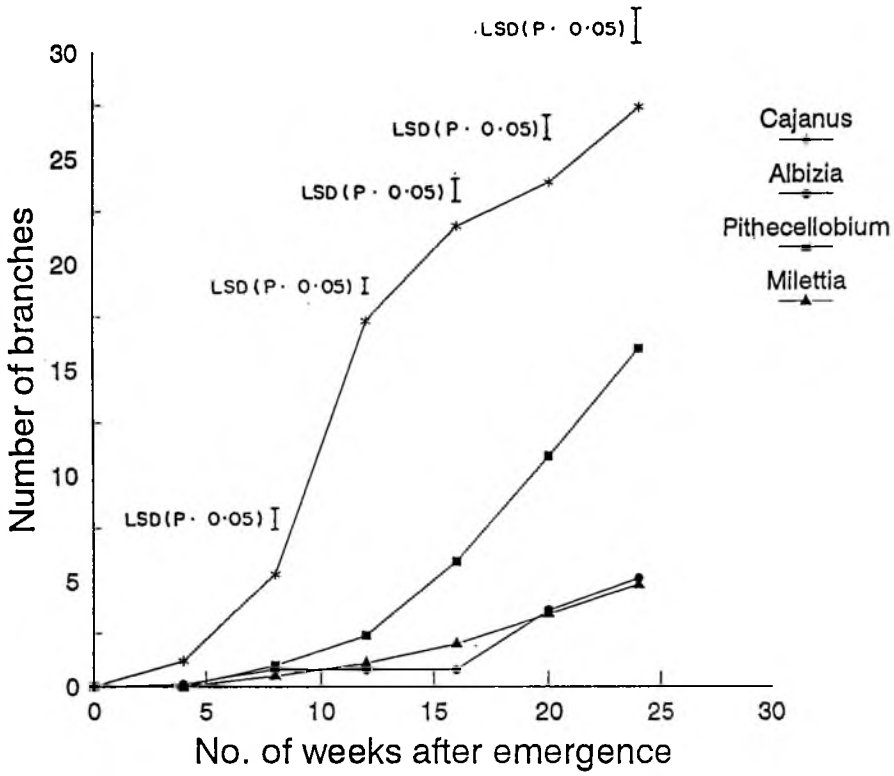

Figure 6.2: Development of primary branches of five browse plants with age

6.4 DISCUSSION

6.4.1 Seedling emergence

The very high seedling emergence (>82%) for all the species could be explained by the scarification that was done before the seeds were planted. This might have enhanced the imbition of water by the seeds. Onwueme and Adegoroye (1975) reported that seedling emergence decreased with increasing depth of sowing as well as with heat stress. Care was taken that the seeds were not sown beyond 3cm deep hence the high emergence of the seedlings. Geiger (1959) reported that soil surface temperatures of over 50°C on newly prepared seedbeds are quite common on hot days in the Tropics and that such high temperatures are detrimental to seedling emergence. The seeds of the browse plants were planted in June when the major rainy season was at its peak. Soil moisture was therefore adequate and the temperature range was between 23.4 - 29.9°C which was far below the 50°C found to be detrimental to seedling emergence.

6.4.2 Plant survival

The percentage survival of browse plants up to 16 weeks is not well documented in the literature. However, Akkaseung *et al.*, (1989) as cited by Wanapat (1989) recorded survival percentages of 90 and 77 for *Cajanus cajan* and *Albizia lebbek* respectively compared to 100% and 91.9% respectively obtained for *Cajanus cajan and Albizia lebbek* in the study. Since the studies were carried out in different localities climatic conditions, especially temperature and rainfall, may

explain the differences.

6.4.3 Plant height at 24 weeks

The field work has shown that whilst the growth of *Cajanus cajan* was very fast, that of *Afzelia africana* was almost constant throughout the growth period. *Afzelia africana* grew to a certain point and remained static thereafter. These differences in growth agree with the findings of Larbi *et al* (1993) who, based on plant height at 52 weeks classified some browse plants into fast, slow and very slow growth rate types.

The higher DM yield at 8 months compared to those of 6 and 7 months harvests was expected as generally dry matter yield of forages increases with advancing growth period. This has been confirmed by such workers as Wilman and Omaliko (1978), Asiedu (1980), Fleischer (1987) Akinola and Olorunju (1990). The species differences in the yield of DM was also in agreement with published results (Gutteridge, 1990, Thomas and Schultz-Kraft, 1990, Larbi *et al* (1993).

The development of primary branches and stem girth is not well documented in the literature. However the differences observed could be attributed to species differences . The stem girth may be related to plant height as it was observed that *Cajanus cajan* which recorded the highest plant height also had the widest stem girth at 24 weeks.

CHAPTER SEVEN

EXPERIMENT FIVE

TITLE: FORAGE QUALITY OF SOME NATIVE BROWSE PLANTS IN GHANA

7.1 INTRODUCTION

The major value of tropical browse plants is that they provide proteins, vitamins and mineral elements which are contained in much smaller amounts in grass pastures especially during the dry season. They also provide feed reserves so that livestock are able to survive critical periods of feed shortages and prolonged droughts without losses. Indeed, quality studies are yet to be done on the wide range of browse plants used by stockmen in the country. There is therefore the need to conduct studies into the herbage quality of browse plants so as to derive the maximum benefit from them for man and his animals.

The objective of the study therefore was to conduct studies into the feed quality of some native browse plants both in the field and in the laboratory.

7.2 MATERIALS AND METHODS

The materials and methods have been described in Chapter 6 (Experiment 4). The leaf fractions harvested from the three sub-plots at 24 weeks (6 months), 28 weeks (7 months) and 32 weeks (8 months) respectively and oven dried at 60°C for 72 hours for dry matter determination were milled to pass through a 1 mm sieve and then sub sampled for chemical analysis, *in vitro* dry matter digestibility (IVDMD)

and *in sacco* DM and N degradability.

7.2.1 Chemical analysis

Nitrogen (N) content was analysed by the micro-Kjeldahl method and the value obtained was multiplied by the factor 6.25 to give the percentage crude protein (CP). For mineral analysis, leaf samples of the forages were ashed at 500°C for 8 hours and the ash extracted with 6M HCl as described by IITA (1979). Contents of Mg, Zn, Cu, Fe and Mn were determined using the Parkin-Elmer atomic absorption spectrophotometer. A flame photometer was used for Na, K and Ca determination and P was determined by standard methods (AOAC, 1975). The neutral detergent fibre (NDF), acid detergent fibre (ADF), cellulose and lignin were determined using the method of Goering and Van Soest (1970) Hemicellulose was determined as the difference between NDF and ADF.

7.2.2 *In vitro* dry-matter digestibility (IVDMD)

The *in vitro* dry matter digestibility (IVDMD) of all the species was determined using the two stage technique of Tilley and Terry (1963).

7.2.3 *In sacco* CP and DM degradation of the forages

Two matured Nungua blackhead wethers weighing approximately 30kg and fitted with permanent ruminal cannulae were used for rumen DM and CP degradation studies (Ørskov and McDonald, 1979). The wethers were maintained

on a basal diet of urea treated straw supplemented with the forages under investigation in a ratio of 1:3 *ad libitum*. Water and mineral lick were always available for the animals. The nylon bags used were of dimensions 12 x 16cm with an approximate pore size of 0.10mm made from polyester material using double seam and rounded corners. Five grams air-dried sample ground to pass through a 1mm sieve was weighed into each bag. Two bags were incubated per animal per sample per incubation time. Six bags were tied to a drop line weighted with a steel bolt at one end. Up to four drop lines were incubated at a time in the rumen attaching the wire hook at the end of the drop line to the fistula cap.

Sets of bags were withdrawn after 0, 3, 6, 9, 12, 24, 36 and 48 hours of incubation. After removal from the rumen, the bags were dipped into 60% ethanol to arrest the microbial fermentation after which the bags were individually washed under running tap water until the rinsing water became clear. The unopened bags were then dried at 50°C to a constant weight. Individual forage residues were bulked for each incubation time and then analysed for dry matter (DM) and crude protein (CP). The bags were thereafter washed with soapy water and inspected for tear and holes before reuse.

The rate of CP and DM disappearance from the nylon bags after incubation was then fitted into the exponential equation.

$$P = a + b (1 - e^{-ct})$$

derived by Ørskov and McDonald (1979) where

P = percent disappearance after time "t"

a = the intercept of the degradation curve at time zero, or the water soluble fraction.

b = the potential degradability of the component of the protein or dry matter which degrade in the rumen in time (t) and

c = rate at which the "b" fraction degrades, a, b and c being constants.

The constants a, b and c were calculated by fitting a curve by the eye to the data points of Figures 7.1-7.6 according to simple algebra (Ørskov *et al*, 1980).

7.2.4 Statistical analysis

Data obtained from the chemical analysis and IVDMD were subjected to analysis of variance (ANOVA). The Student-Newman-Keuls' test (SNK) was used to separate the means of significant difference according to Steel and Torrie (1980).

7.3 RESULTS

7.3.1 Chemical composition

The dry matter content, chemical composition and IVDMD of the browse foliage are presented in Tables 7.1-7.16. The dry matter content, Table 7.1 varied widely among species.

Table 7.1: Foliage dry matter content of 5 browse plants as influenced by age (g/kg)

Species	Harvesting date (Months)			$\bar{X}$	S.E
	6	7	8		
Cajanus cajan	385.5	406.5	430.0	407.3^{b}	12.85
Albizia lebbek	351.5	385.5	408.8	381.9^{b}	16.64
Pithecellobium dulce	476.3	556.5	487.0	506.6^{a}	25.14
Milettia thonningii	447.0	421.8	416.3	428.3^{b}	9.45
Afzelia africana	558.3	706.0	844.3	702.8^{a}	82.57
$\bar{X}$	443.7^{B}	495.3^{A}	517.2^{A}		
S.E	36.12	60.60	82.90		

Means with the same superscripts are not significantly different at 5% level.

Afzelia africana had the highest dry matter content of 702.8g/kg and *Albizia lebbek* the lowest (381.9g/kg). The rest were *Pithecellobium dulce* (506.6 g/kg), *Milettia thoningii* (428.3 g/kg) and *Cajanus cajan* (407.3 g/kg).

The dry matter yield of *Afzelia africana* was so low (see Table 6.3) that sample was not sufficient for laboratory analyses. The crude protein (CP) content of the browse plants ranged from 14.8-25% (Table 7.2).

Table 7.2: Foliage crude protein content of 5 browse plants as influenced by age (%)

Species	Harvesting date (Months)			$\bar{X}$	S.E
	6	7	8		
Cajanus cajan	21.43	21.38	18.70	20.50^{b}	0.90
Albizia lebbek	27.63	23.55	23.83	25.00^{a}	1.32
Pithecellobium dulce	20.68	19.23	19.63	19.84^{b}	0.43
Milettia thonningii	22.20	20.05	20.18	20.81^{b}	0.70
Afzelia africana	15.65	14.15	14.48	14.76^{c}	0.46
$\bar{X}$	21.52^{A}	19.67^{B}	19.36^{B}		
SE	1.91	1.56	1.50		

Means with the same superscripts are not significantly different at 5% level.

Albezia lebbek had the highest value (25%) and this was significantly higher ($P<0.05$) than all the other species (14.8-20.8%). There were no significant differences ($P>0.05$) in CP content among *Cajanus cajan,*(20.5%) *Pithecellobium dulce* (19.8%) and *Milettia thonningii* (20.8%) but these values were significantly higher ($P<0.05$) than the 14.8% for *Afzelia africana.*

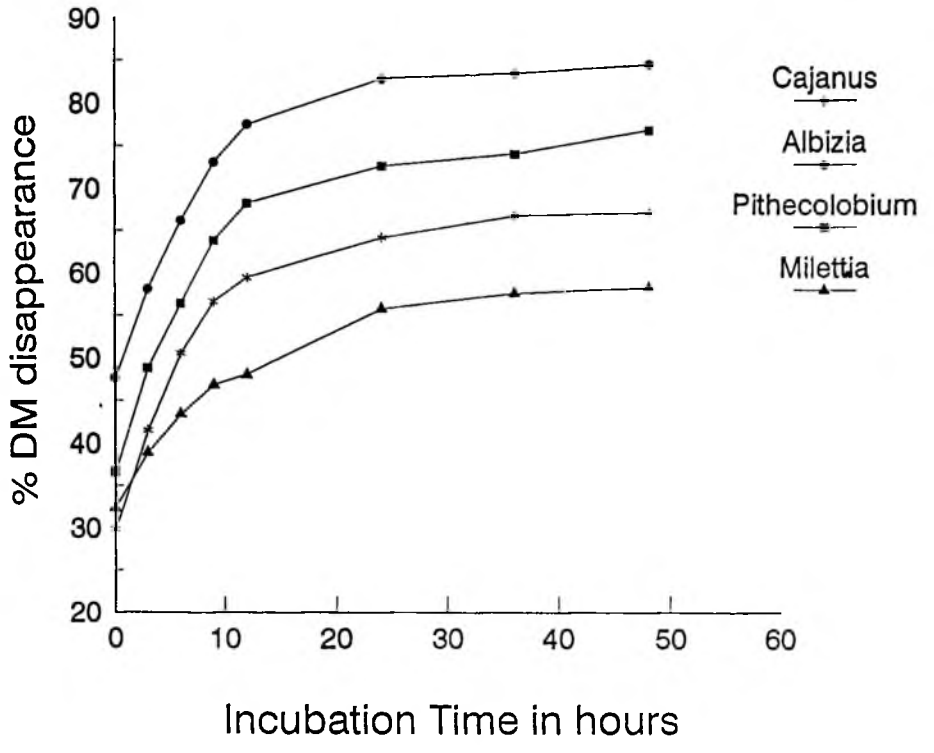

Figure 7.1 In situ DM disappearance(%) from 4 selected browse plants harvested at 6 months after planting incubated in the rumen of sheep

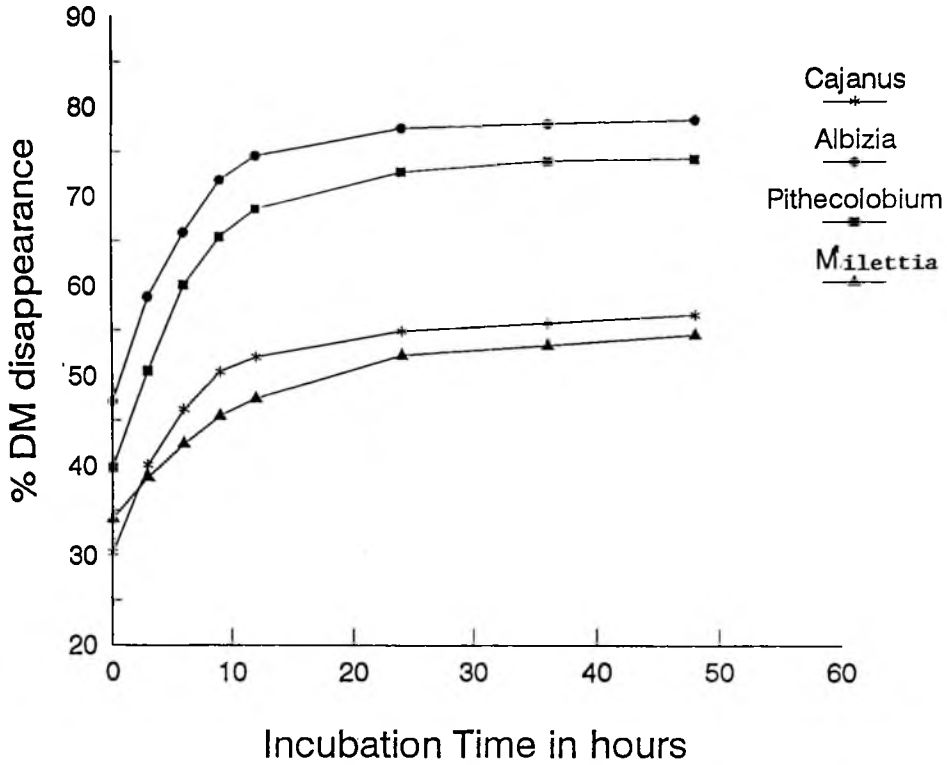

Figure 7.2 In situ DM disappearance(%) from 4 selected plants harvested at 7 months after planting incubated in the rumen of sheep

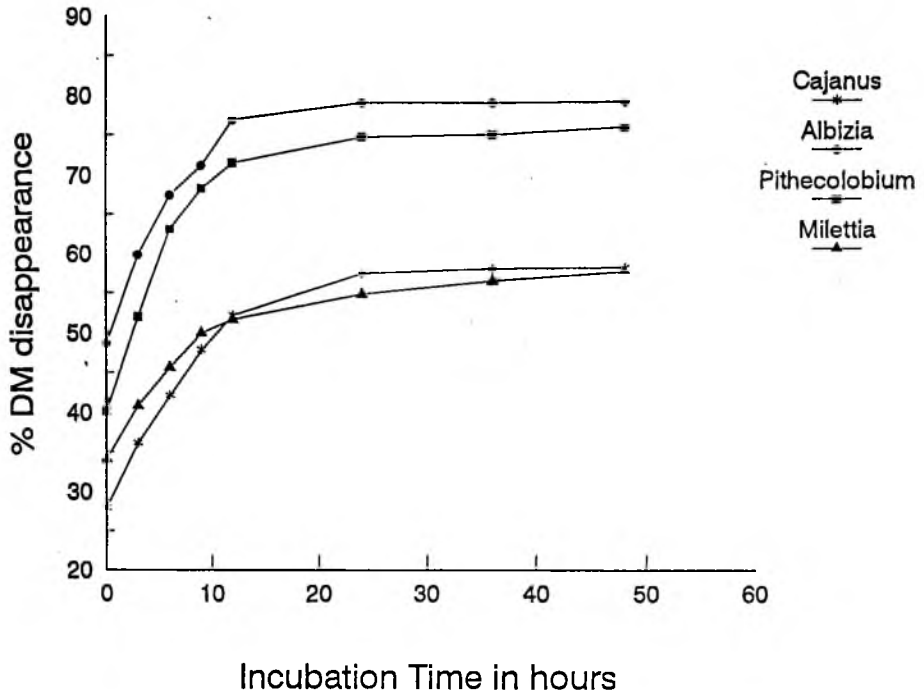

Figure 7.3 In situ DM disappearance(%) from 4 selected browse plants harvested at 8 months after planting incubated in the rumen of sheep

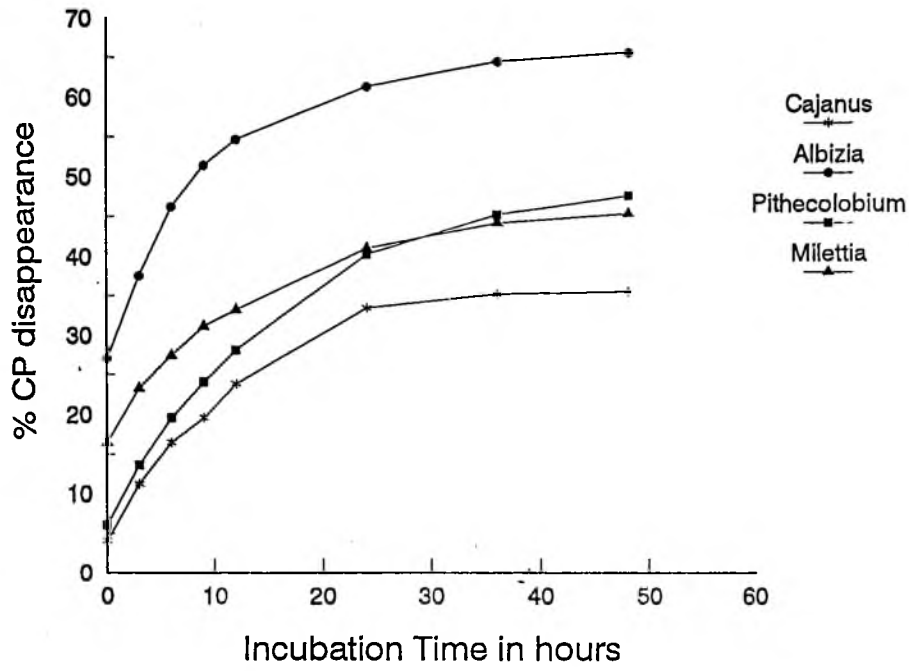

Figure 7.4 In situ CP disappearance(%) from 4 selected browse plants harvested at 6 months after planting Incubated in the rumen of sheep

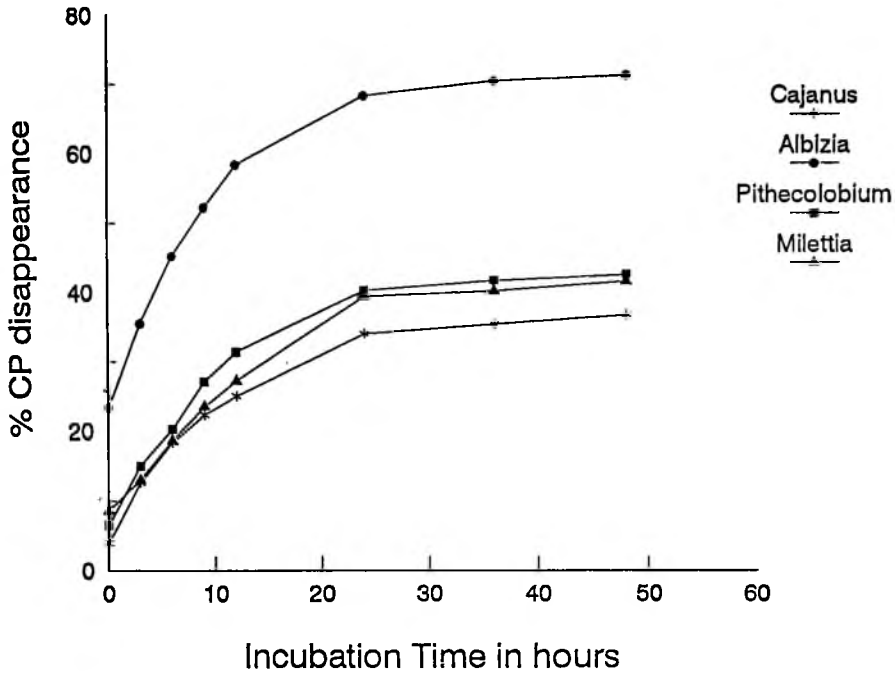

Figure 7.5 In situ CP disappearance(%) from 4 selected browse plants harvested at 7 months after planting incubated in the rumen of sheep

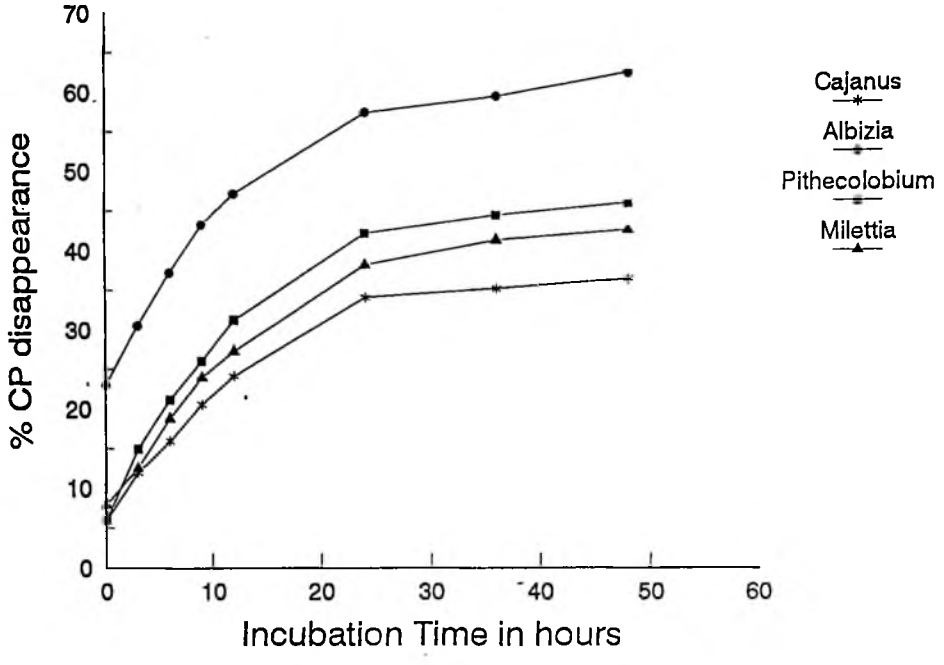

Figure 7.6. In situ CP disappearance(%) from 4 selected browse plants harvested at 8 months after planting incubated in the rumen of sheep

The date of harvest (Table 7.2) had a significant effect ($P<0.05$) on the CP content of the browse plants. The CP content for the harvest at 6 months (21.5%) was significantly higher ($P<0.05$) than those of 7 and 8 months which were not significantly different ($P>0.05$) from each other (19.7% and 19.4% respectively).

NDF values ranged between 39% and 64% (Table 7.3).

Table 7.3: Foliage NDF content of 5 browse plants as influenced by age (%)

Species	Harvesting date (Months)			$\bar{X}$	S.E
	6	7	8		
Cajanus cajan	64.05	59.40	57.90	60.45^{a}	1.85
Albizia lebbek	39.28	42.46	39.82	40.52^{c}	0.98
Pithecellobium dulce	47.76	49.92	49.52	49.06^{b}	0.66
Milettia thonningii	62.22	60.84	58.29	60.45^{a}	1.15
Afzelia africana	-	-	-	-	
$\bar{X}$	53.33^{A}	53.16^{A}	51.38^{A}		
SE	5.93	4.31	4.35		

Means with the same superscripts are not significantly different at 5% level.

Cajanus cajan and *Milettia thonningii* had the same values (60.5%) regardless of age at harvest and were significantly higher ($P<0.05$) than the rest of the species. *Albizia lebbek* had the smallest value (40.5%) which was significantly lower ($P<0.05$) than that of *Pithecellobium dulce* (49.1%).

ADF values ranged from 26% to 41% (Table 7.4).

Table 7.4: Foliage ADF content of 5 browse plants as influenced by age (%)

Species	Harvesting date (Months)			$\bar{X}$	S.E
	6	7	8		
Cajanus cajan	39.63	38.03	37.28	38.31^{a}	0.69
Albizia lebbek	24.40	26.72	25.98	25.70^{b}	0.68
Pithecellobium dulce	27.49	27.57	27.47	27.51^{b}	0.03
Milettia thonningii	39.98	42.08	39.77	40.61^{a}	0.74
Afzelia africana	-	-	-	-	-
$\bar{X}$	32.88^{A}	33.60^{A}	32.63^{A}		
SE	4.05	3.82	3.46		

Means with the same superscripts are not significantly different at 5% level.

The highest value was given by *Milettia thonningii* whilst the lowest value was given by *Albizia lebbek.* The ADF value for *Milettia thonningii* and that of *Cajanus cajan* was the same and were significantly higher ($P<0.05$) than the values for *Pithecellobium dulce* and *Albizia lebbek.* The difference between the values of *Pithecellobium dulce* and that of *Albizia lebbek* was significant ($P<0.05$).

Cellulose content (Table 7.5) for *Milettia thonningii* was the highest (25%) and was significantly different ($P<0.05$) from the rest of the browse plants. The

cellulose content of *Albizia lebbek* and *Cajanus cajan* were similar (P>0.05) but the value for *Albizia lebbek* was significantly higher (P<0.05) than that of *Pithecellobium dulce.*

Table 7.5: Foliage cellulose content of 5 browse plants as influenced by age (%)

Species	Harvesting date (Months)			$\bar{X}$	S.E
	6	7	8		
Cajanus cajan	17.29	14.47	16.00	16.57^{bc}	0.38
Albizia lebbek	18.72	18.29	18.40	18.47^{b}	0.12
Pithecellobium dulce	15.58	15.77	14.93	15.42^{c}	0.25
Milettia thonningii	25.05	25.13	24.83	25.00^{a}	0.09
Afzelia africana	-	-	-	-	-
$\bar{X}$	19.16^{A}	18.92^{A}	18.54^{A}		
SE	2.07	2.14	2.22		

Means with the same superscripts are not significantly different at 5% level.

Hemicellulose content (Table 7.6) ranged from 14.8% to 22.1%. *Cajanus cajan* scored the highest value whilst *Albizia lebbek* scored the lowest value. *Albizia lebbek* was significantly (P<0.05) the lowest.

Table 7.6: Foliage hemicellulose content of 5 browse plants as influenced by age (%)

Species	Harvesting date (Months)			$\bar{X}$	S.E
	6	7	8		
Cajanus cajan	24.42	21.37	20.62	22.14^{a}	1.16
Albizia lebbek	14.89	15.74	13.84	14.82^{b}	0.55
Pithecellobium dulce	20.27	22.35	22.05	21.56^{a}	0.65
Milettia thonningii	22.24	18.76	18.52	19.84^{a}	1.20
Afzelia africana	-	-	-	-	-
$\bar{X}$	20.46^{A}	19.56^{A}	18.76^{A}		
SE	2.04	1.48	1.79		

Means with the same superscripts are not significantly different at 5% level.

Lignin content (Table 7.7) of the browse species ranged from 6.3% to 19.8%. The highest value was given by *Cajanus cajan* and this was significantly higher ($P<0.05$) than that of the other species. The values of all the species were significantly different ($P<0.05$) from each other.

Table 7.7: Foliage lignin content of 5 browse plants as influenced by age (%)

Species	Harvesting date (Months)			$\bar{X}$	S.E
	6	7	8		
Cajanus cajan	20.00	19.68	19.03	19.57^{a}	0.29
Albizia lebbek	5.00	7.39	6.57	6.32^{d}	0.70
Pithecellobium dulce	10.49	10.14	10.59	10.41^{c}	0.14
Milettia thonningii	12.89	15.24	12.55	13.49^{b}	0.78
Afzelia africana	-	-	-	-	-
$\bar{X}$	12.10^{A}	13.06^{A}	12.19^{A}		
SE	3.11	2.71	2.60		

Means with the same superscripts are not significantly different at 5% level.

Calcium content (Table 7.8) was highest in *A. lebbek* (5.6%) and this was significantly different ($P<0.05$) from the rest of the species. The values for *M. thonningii* and *P. dulce* were similar ($P>0.05$) but were significantly higher ($P<0.05$) than values for *A. africana* and *C. cajan* which were also similar ($P>0.05$).

Table 7.8: Foliage calcium content of 5 browse plants as influenced by age (%)

Species	Harvesting date (Months)			$\bar{X}$	S.E
	6	7	8		
Cajanus cajan	2.26	2.07	2.29	2.21^{c}	0.07
Albizia lebbek	5.02	5.52	6.15	5.56^{a}	0.33
Pithecellobium dulce	2.94	3.23	3.67	3.28^{b}	0.21
Milettia thonningii	3.38	3.99	3.52	3.63^{b}	0.18
Afzelia africana	2.42	2.36	2.58	2.45^{c}	0.07
$\bar{X}$	3.20^{A}	3.43^{A}	3.64^{A}		
SE	0.50	0.62	0.68		

Means with the same superscripts are not significantly different at 5% level.

Phosphorus (P) content (Table 7.9) ranged from 0.15% to 0.23%. The value for *A. africana* was the lowest and significantly different ($P<0.05$) from the others. There was no significant difference ($P>0.05$) in the values for *Albizia lebbek, Cajanus cajan* and *Pithecellobium dulce.*

Table 7.9: Foliage phosphorus content of 5 browse plants as influenced by age (%)

Species	Harvesting date (Months)			$\bar{X}$	S.E
	6	7	8		
Cajanus cajan	0.18	0.19	0.15	0.17^{a}	0.01
Albizia lebbek	0.20	0.18	0.15	0.18^{a}	0.01
Pithecellobium dulce	0.18	0.20	0.17	0.18^{a}	0.01
Milettia thonningii	0.25	0.23	0.22	0.23^{a}	0.01
Afzelia africana	0.10	0.25	0.10	0.15^{a}	0.04
$\bar{X}$	0.18^{A}	0.21^{A}	0.16^{A}		
SE	0.02	0.01	0.02		

Means with the same superscripts are not significantly different at 5% level.

Potassium content (Table 7.10) ranged from 1.2% to 2.8% the value of *Milettia thonningii* (2.8%) was significantly ($P<0.05$) the highest while that of *Afzelia africana* (1.2%) was significantly the lowest. The values for *Cajanus cajan, Albizia lebbek* and *Pithecellobium dulce* (1.6%, 1.8%, and 1.6% respectively) were similar.

Table 7.10: Foliage potassium content of 5 browse plants as influenced by age (%)

Species	Harvesting date (Months)			$\bar{X}$	S.E
	6	7	8		
Cajanus cajan	1.71	1.71	1.43	1.62^{b}	0.07
Albizia lebbek	1.77	1.91	1.68	1.78^{b}	0.05
Pithecellobium dulce	1.66	1.52	1.48	1.55^{b}	0.04
Milettia thonningii	2.76	2.77	2.86	2.79^{a}	0.03
Afzelia africana	1.19	1.09	1.34	1.21^{c}	0.07
$\bar{X}$	1.82^{A}	1.80^{A}	1.76^{A}		
SE	0.26	0.28	0.28		

Means with the same superscripts are not significantly different at 5% level.

Magnesium content (Table 7.11) ranged from 0.3% to 0.6%. *Albizia lebbek* had the highest value whilst *Afzelia africana* had the lowest value. These values were significantly different (P<0.05).

Table 7.11: Foliage magnesium content of 5 browse plants as influenced by age (%)

Species	Harvesting date (Months)			$\bar{X}$	S.E
	6	7	8		
Cajanus cajan	0.46	0.50	0.54	0.50^{bc}	0.02
Albizia lebbek	0.65	0.64	0.64	0.64^{a}	0
Pithecellobium dulce	0.55	0.63	0.60	0.59^{ab}	0.02
Milettia thonningii	0.43	0.41	0.35	0.40^{c}	0.02
Afzelia africana	0.27	0.30	0.34	0.30^{d}	0.02
$\bar{X}$	0.47^{A}	0.50^{A}	0.50^{A}		
SE	0.06	0.07	0.06		

Means with the same superscripts are not significantly different at 5% level.

Apart from *Afzelia africana* which was significantly higher (P<0.05) in Na content (Table 7.12) than the rest of the species, no significant differences (P>0.05) were observed among the species. *Milettia thonningii* had significantly higher (P<0.05).

Table 7.12: Foliage sodium content of 5 browse plants as influenced by age (%)

Species	Harvesting date (Months)			$\bar{X}$	S.E
	6	7	8		
Cajanus cajan	0.08	0.13	0.13	0.11^{b}	0.02
Albizia lebbek	0.10	0.06	0.12	0.09^{b}	0.02
Pithecellobium dulce	0.12	0.11	0.14	0.12^{b}	0.01
Milettia thonningii	0.08	0.01	0.02	0.04^{b}	0.02
Afzelia africana	0.68	0.35	0.25	0.43^{a}	0.10
$\bar{X}$	0.21^{A}	0.13^{A}	0.13^{A}		
SE	0.12	0.06	0.04		

Means with the same superscripts are not significantly different at 5% level.

Zinc content (Table 7.13) than the other species. No significant differences ($P>0.05$) were observed among the rest of the species.

Table 7.13: Foliage zinc content of 5 browse plants as influenced by age (ppm)

Species	Harvesting date (Months)			$\bar{X}$	S.E
	6	7	8		
Cajanus cajan	35.00	41.15	38.49	38.21^{b}	1.78
Albizia lebbek	30.77	17.72	15.36	21.28^{b}	4.79
Pithecellobium dulce	31.06	32.51	30.36	31.31^{b}	0.63
Milettia thonningii	61.08	71.51	60.64	64.41^{a}	3.55
Afzelia africana	11.09	9.43	45.97	22.16^{b}	11.91
$\bar{X}$	33.80^{A}	34.46^{A}	38.16^{A}		
SE	7.99	10.79	7.57		

Means with the same superscripts are not significantly different at 5% level.

No copper (Cu) (Table 7.14) was detected in *Afzelia africana*. *Cajanus cajan* had the highest Cu content (13.71ppm) whilst *Albizia lebbek* had the lowest Cu content (3.62ppm) but these were not significantly different.

Table 7.14: Foliage Copper content of 5 browse plants as influenced by age (ppm)

Species	Harvesting date (Months)			$\bar{X}$	S.E
	6	7	8		
Cajanus cajan	8.83	26.21	6.09	13.71^{a}	6.30
Albizia lebbek	4.46	3.88	2.52	3.62^{a}	0.57
Pithecellobium dulce	8.09	10.61	7.89	8.86^{a}	0.88
Milettia thonningii	7.89	3.67	2.53	4.70^{a}	1.63
Afzelia africana	*	*	*		
$\bar{X}$	7.32^{A}	11.09^{A}	4.76^{A}		
SE	0.97	5.29	1.34		

Means with the same superscripts are not significantly different at 5% level.

* No Copper was detected in *Afzelia africana* in all the three harvesting dates.

Manganese (Mn) content (Table 7.15) of the browse species ranged between 12.73ppm and 76.39ppm. *Afzelia africana* showed the lowest value and was significantly lower ($P<0.05$) than the other species. No significant differences ($P>0.05$) were found among the other species. Date of harvest had no significant effect ($P>0.05$) on the mineral contents of the browse plants (Tables 7.8 - 7.15).

Table 7.15: Foliage manganese content of 5 browse plants as influenced by age (%)

Species	Harvesting date (Months)			$\bar{X}$	S.E
	6	7	8		
Cajanus cajan	61.44	52.90	58.44	57.59 [a]	2.50
Albizia lebbek	89.11	70.72	69.35	76.39[a]	6.37
Pithecellobium dulce	79.44	75.91	72.71	76.02[a]	1.94
Milettia thonningii	57.72	68.72	50.84	59.02[a]	5.21
Afzelia africana	20.02	8.08	10.08	12.73[b]	0.69
$\bar{X}$	61.55[A]	55.27[A]	52.28[A]		
SE	11.87	12.41	11.25		

Means with the same superscripts are not significantly different at 5% level.

The *in vitro* dry matter digestibility (IVDMD) values (Table 7.16) ranged between 44% and 63%. *Afzelia africana* had the highest value but this was not significantly different (P>0.05) from the values of *Albizia lebbek* and *Pithecellobium dulce.* These were however significantly higher (P<0.05) from the values of *Milettia thonningii* and *Cajanus cajan. Cajanus cajan* had the lowest IVDMD value and was significantly lower (P<0.05) than that of *Milettia thonningii.*

Table 7.16: Foliage IVDMD of 5 browse plants as influenced by age (%)

Species	Harvesting date (Months)			$\bar{X}$	S.E
	6	7	8		
Cajanus cajan	45.80	45.34	41.43	44.21^{c}	1.39
Albizia lebbek	63.15	60.80	60.14	61.37^{a}	0.91
Pithecellobium dulce	58.91	59.13	60.29	59.44^{a}	0.43
Milettia thonningii	52.74	53.20	54.24	53.39^{b}	0.44
Afzelia africana	63.98	61.47	63.25	62.90^{a}	0.75
$\bar{X}$	56.91^{A}	55.99^{A}	55.87^{A}		
SE	3.42	3.04	3.89		

Means with the same superscripts are not significantly different at 5% level.

7.3.2 *In sacco* DM and CP digestibility of the browse plants

Rumen degradability characteristics with respect to dry matter (DM) and crude protein (CP) of the browse plants are presented in Table 7.17. At 6 months, *Albizia*

lebbek had the highest soluble fraction (a) for both DM and CP (48% and 27%) respectively, whilst *Cajanus cajan* had the lowest.

Table 7.17: *In sacco* degradability characteristics (a, b and c) of DM and CP of browse species harvested at 6, 7 and 8 months after planting

Degradability Parameters	Age of plant (mths)	*Cajanus cajan*	*Albizia lebbek*	*Pithecellobium dulce*	*Milettia thonningii*
% Soluble fraction(a)					
DM	6	30	48	37	32
	7	30	47	39	34
	8	28	49	40	34
CP	6	4.1	27	6.3	16.4
	7	4.0	23.3	6.5	8.6
	8	6.0	23	6.0	7.9
Potential degradability (a + b)%					
DM	6	67	84	77	58
	7	57	79	74	54
	8	58	79	76	58
CP	6	35.5	65.6	47.6	45.4
	7	36.6	71.2	42.5	41.5
	8	36.3	62.4	45.9	42
Rate of degradation (c)%/hr.					
DM					
	6	0.13	0.16	0.12	0.09
	7	0.15	0.16	0.14	0.09
CP	8	0.12	0.18	0.19	0.11
	6	0.07	0.11	0.06	0.08
	7	0.09	0.10	0.09	0.07
	8	0.07	0.08	0.08	0.07
Undegradable fraction [100 - (a + b)]					
DM	6	33	16	23	42
	7	43	21	26	46
	8	42	21	24	42
CP	6	64.5	34.4	52.4	54.6
	7	63.4	28.8	57.5	58.5
	8	63.5	37.6	54.1	57.5

The potential degradability (a + b) was highest in *Albizia lebbek* with respect to both DM and CP. *Milettia thonningii* had the lowest DM degradability (58%) whilst *Cajanus cajan* had the lowest CP degradability (35.5%).

The highest rate of degradation (C) was recorded in *Albizia lebbek* for both DM and CP (0.16%/hr and 0.11%/hr. respectively) whilst the lowest value for DM and CP were obtained by *Milettia thonningii* (0.09%/hr) and *Pithecellobium dulce* (0.06%/hr) respectively.

The undegradable fraction for DM was highest for *Milettia thonningii* (42%). The lowest value was noticed in *Albizia lebbek* (16%). The highest value for undegradable fraction for CP was obtained in *Cajanus cajan.* The lowest undegradable CP was obtained by *Albizia lebbek* (34.4%).

At 7 months after planting, *Albizia lebbek* had the highest soluble fraction (a) for both DM and CP (47% and 23.3%) respectively. *Cajanus cajan* had the lowest soluble fraction for both DM (30%) and CP (4%). The highest potential degradability for both DM and CP were in *Albizia lebbek* (79% and 71.2% respectively). The lowest degradability values for both DM and CP were recorded in *Milettia thonningii* (54%) and *Cajanus cajan* (36.6%) respectively.

The highest rates of degradation were recorded in *Albizia lebbek* for both DM and CP (0.16%/hr and 0.10%/hr) respectively. The lowest rates of degradation for both DM (0.09%/hr) and CP (0.07%/hr) were obtained in *Milettia thonningii.* The undegradable fraction for DM were highest in *Milettia thonningii* (46%) and *Cajanus cajan* (43%). The lowest undegradable fraction for DM (21%) was given by *Albizia lebbek.* The undegradable fraction for CP were highest in *Cajanus cajan* (63.4%) but *Albizia lebbek* gave the lowest CP value (28.8%).

At 8 months after planting, *Albizia lebbek* had the highest soluble fraction for both DM and CP (49% and 23% respectively). The lowest solubility for DM was given by *Cajanus cajan* (28%) whilst *Cajanus cajan (6%)* and *Pithecellobium dulce* (6%) gave the lowest solubility values for CP.

The potential degradability for both DM and CP were highest in *Albizia lebbek* (79% and 62.4%) respectively. *Milettia thonningii and Cajanus cajan* gave the lowest degradability for DM (58%) for both cases. The lowest degradability value for CP was given by *Cajanus cajan* (36.3%). The rates of degradation for DM were highest in *Albizia lebbek* and *Pithecellobium dulce* (0.18%/hr. and 0.19%/hr respectively. The rates of degradation for both species for CP were also the highest (0.08%/hr) each. The lowest rates of degradation were obtained from both *Cajanus cajan* and *Milettia thonningii* for both DM and CP. The highest undegradable fraction for DM was obtained in both *Cajanus cajan* and *Milettia thonningii* (42%). *Cajanus cajan* also had the highest undegradable fraction for CP (63.5%). *Albizia lebbek* indicated the lowest undegradable fraction for both DM and CP (21% and 37.6%) respectively.

7.4 DISCUSSION

7.4.1 Chemical composition

The chemical composition and the differences observed among them were similar to those reported by Rose Innes and Mabey (1964 a,b), Rose Innes (1966), Lawton (1980), Le Houerou (1980c) Gohl (1981); Mohammed and Ravoov (1987)

as cited by Chee (1989), Wanapat (1989), Ahn *et al.,* (1989), Karbo and Barnes (1993), Norton (1994), Lowry *et al.,* 1994).

7.4.2 Dry matter content

The dry matter contents obtained were slightly higher than values reported by Rose Innes and Mabey (1964 a,b), Rose Innes (1966), Le Houerou (1980c), and Gohl (1981) but lower than those reported by Wanapat (1989). The differences may be due to location, climatic conditions, cultural practices, time of harvesting (age of forage at harvest), leaf:stem ratio of the plant fraction sampled etc. The values obtained for the DM content suggest that the fresh forages contain about 30-70% moisture. Some of the browse forages may be able to provide the ruminant with reasonable amounts of their water needs during the dry season when that is also scarce. This is in agreement with the report of ARC (1965) that herbage of low dry matter content may supply water in excess of livestock requirements but leads to a reduction in energy available for liveweight gain or milk production (Wilman and Wright, 1978). With moisture content above 60%, there may be low intake and consequently a drop in nutrient supply, as the amount of a forage consumed by the animal is important because of the effect on the total nutrient intake and therefore the animal's production response (Crowder and Chheda, 1982). There is therefore the need to reduce the moisture content of forages with moisture content above 60% (*Albizia lebbek, Cajanus cajan,* and *Milettia thonningii)* by wilting before feeding them to the animals so as to enable the animal consume more dry matter. On the

other hand *Afzelia africana* and *Pithecellobium dulce* with moisture content below 50% need not be wilted before being fed to the animals.

7.4.3 Crude protein (CP) content

The CP values for the forages ranged from 15 to25% which is within the range of values reported for forage tree legumes by Norton (1994). The values are however higher than the 11 - 12% crude protein considered adequate for moderate level of production for ruminants (ARC, 1980). The importance of this is that if adequate amounts of these browse plants are available, they will be beneficial to supplement them in the feeding of ruminants in areas where animals will have to subsist on poor quality roughages for the greater part of the year. The higher CP content at 6 months (21.5%) as compared to those of 7 months (19.7%) and 8 months (19.4%) was expected as generally CP declines with advancing maturity. This has been confirmed by such workers as Ademosum, (1973), Fleischer (1987) and Akinola and Olorunju (1990).

7.4.4 Cell wall constituents (CWC) and minerals

The very low digestibility of *Cajanus cajan* compared with the others may be explained by the fact that *Cajanus cajan* had the highest lignin content. Sullivan (1959) reported that, within plant species increasing lignin content almost invariably resulted in a lower digestibility. McDonald *et al.* (1988) have suggested that the extent to which cellulose is digested in the rumen depends particularly on the degree

of lignification of the plant material since lignin like cutin is resistant to anaerobic bacterial attack probably because of its condensed structure which inhibits hydrolysis.

Cajanus cajan also had the highest NDF value which may also explain its low digestibility. Norton (1994) reported that tree forages with low NDF (20-35%) are usually high in digestibility. The high digestibility value recorded by *Afzelia africana* therefore cannot be explained in terms of its NDF and ADF values which were not determined. It could be inferred that its NDF and lignin values might have been lower than those of the other plants.

The high digestibility value of *Albizia lebbek* could be explained by its low NDF and lignin contents. With *Milettia thonningii* having the same NDF value as *Cajanus cajan,* it was expected that the digestibility of *Milettia thonningii* would be the same as that of *Cajanus cajan* but this was not so as *Milettia thonningii* had a higher digestibility than *Cajanus cajan.* This could be explained by the fact that *Milettia thonningii* had a lower lignin content than *Cajanus cajan* in conformity with the findings of Sullivan (1959) and Ahn *et al.* (1989) that lignin and condensed tannins were responsible for low forage digestibilities.

Le Houerou (1980b) reported that the mineral content of browse is on the whole adequate for P (0.15%) and Mg (0.6%) but is a little high for Ca (1.17%) and K (1.5%) and that the Ca:P ratio is too high (11) relative to the optimum figure of 1-2%. The Ca content of the forages studied were higher than the value of 1.7% reported by Le Houerou (1980b). The value for P (0.15 - 0.23%) is within the range

reported by Le Houerou (1980b). However the Ca:P of the forages ranged between 13 - 31 and is far higher than the value of 11 reported by Le Houerou (1980b). Since the value for P is within the range reported by Le Houerou (1980b) the high Ca:P ratio detected was due to the high Ca content of the browse plants. Since no soil analysis was done before and after the trial it cannot be said whether it was the soil which contributed to the high levels of Ca in the plants or not.

Vercoe (1987) reported that the copper values of browse plants ranged from 4-152ppm. In the present study, no Cu was detected in *Afzelia africana,* while the Cu content of *Albizia lebbek* was slightly lower than 4ppm. It could be said that the mineral contents of the browse plants are adequate to meet the requirements of ruminants since the mineral content of the browse plants are slightly higher than the minimum requirements for ruminants.

The differences in the mineral content observed in the study as compared to the findings of other workers such as Le Houerou (1980b), Vercoe (1987) may be attributed to location, species differences, cultural practices such as the application of fertilizers and which part of the plant was used for the analysis.

7.4.5 *In sacco* degradability of the forages

The observation that *Milettia thonningii* and *Cajanus cajan* had low degradability for DM and CP respectively is in consonnance with IVDMD scores. This low digestibility could be attributed to the high NDF value (60.45%) for both species, according to Norton (1994), tree forages with low NDF content (20 - 35%)

were usually high in digestibility. Tannins could also be involved in the low DM and CP degradability of *Milettia thonningii* as Milettia sutherlandi has been found to contain 2.2% of tannin (Watt and Breyer - Brandwijk 1962)

According to Baggio and Hueveldop (1994) and Robertson (1988) [both cited by Palmer *et al.* (1994)] tannins are of an advantage in that they ensure protected (by pass) protein, but high levels of tannin may reduce the digestibility of protein for livestock. The *in sacco* DM and CPdigestibilities for *Albizia lebbek* were higher than that reported by Norton (1994) while that of DM for *Cajanus cajan* was more than that reported by Norton (1994). This variation may be due to dissimilarities in climate, location and the stage of growth of the plants as well as the composition of the basal diet and the level at which it was fed to the animals (Kempton, 1980, Ørskov *et al.* 1980).

The rates of degradation for DM and CP were quite similar in all the species. The fact that *Milettia thonningii* and *Cajanus cajan* had low DM and CP digestibility as compared to the other species may be explained by the fact that initially the rate of digestion might be fast but with time the rate might have been inhibited by some factors. This might have led to both *Milettia thonningii* and *Cajanus cajan* having the highest fraction of undegradable DM and CP. It has been reported by Balch and Campling (1962) as cited by Ørskov *et al.*, (1980) that the rate of digestion of cellulosic material is an important factor affecting voluntary intake. Because of the high undegradable fraction for *Cajanus cajan* and *Milettia thonningii*, their supplementation to ruminant diets will just distend the rumen and this will eventually

reduce their intake if the rate of digestion and passage from the rumen is slow.

That *Albizia lebbek* had the highest soluble fraction (a), potential degradability (a + b) and rate of digestion (c) for DM and CP was in agreement with that of Budu-Biney (1993) Ahn *et al* (1989) reported that drying of tree legume leaves decreases their tannin content and increase CP degradability. It is therefore suggested that browse species such as *Milettia thonningii* and *Cajanus cajan* which have low DM and CP degradability should be dried before feeding to ruminants so as to improve their degradabilities. Again, supplementing the diets of ruminants with *Milettia thonningii* and *Cajanus cajan* will yield better results if combined with the highly degradable samples such as *Albizia lebbek.*

CHAPTER EIGHT

GENERAL DISCUSSION

The aim of the first experiment was to study the effect of different treatments on the laboratory germination of seeds of some native browse plants. Differences in germination were observed among the various treatment methods. Higher germination occurred in the mechanically scarified seeds of all the species with the exception of *Grewia carpinifolia* and *Khaya senegalensis*. Workers such as Viliers (1972), Ellis *et al.,* (1985) Milthorpe and Moorby (1986), Tybirk (1991) have reported high germination with scarification. Such scarification is known to improve germination by enhancing permeability of the seed coat to moisture and gases. The lower germination noted with *Grewia carpinifolia and Khaya senegalensis* has been observed by others (Clark *et al.,* 1968, Bewley and Black 1978). It is believed that some of the seeds were so small that scarification easily destroyed the embryo. Again some of the seeds had soft seed coats and scarification easily peeled off greater part of the seed coat leading to the destruction of the embryo and subsequent attack by fungal pathogens. The seeds of *Grewia carpinifolia* used in the study were very small while those of *Khaya senegalensis* had soft seed coat which led to a greater part of the seed coat peeling off on scarification.

Differences in the germination of seeds with the different treatments may be due to differences in the ages of the seeds. Some of the seeds were collected for the study after they had dispersed from the plant whilst some others were collected while

still on the plant. This confirms the report of Schmidt (1988) as cited by Tybirk (1991) that freshly harvested seed have been found to germinate differently from seeds that have been stored for some period. *Grewia carpinifolia* and *Dialium guineense* gave very low germination both in warm and hot water treatments. This might be due to soaking injury resulting from rapid imbibition of water (Rudrapel and Basu 1980, Ellis *et al.,* 1985). It might also be due to the fact that, the treatment period was not enough as reported by Tybirk (1991).

The failure of *Baphia nitida* and *Griffonia simplicifolia* to germinate was not immediately clear. However the seed got mouldy within 24 hours after sowing and some greenish liquid was found in them. The seed may also require some "afterripening" period since they were recently harvested from the plants.

Having established the fact that the mechanically scarified seeds germinated better than the other treatments, it was used for the seeds in Experiment 2 which aimed at studing the changes with age of the browse plants in height, relative growth rate (RGR), net assimilation rate (NAR) and leaf area ratio (LAR). The differences in growth rates observed confirmed similar observations by Greulach (1973) who reported that although environmental factors have considerable influence on the rate of growth of any particular plant, some species grow much more rapidly than others. Larbi *et al* (1993) classified some browse species into fast, slow and very slow growth rate types of plants. Based on the results of the RGR, NAR, and LAR, it was observed that *Cajanus cajan* increased its dry weight faster than the rest of the species.

Experiment 3 was therefore conducted to study the sprouting ability as well as the growth rate of some native browse plants by the use of hard wood stem cuttings with the help of a rooting hormone. While some of the cuttings never sprouted others did but died before they were four weeks old. A close look at the base of the cuttings which died as well as those that never sprouted indicated that, no roots developed on them. It would appear that the hormone was not effective in these cases. Among the cuttings that survived, *Pithecellobium dulce* grew fastest as reflected in greater than 50cm growth in 6 months in the normal hormone concentration. On the other hand, *Baphia nitida* was very slow as shown by the less than 10cm growth in 6 months. Larbi *et al.,* (1993) observed that *Baphia nitida* is a very slow growing browse plant. Since the stem cuttings used were taken from plants whose ages were not known, it is possible that they were physiologically varied as age of the cuttings is reported to affect growth (Falvey 1982, Glover, 1989, as cited by Shelton 1994a). Also the diameter and length of the cuttings used in the study were 15mm and 30cm respectively in contrast with 7cm and 0.5 - 2m in diameter and length respectively recommended by Falvey (1982) and Glover (1989) as cited by Shelton, (1994a). The failure of some of the species to sprout and develop roots may also be attributed to the depth of planting. It has been recommended that cuttings should be planted 20-50cm deep into the soil (Glover 1989 as cited by Shelton 1994a). In this study however, a planting depth of less than 6 cm was used.

Experiment 4 was conducted using mechanical scarification to plant five native browse plants on the field. The aim of the study was to establish the plants on the field as well as study their biomass yield. Seedling emergence was quite high (>82%) for all the 5 species. Care was taken so that the seeds were not sown beyond 3cm deep. Onwueme and Adegoroye (1975) have reported that seedling emergence decreases with increasing depth of sowing. The percentage survival of *Cajanus cajan* and *Albizia lebbek* up to 16 weeks as reported in the literature (Akkaseung *et al.*, (1989) as cited by Wanapat, 1989) was found to be lower than what was obtained in the present study. It is thought that, rainfall and temperature as well as soil factors and pests may have influenced these differences.

Whilst *Cajanus cajan* grew very fast, the growth of *Afzelia africana* was almost constant throughout the trial period. Higher DM yield was observed at 8 months as compared to 6 and 7 months. Generally, DM yield increases with plant age. The species differences in yield has also been confirmed by Gutteridge (1990), Thomas and Schultz-Kraft (1990) and Larbi *et al.* (1993) who recorded species differences in DM yield. There were differences observed in the development of primary branches and stem girth in the species and this could be attributed to species differences. Experiment 5 was conducted by using foliage material that were harvested in Experiment 4 to determine the nutritive qualities of the browse plants. The values obtained for DM content suggest that the fresh forages contain about 30-70% moisture. This suggests that ruminants could subsist on forages with high moisture content such as *Albizia lebbek* for a longer period without water while they

cannot subsist on *Afzelia africana* for a longer period without water. However, such forages with high moisture content influence the available energy for liveweight gain or milk production (Wilman and Wright, 1978). The higher the moisture content, the lower would be the intake of dry matter and consequently a drop in nutrient supply. This is because the amount of DM consumed by the animal is important and it affects the total intake and therefore the animals response (Crowder and Chheda, 1982). There is therefore the need to reduce the moisture content of the species where this is above 60% (*Albizia lebbek, Cajanus cajan* and *Milettia thonningii*) by wilting before feeding them to animals to enable them consume more dry matter. They could also be supplemented with straw and stover if they were not to be wilted. *Afzelia africana* and *Pithecellobium dulce* with moisture content below 50% need not be wilted before feeding.

The CP values for the forages ranged between 15 and 25%. The values are however higher than the minimum level (11-12%) considered adequate for a moderate level of production for ruminants (ARC, 1980). All the species tested in the study seemed to have the capacity to supply high levels of CP. However, this capacity may vary with season and the concentration of phenolic compounds known to inhibit N availability (Arthun *et al.* 1992).

Apart from *Cajanus cajan* which had very low digestibility (44%), all the others had IVDMD above 53%. This is above the minimum level of digestibility (50%) required to support ruminant production (Reid *et al.*, 1973). The digestibility of the *Cajanus cajan* as well as the other forages can be improved by dosing them

with polyethylene glycol (PEG) to displace tannins from tannin-protein complexes which improves nitrogen digestibility (Pritchard *et al.* 1985, Norton, 1994).

The mean calcium content of the forages was 3.4% while that of phosphorus was 0.18%. The Ca:P ratio of the forages was high (18.8). It could be said that the mineral contents of the browse used in the study were slightly higher than the minimum mineral requirements of ruminants.

The observation that *Milettia thonningii* and *Cajanus cajan* had low degradability for DM and CP respectively could be attributed to the high NDF value (60.45%) for both species. This low degradability suggests that not enough of the material is broken down hence not enough energy is released to the animal hence the animal will be handicapped so far as its energy requirements are concerned. According to Baggio and Hueveldop (1994) and Robertson (1988) both cited by Palmer *et al.* (1994), tannins are an advantage in that they ensure protected (by pass) protein but at the same time high levels of tannin may reduce the digestibility of protein by livestock. The *in sacco* digestibility for DM and CP obtained for *Albizia lebbek* were higher. This suggests that enough of the material will be broken down and this may lead to the animal getting enough energy for its activities.

Ahn *et al.,* (1989) reported that drying of tree legume leaves decreases their tannin content and that in most species drying decreased the tannin content and increased CP degradability. It is therefore suggested that diets of ruminants should be supplemented with species such as *Milettia thonningii* and *Cajanus cajan* so as to yield better results if they are in combination with a highly digestible source like

Albizia lebbek.

CHAPTER NINE

CONCLUSIONS AND RECOMMENDATION

From the results, high percentage germination (>80%) was obtained in *Cajanus cajan, Albizia lebbek, Milettia thonningii* and *Afzelia africana* whilst low values (<40%) were recorded for *Grewia carpinifolia, Khaya senegalensis* and *Dialium guineense.* The percentage germination were further improved by mechanical scarification. It is therefore recommended that in the establishment of the browse plants, scarification should be done for all the species with the exception of *Khaya senegalensis* where scarification did not improve germination.

The performance of the browse plants with stem cuttings was not encouraging. The growth rates of the species that survived were very low with the exception of *Pithecellobium dulce* which was a bit higher. It is therefore recommended that, for the establishment of the browse plants, seeds must be used unless viable seeds are not produced by the species and the only alternative is to use stem cuttings for establishment. Though there may be many rooting hormone, their effectiveness should be ascertained before being used.

The results of the RGR, NAR and LAR showed that *Milettia thonningii* had the highest RGR and NAR values, but had the lowest LAR value. *Cajanus cajan* on the other hand which had the lowest

value for NAR had the highest value for LAR and also recorded the highest dry matter yield.

The CP content of the browse plants ranged between 15and 25% which is high enough to furnish the protein requirement of ruminants for moderate production. The digestibility of the plants which ranged from 44-61% was high enough indicating that the browse species are promising supplementary feed sources for ruminants. It must be cautioned that digestibility studies alone cannot be used as a sole index of selecting a particular browse species as being the best but the palatability and acceptability of the forage material by the ruminant must also be borne in mind hence the final decision as to the best species for use in ruminant production will depend on the animal. The high undergradable DM for *Milettia thonningii* and *Cajanus cajan* is a limitation which may affect the voluntary intake of the plant. It is therefore recommended that very efficient management practices such as the application of fertilizers be adopted so as to improve the yield of the browse plants for efficient ruminant production systems. It is also recommended that the work done so far should be extended to include studies with animals so as to ascertain the voluntary intake, *in vivo* dry matter digestibility and animal responses or performances.

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APPENDIX 1

SYMBOLS REPRESENTING THE BROWSE SPECIES USED AND DATE OF HARVEST

BS_1	=	*Cajanus cajan*
BS_2	=	*Albizia lebbek*
BS_3	=	*Pithecellobium dulce*
BS_4	=	*Milettia thonningii*
BS_5	=	*Afzelia africana*
BS_6	=	*Grewia carpinifolia*
BS_7	=	*Khaja senegalensis*
BS_8	=	*Baphia nitida*
BS_9	=	*Griffonia simplicifolia*
BS_{10}	=	*Dialium guineense*
BS_{11}	=	*Ficus exasperata*
BS_{12}	=	*Spondias mombin*

D_1 First date of harvest (Browse species harvested at 6 months after planting)
D_2 Second date of harvest (Browse species harvested at 7 months after planting)
D_2 Third date of harvest (Browse species harvested at 8 months after planting)

APPENDIX 2

ANOVA ON PERCENTAGE GERMINATION OF EIGHT SPECIES OF BROWSE PLANTS UNDER DIFFERENT SEED TREATMENTS

SV	df	SS	MS	F Observed	F TAB	
					5%	1%
Total	127	74226.12				
Reps	3	63.58	21.19	0.25		
Treatment	(31)	(66112.45)	2132.66	25.43**	1.41	151
Species	7	44725.20	6389.31	76.19**	2.10	2.82
Seed Trt.	3	4083.33	1361.11	16.23**	2.70	3.98
Sp x ST	21	17303.92	824.0	9.83**	1.68	2.06
Error	96	8050.12	83.86			

** Significant at the 1% level

LSD Between species means

$$= \frac{t\alpha}{2}\sqrt{\frac{(2 \times 83.16)}{16}}$$

LSD 0.05 = 1.982 (3.24) = 6.42
LSD 0.01 = 2.625 (3.24) = 8.51

LSD Between seed treatment means

$$= \frac{t\alpha}{2}\sqrt{\frac{(2 \times 83.86)}{32}}$$

LSD 0.05 = 1.982 (2.29) = 4.54
LSD 0.01 = 2.625 (2.29) = 6.01

LSD Interaction effects (Sp x ST)

$$= \frac{t\alpha}{2}\sqrt{\frac{(2 \times 83.86)}{8}}$$

LSD 0.05 = 1.982 (4.58) = 9.08
LSD 0.01 = 2.625 (4.58) = 12.02

APPENDIX 2a

ANOVA FOR *CAJANUS CAJAN*

SV	df	SS	MS	F Observed	F TAB	
					5%	1%
Total	15	1127.74				
Reps	3	10.31	3.44	0.10		
Treatment	3	790.51	263.5	7.25**	3.86	6.99
Error	9	326.92	36.32			

** Significant at the 1% level

$$LSD = \frac{t\alpha}{2}\sqrt{\frac{(2 \times 36.32)}{4}}$$

LSD 0.05 = 2.262 (4.26) = 9.6
LSD 0.01 = 3.25 (4.26) = 13.8

APPENDIX 2b

ANOVA FOR *ALBIZIA LEBBEK*

SV	df	SS	MS	F Observed	F TAB	
					5%	1%
Total	15	7840.62				
Reps	3	275.91	91.97	2.84		
Treatment	3	7273.44	2424.48	74.92**	3.86	6.99
Error	9	291.27	32.36			

** Significant at the 1% level

$$LSD = \frac{t\alpha}{2}\sqrt{\frac{(2 \times 32.36)}{4}}$$

LSD 0.05 = 2.262 (4.02) = 9.1
LSD 0.01 = 3.25 (4.02) = 13.1

APPENDIX 2c

ANOVA FOR *MILETTIA THONNINGII*

SV	df	SS	MS	F Observed	F TAB 5%	F TAB 1%
Total	15	1320.26				
Reps	3	76.48	25.49	0.43		
Treatment	3	605.20	201.7	3.37NS	3.86	6.99
Error	9	538.58	59.84			

N.S = Not Significant

APPENDIX 2d

ANOVA FOR *AFZELIA AFRICANA*

SV	df	SS	MS	F Observed	F TAB 5%	F TAB 1%
Total	15	3554.42				
Reps	3	279.57	93.19	0.46		
Treatment	3	1434.51	478.17	2.34NS	3.86	6.99
Error	9	1840.34	204.48			

NS = Not Significant

APPENDIX 2e

ANOVA FOR *PITHECELLOBIUM DULCE*

SV	df	SS	MS	F Observed	F TAB 5%	F TAB 1%
Total	15	1757.88				
Reps	3	436.16	145.39	1.88		
Treatment	3	625.83	208.61	2.70NS	3.86	6.99
Error	9	695.89	77.32			

NS = Not Significant

APPENDIX 2f

ANOVA FOR *KHAYA SENEGALENSIS*

SV	df	SS	MS	F Observed	F TAB	
					5%	1%
Total	15	3280.92				
Reps	3	23.32	7.77	0.11		
Treatment	3	2600.59	866.86	11.87**	3.86	6.99
Error	9	657.01	73.00			

** Significant at the 1% level

$$LSD = \frac{t\alpha}{2}\sqrt{\frac{(2 \times 73.00)}{4}}$$

LSD 0.05 = 2.262 (6.04) = 13.7
LSD 0.01 = 3.25 (6.04) = 19.6

APPENDIX 2g

ANOVA FOR *GREWIA CARPINIFOLIA*

SV	df	SS	MS	F Observed	F TAB	
					5%	1%
Total	15	6594.2				
Reps	3	395.23	131.74	0.54		
Treatment	3	4000.83	1333.61	5.46	3.86	6.99
Error	9	2198.14	244.24			

$$LSD = \frac{t_{0.05}}{2}\sqrt{\frac{(2 \times 244.24)}{4}}$$

$$= 2.262\ (2.21) = 4.99$$

APPENDIX 2h

ANOVA FOR *DIALIUM GUINEENSE*

SV	df	SS	MS	F Observed	F TAB	
					5%	1%
Total	15	4024.90				
Reps	3	41.50	13.83	1.10		
Treatment	3	3870.75	1290.25	103.06**	3.86	6.99
Error	9	112.65	12.52			

** Significant at the 1% level

$$LSD = \frac{t\alpha}{2}\sqrt{\frac{(2 \times 12.52)}{4}}$$

LSD 0.05 = 2.262 (2.50) = 5.7
LSD 0.01 = 3.25 (2.50) = 8.1

APPENDIX 2i

ANOVA FOR CONTROL TREATMENT

SV	df	SS	MS	F Observed	F TAB 5%	F TAB 1%
Total	31	13137.96				
Reps	3	220.04	73.35	0.71		
Species	7	10747.32	1535.33	14.85**	2.49	3.65
Error	21	2170.60	103.36			

** Significant at the 1% level

$$LSD = \frac{t\alpha}{2}\sqrt{(2 \times 103.36)}{\sqrt{4}}$$

LSD 0.05 = 2.08 (7.19) = 15.0
LSD 0.01 = 2.831 (7.19) = 20.35

APPENDIX 2j

ANOVA FOR WARM WATER TREATMENT

SV	df	SS	MS	F Observed	F TAB 5%	F TAB 1%
Total	31	1666.02				
Reps	3	77.86	25.95	0.54		
Species	7	15586.65	2226.66	46.59**	2.49	3.65
Error	21	1003.51	47.79			

** Significant at the 1% level

$$LSD = \frac{t\alpha}{2}\sqrt{(2 \times 47.79)}{\sqrt{4}}$$

LSD 0.05 = 2.08 (4.89) = 10.2
LSD 0.01 = 2.831 (4.89) = 13.8

APPENDIX 2k

ANOVA FOR HOT WATER TREATMENT

SV	df	SS	MS	F Observed	F TAB	
					5%	1%
Total	31	20177.47				
Reps	3	172.17	57.39	0.95		
Species	7	18737.34	2676.76	44.33**	2.49	3.65
Error	21	1267.96	60.38			

** Significant at the 1% level

$$LSD = \frac{t\alpha}{2}\sqrt{\frac{(2 \times 60.38)}{4}}$$

LSD 0.05 = 2.08 (5.50) = 11.4
LSD 0.01 = 2.831 (5.50) = 15.6

APPENDIX 2l

ANOVA FOR MECHANICAL SCARIFICATION

SV	df	SS	MS	F Observed	F TAB	
					5%	1%
Total	31	20159.37				
Reps	3	241.84	80.61	0.57		
Species	7	16957.79	2422.54	17.19**	2.49	3.65
Error	21	2959.74	140.94			

** Significant at the 1% level

$$LSD = \frac{t\alpha}{2}\sqrt{\frac{(2 \times 140.94)}{4}}$$

LSD 0.05 = 2.08 (8.39) = 17.5
LSD 0.01 = 2.831 (8.39) = 23.18

APPENDIX 3

ANOVA ON DAYS TAKEN TO GERMINATE BY EIGHT SPECIES OF BROWSE PLANTS UNDER DIFFERENT SEED TREATMENTS

SV	df	SS	MS	F Observed	F TAB	
					5%	1%
Total	127	2109.88				
Reps	3	7.19	2.40	1.01		
Treatment	(31)	(1876.38)	60.53	25.43		
Species	7	1260.25	180.04	75.65**	2.10	2.82
Seed Trt.	3	170.63	56.88	23.90**	2.70	3.98
Sp x ST	21	445.5	21.21	8.91**	1.68	2.06
Error	96	226.31	2.38			

** Significant at the 1% level

LSD interaction effects (Sp x ST

$$= \frac{t\alpha}{2}\sqrt{\frac{(2 \times 2.38)}{8}}$$

LSD 0.05 = 1.982 (0.77) = 1.53
LSD 0.01 = 2.625 (0.77) = 2.02

LSD Between seed species means

$$= \frac{t\alpha}{2}\sqrt{\frac{(2 \times 2.38)}{16}}$$

LSD 0.05 = 1.982 (0.55) = 1.09
LSD 0.01 = 2.625 (0.55) = 1.44

LSD Between Seed Treatment means

$$= \frac{t\alpha}{2}\sqrt{\frac{(2 \times 2.38)}{32}}$$

LSD 0.05 = 1.982 (0.39) = 0.77
LSD 0.01 = 2.625 (0.39) = 1.02

APPENDIX 3a

ANOVA FOR *CAJANUS CAJAN*

SV	df	SS	MS	F Observed	F TAB	
					5%	1%
Total	15	3.75				
Reps	3	1.25	0.42	1.68		
Treatment	3	0.25	0.08	0.32NS	3.86	6.99
Error	9	2.25	0.25			

NS = Not Significant

APPENDIX 3b

ANOVA FOR *ALBIZIA LEBBEK*

SV	df	SS	MS	F Observed	F TAB	
					5%	1%
Total	15	445.75				
Reps	3	10.25	3.42	0.49		
Treatment	3	373.25	124.42	17.98**	3.86	6.99
Error	9	62.25	6.92			

** Significant at the 1% level

$$LSD = \frac{t\alpha}{2}\sqrt{\frac{(2 \times 6.92)}{4}}$$

LSD 0.05 = 2.262 (1.86) = 4.21
LSD 0.01 = 3.25 (1.86) = 6.05

APPENDIX 3c

ANOVA FOR *MILETTIA THONNINGII*

SV	df	SS	MS	F Observed	F TAB 5%	F TAB 1%
Total	15	5.44				
Reps	3	1.19	0.40			
Treatment	3	2.69	0.90	5.29	3.86	6.99
Error	9	1.56	0.17			

$$LSD_{0.05} = \frac{t_{0.05}\sqrt{(2 \times 0.17)}}{2\quad\sqrt{4}}$$

$$= 2.262\ (0.29) = 0.7$$

APPENDIX 3d

ANOVA FOR *AFZELIA AFRICANA*

SV	df	SS	MS	F Observed	F TAB 5%	F TAB 1%
Total	15	138.43				
Reps	3	3.69	1.23	0.48		
Treatment	3	111.69	37.23	14.59**	3.86	6.99
Error	9	23.05	2.56			

** Significant at the 1% level

$$LSD = \frac{t\alpha\sqrt{(2 \times 2.56)}}{2\quad\sqrt{4}}$$

LSD 0.05 = 2.262 (1.13) = 2.6
LSD 0.01 = 3.25 (1.13) = 3.7

APPENDIX 3e

ANOVA FOR *PITHECELLOBIUM DULCE*

SV	df	SS	MS	F Observed	F TAB	
					5%	1%
Total	15	19.44				
Reps	3	1.19	0.40	1.00		
Treatment	3	14.69	4.90	12.25**	3.86	6.99
Error	9	3.56	0.40			

** Significant at the 1% level

$$LSD = \frac{t\alpha}{2}\sqrt{(2 \times 0.40)}{\sqrt{4}}$$

LSD 0.05 = 2.262 (0.45) = 1.0
LSD 0.01 = 3.25 (0.45) = 1.4

APPENDIX 3f

ANOVA FOR *KHAYA SENEGALENSIS*

SV	df	SS	MS	F Observed	F TAB	
					5%	1%
Total	15	85.44				
Reps	3	26.19	8.73	2.09		
Treatment	3	21.69	7.23	1.73NS	3.86	6.99
Error	9	37.56	4.17			

NS = Not Significant

APPENDIX 3g

ANOVA FOR *GREWIA CARPINIFOLIA*

SV	df	SS	MS	F Observed	F TAB	
					5%	1%
Total	15	113.94				
Reps	3	22.69	7.56	2.09		
Treatment	3	58.69	19.56	5.40	3.86	6.99
Error	9	32.56	3.62			

$$LSDo.o5 = \frac{t_{0.05}}{2}\sqrt{\frac{(2 \times 3.62)}{4}}$$

$$= 2.262(1.35) = 3.0$$

APPENDIX 3h

ANOVA FOR *DIALIUM GUINEENSE*

SV	df	SS	MS	F Observed	F TAB	
					5%	1%
Total	15	37.44				
Reps	3	0.68	0.23	0.58		
Treatment	3	33.19	11.06	27.65**	3.86	6.99
Error	9	3.57	0.40			

** Significant at the 1% level

$$LSD = \frac{t\alpha}{2}\sqrt{\frac{(2 \times 0.40)}{4}}$$

LSD 0.05 = 2.262 (0.43) = 0.97
LSD 0.01 = 3.25 (0.43) = 1.39

APPENDIX 3i

ANOVA FOR CONTROL

SV	df	SS	MS	F Observed	F TAB 5%	F TAB 1%
Total	31	518.00				
Reps	3	5.75	1.92	0.47		
Species	7	426.5	60.93	14.93**	2.49	3.65
Error	21	85.75	4.08			

** Significant at the 1% level

$$LSD = \frac{t\alpha}{2}\sqrt{\frac{(2 \times 4.08)}{4}}$$

LSD 0.05 = 2.08 (1.42) = 3.0
LSD 0.01 = 2.831 (1.42) = 4.0

APPENDIX 3i

ANOVA FOR WARM WATER TREATMENT

SV	df	SS	MS	F Observed	F TAB 5%	F TAB 1%
Total	31	786.88				
Reps	3	1.38	0.46	0.55		
Species	7	767.88	109.70	130.60**	2.49	3.65
Error	21	17.62	0.84			

** Significant at the 1% level

$$LSD = \frac{t\alpha}{2}\sqrt{\frac{(2 \times 0.84)}{4}}$$

LSD 0.05 = 2.08 (0.65) = 1.40
LSD 0.01 = 2.831 (0.65) = 1.80

APPENDIX 3k

ANOVA FOR HOT WATER TREATMENT

SV	df	SS	MS	F Observed	F TAB	
					5%	1%
Total	31	447.5				
Reps	3	8.25	2.80	1.09		
Species	7	385.5	55.07	21.50**	2.49	3.65
Error	21	53.75	2.56			

** Significant at the 1% level

$$LSD = \frac{t\alpha}{2}\sqrt{(2 \times 2.56)}/\sqrt{4}$$

LSD 0.05 = 2.08 (1.13) = 2.4
LSD 0.01 = 2.831 (1.13) = 3.2

APPENDIX 3*l*

ANOVA FOR MECHANICAL SCARIFICATION

SV	df	SS	MS	F Observed	F TAB	
					5%	1%
Total	31	186.88				
Reps	3	14.63	4.88	2.21		
Species	7	125.88	17.98	8.14**	2.49	3.65
Error	21	46.37	2.21			

** Significant at the 1% level

$$LSD = \frac{t\alpha}{2}\sqrt{(2 \times 2.21)}/\sqrt{4}$$

LSD 0.05 = 2.08 (1.05) = 2.2
LSD 0.01 = 2.831 (1.05) = 3.0

APPENDIX 4

ANOVA ON RATE OF GERMINATION OF EIGHT SPECIES OF BROWSE PLANTS UNDER DIFFERENT SEED TREATMENTS

SV	df	SS	MS	F Observed	F TAB	
					5%	1%
Total	127	10921.81				
Reps	3	0.21	0.07	1.79		
Treatment	(31)	(10917.98)	352.19	9268.16		
Species	7	3515.59	502.23	13216.58**	2.10	2.82
Seed Trt.	3	2858.57	952.86	25076.05**	2.70	3.98
Sp x ST	21	4543.82	216.37	5693.9**	1.68	2.06
Error	96	3.62	0.04			

** Significant at the 1% level

LSD interaction effects (Sp x ST

$$= \frac{t\alpha}{2}\sqrt{(2 \times 0.04)}{\sqrt{8}}$$

LSD 0.05 = 1.982 (0.097) = 0.19
LSD 0.01 = 2.625 (0.097) = 0.25

LSD Between seed species means

$$= \frac{t\alpha}{2}\sqrt{(2 \times 0.04)}{\sqrt{16}}$$

LSD 0.05 = 1.982 (0.069) = 0.14
LSD 0.01 = 2.625 (0.069) = 0.18

LSD Between Seed Treatment means

$$= \frac{t\alpha}{2}\sqrt{(2 \times 0.04)}{\sqrt{32}}$$

LSD 0.05 = 1.982 (0.049) = 0.10
LSD 0.01 = 2.262 (0.049) = 0.13

APPENDIX 4a

ANOVA FOR *CAJANUS CAJAN*

SV	df	SS	MS	F Observed	F TAB	
					5%	1%
Total	15	36.43				
Reps	3	0.02	0.007	1.0		
Treatment	3	36.35	12.12	1731.43**	3.86	6.99
Error	9	0.06	0.007			

** Significant at the 1% level

$$LSD = \frac{t\alpha}{2}\sqrt{\frac{(2 \times 0.007)}{4}}$$

LSD 0.05 = 2.262 (0.059) = 0.13
LSD 0.01 = 3.25 (0.059) = 0.19

APPENDIX 4b

ANOVA FOR *ALBIZIA LEBBEK*

SV	df	SS	MS	F Observed	F TAB	
					5%	1%
Total	15	4309.10				
Reps	3	0.14	0.05	0.71		
Treatment	3	4308.33	1436.11	20515.86**	3.86	6.99
Error	9	0.63	0.07			

** Significant at the 1% level

$$LSD = \frac{t\alpha}{2}\sqrt{\frac{(2 \times 0.07)}{4}}$$

LSD 0.05 = 2.262 (0.19) = 0.43
LSD 0.01 = 3.25 (0.19) = 0.62

APPENDIX 4c

ANOVA FOR *MILETTIA THONNINGII*

SV	df	SS	MS	F Observed	F TAB	
					5%	1%
Total	15	1938.4				
Reps	3	0.31	0.10			
Treatment	3	1937.63	645.88	12917.6**	3.86	6.99
Error	9	0.46	0.05			

** Significant at the 1% level

$$LSD = \frac{t\alpha}{2}\sqrt{\frac{(2 \times 0.05)}{4}}$$

LSD 0.05 = 2.262 (0.16) = 0.36
LSD 0.01 = 3.25 (0.16) = 0.52

APPENDIX 4d

ANOVA FOR *AFZELIA AFRICANA*

SV	df	SS	MS	F Observed	F TAB	
					5%	1%
Total	15	5.87				
Reps	3	0.08	0.03	3.00		
Treatment	3	5.70	1.90	190.00**	3.86	6.99
Error	9	0.09	0.01			

** Significant at the 1% level

$$LSD = \frac{t\alpha}{2}\sqrt{\frac{(2 \times 0.01)}{4}}$$

LSD 0.05 = 2.262 (0.07) = 0.16
LSD 0.01 = 3.25 (0.07) = 0.23

APPENDIX 4e

ANOVA FOR *PITHECELLOBIUM DULCE*

SV	df	SS	MS	F Observed	F TAB	
					5%	1%
Total	15	168.04				
Reps	3	0.21	0.07	1.31		
Treatment	3	167.35	55.78	1045.88**	3.86	6.99
Error	9	0.48	0.05			

** Significant at the 1% level

$$LSD = \frac{t\alpha}{2}\sqrt{\frac{(2 \times 0.05)}{4}}$$

LSD 0.05 = 2.262.(0.16) = 0.36
LSD 0.01 = 3.25 (0.16) = 052

APPENDIX 4f

ANOVA FOR *GREWIA CARPINIFOLIA*

SV	df	SS	MS	F Observed	F TAB	
					5%	1%
Total	15	44.81				
Reps	3	0.04	0.13	1.9		
Treatment	3	44.71	14.9	2128.57**	3.86	6.99
Error	9	0.06	0.007			

** Significant at the 1% level

$$LSD = \frac{t\alpha}{2}\sqrt{\frac{(2 \times 0.007)}{4}}$$

LSD 0.05 = 2.262 (0.059) = 0.13
LSD 0.01 = 3.25 (0.059) = 0.19

APPENDIX 4g

ANOVA FOR *KHAYA SENEGALENSIS*

SV	df	SS	MS	F Observed	F TAB	
					5%	1%
Total	15	29.69				
Reps	3	0.10	0.03	0.38		
Treatment	3	28.87	9.62	120.25**	3.86	6.99
Error	9	0.72	0.08			

** Significant at the 1% level

$$LSD = \frac{t\alpha}{2}\sqrt{\frac{(2 \times 0.08)}{4}}$$

LSD 0.05 = 2.262 (0.2) = 0.45
LSD 0.01 = 3.25 (0.2) = 0.65

APPENDIX 4h

ANOVA FOR *DIALIUM GUINEENSE*

SV	df	SS	MS	F Observed	F TAB	
					5%	1%
Total	15	873.87				
Reps	3	0.06	0.02	0.51		
Treatment	3	873.46	291.15	7465.38**	3.86	6.99
Error	9	0.35	0.039			

** Significant at the 1% level

$$LSD = \frac{t\alpha}{2}\sqrt{\frac{(2 \times 0.039)}{4}}$$

LSD 0.05 = 2.262 (0.14) = 0.32
LSD 0.01 = 3.25 (0.14) = 0.45

APPENDIX 4i

ANOVA FOR CONTROL

SV	df	SS	MS	F Observed	F TAB	
					5%	1%
Total	31	129.22				
Reps	3	0.006	0.002	0.005		
Species	7	121.05	17.29	44.33**	2.49	3.65
Error	21	8.16	0.39			

** Significant at the 1% level

$$LSD = \frac{t\alpha}{2}\sqrt{\frac{(2 \times 0.39)}{4}}$$

LSD 0.05 = 2.08 (0.44) = 0.92
LSD 0.01 = 2.831 (0.44) = 1.25

APPENDIX 4i

ANOVA FOR WARM WATER TREATMENT

SV	df	SS	MS	F Observed	F TAB	
					5%	1%
Total	31	570.36				
Reps	3	0.04	0.01	1.25		
Species	7	570.15	81.45	10181.25**	2.49	3.65
Error	21	0.17	0.008			

** Significant at the 1% level

$$LSD = \frac{t\alpha}{2}\sqrt{\frac{(2 \times 0.008)}{4}}$$

LSD 0.05 = 2.08 (0.063) = 0.13
LSD 0.01 = 2.831 (0.063) = 0.18

APPENDIX 4k

ANOVA FOR HOT WATER TREATMENT

SV	df	SS	MS	F Observed	F TAB 5%	F TAB 1%
Total	31	1482.88				
Reps	3	0.11	0.035	2.5		
Species	7	1482.47	211.78	15127.14**	2.49	3.65
Error	21	0.30	0.014			

** Significant at the 1% level

$$LSD = \frac{t\alpha}{2}\sqrt{(2 \times 0.014)}{\sqrt{4}}$$

LSD 0.05 = 2.08 (0.084) = 0.17
LSD 0.01 = 2.831 (0.084) = 0.24

APPENDIX 4l

ANOVA FOR MECHANICAL SCARIFICATION

SV	df	SS	MS	F Observed	F TAB 5%	F TAB 1%
Total	31	5888.79				
Reps	3	0.55	0.18	1.5		
Species	7	5885.75	840.82	7006.83**	2.49	3.65
Error	21	2.49	0.12			

** Significant at the 1% level

$$LSD = \frac{t\alpha}{2}\sqrt{(2 \times 0.12)}{\sqrt{4}}$$

LSD 0.05 = 2.08 (0.25) = 0.52
LSD 0.01 = 2.831 (0.25) = 0.71

APPENDIX 5

ANOVA FOR LEAF AREA DETERMINATION

SV	df	SS	MS	F Observed	F TAB 5%	F TAB 1%
Week	3	1977151924	6590506413			
Species	4	8208729731	205218243	2.89NS	3.26	5.4
Error	12	8516169310	7096807758			
Total	19	16697123450				

N.S = Not Significant

APPENDIX 5a

ANOVA FOR DRY MATTER ACCUMULATION

SV	df	SS	MS	F Observed	F TAB 5%	F TAB 1%
Week	3	10707.5	3569.17			
Species	4	27137.66	6784.41	2.28NS	3.26	5.4
Error	12	35742.41	2978.53			
Total	19	73587.57				

N.S = Not Significant

APPENDIX 6

ANOVA FOR SEEDLING EMERGENCE

SV	df	SS	MS	F Observed	F TAB 5%
Block	3	337.93	112.64		
Species	4	3514.78	878.69	11.40*	3.26
Error (a)	12	925.37	77.11		
Date	2	32.51	16.24	0.27	3.32
Date x Species	8	184.92	23.11	0.39	2.27
Error (b)	30	1798.57	59.95		
Total	59	6794.07			

* Significant at 5% level; CV = 5.88
CV = Coefficient of variation

STUDENT-NEWMAN-KEULS' TEST

$$SY = \frac{\sqrt{(77.11)}}{\sqrt{12}} = 2.53$$

Range	2	3	4	5	
q (5% level)	3.08	3.77	4.20	4.51	
Wp (5% level)	7.81	9.56	10.65	11.43	
Means (In Array)					
Species	BS_1	BS_3	BS_5	BS_2	BS_4
	98.45	88.03	87.53	87.53	82.82
	a	b	b	b	b

Means with the same letter are not significantly different (P>0.05)

APPENDIX 7

ANOVA FOR SEEDLING SURVIVAL

SV	df	SS	MS	F Observed	F TAB 5%
Block	3	1231.47	410.49		
Species	4	4115.21	1028.80	8.47*	3.26
Error (a)	12	1457.20	121.43		
Date	2	455.30	227.65	1.39	3.32
Date x Species	8	888.49	111.06	0.68	2.27
Error (b)	30	4919.22	163.97		
Total	59	13066.89			

* Significant at 5% level; CV = 7.23%
CV = Coefficient of variation

STUDENT-NEWMAN-KEULS' TEST

$$SY = \frac{\sqrt{(121.43)}}{\sqrt{12}} = 3.18$$

Range	2	3	4	5	
q (5% level)	3.08	3.77	4.20	4.51	
Wp (5% level)	9.80	12.00	13.36	14.34	
Means (In Array)					
Species	BS_1	BS_5	BS_2	BS_3	BS_4
	90.00	77.33	76.65	72.28	64.55
	a	b	b	b	b

Means with the same letter are not significantly different (P>0.05)

APPENDIX 8

ANOVA FOR PLANT HEIGHT

SV	df	SS	MS	F Observed	F TAB 5%
Block	3	1987.78	6632.59		
Species	4	274064.74	68516.19	12.33*	3.26
Error (a)	12	66707.22	5558.94		
Date	2	2125.08	1062.54	1.08	3.32
Date x Species	8	5001.64	625.21	0.64	2.27
Error (b)	30	29440.56	981.35		
Total	59	397237.03			

* Significant at 5% level; CV = 30.68%
CV = Coefficient of variation

STUDENT-NEWMAN-KEULS' TEST

$$SY = \frac{\sqrt{(5558.94)}}{\sqrt{12}} = 21.52$$

Range	2	3	4	5	
q (5% level)	3.08	3.77	4.20	4.51	
Wp (5% level)	66.31	81.21	90.37	97.02	
Means (In Array)					
Species	BS_1	BS_2	BS_3	BS_4	BS_5
	225.68	155.49	124.33	71.98	30.32
	a	b	b	c	d

Means with the same letter are not significantly different (P>0.05)

APPENDIX 9

ANOVA FOR DRY-MATTER YIELD

SV	df	SS	MS	F Observed	F TAB 5%
Block	3	13.03	4.34		
Species	4	423.60	105.90	7.34*	3.26
Error (a)	12	173.03	14.42		
Date	2	54.98	27.49	7.97*	3.32
Date x Species	8	37.66	4.71	1.36	2.27
Error (b)	30	103.58	3.45		
Total	59	805.88			

* Significant at 5% level; CV = 65.69
CV = Coefficient of variation

STUDENT-NEWMAN-KEULS' TEST

$SY = \frac{\sqrt{(14.42)}}{\sqrt{12}} = 1.09$

Range	2	3	4	5	
q (5% level)	3.08	3.77	4.20	4.51	
Wp (5% level)	3.78	4.14	4.60	4.94	
Means (In Array)					
Species	BS_1	BS_2	BS_3	BS_4	BS_5
	7.49	3.98	2.13	0.79	0.08
	a	b	b	b	c

Date of Harvest CV = 64.22

$SY = \frac{\sqrt{(3.45)}}{\sqrt{20}} = 0.41$

Range	2	3
q (5% level)	28.89	3.49
Wp (5% level)	1.20	1.45

Means (In Array)

Date	D_3	D_2	D_1
	4.10	2.82	1.76
	a	b	b

Means with the same letter are not significantly different (P>0.05)

APPENDIX 10

ANOVA FOR DRY-MATTER CONTENT

SV	df	SS	MS	F Observed	F TAB 5%
Block	3	61361.2	20453.7		
Species	4	813429.56	203357.4	47.59*	3.26
Error (a)	12	51278.31	4273.2		
Date	2	56962.8	28481.4	14.33*	3.32
Date x Species	8	134572.04	16821.5		
Error (b)	30	119280.49	3976.0		
Total	59	1236884.4			

* Significant at 5% level; CV = 6.73
CV = Coefficient of variation

STUDENT-NEWMAN-KEULS' TEST

$SY = \frac{\sqrt{(4273.2)}}{\sqrt{12}} = 18.87$

Range	2	3	4	5	
q (5% level)	3.08	3.77	4.20	4.51	
Wp (5% level)	58.12	71.14	79.25	85.11	
Means (In Array)					
Species	BS_5	BS_3	BS_4	BS_1	BS_2
	702.8	506.6	428.3	407.3	381.9
	a	a	b	b	b

Date of Harvest CV = 6.50

$$SY = \frac{\sqrt{(3976)}}{\sqrt{20}} = 14.1$$

Range	2	3
q (5% level)	28.89	3.49
Wp (5% level)	5743.33	49.21

Means (In Array)

Date	D_3	D_2	D_1
	517.2	495.3	443.7
	a	a	b

Means with the same letter are not significantly different (P>0.05)

APPENDIX 11

ANOVA FOR CRUDE PROTEIN

SV	df	SS	MS	F Observed	F TAB 5%
Block	3	12.75	4.25		
Species	4	638.86	159.72	33.98*	3.26
Error (a)	12	56.39	4.70		
Date	2	54.29	27.15	6.36*	3.32
Date x Species	8	27.77	3.47	0.81	2.27
Error (b)	30	128.13	4.27		
Total	59	918.19			

* Significant at 5% level; CV = 5.37
CV = Coefficient of variation

STUDENT-NEWMAN-KEULS' TEST

$SY = \frac{\sqrt{(4.7)}}{\sqrt{12}} = 0.63$

Range	2	3	4	5	
q (5% level)	3.08	3.77	4.20	4.51	
Wp (5% level)	1.93	2.36	2.63	2.82	
Means (In Array)					
Species	BS_2	BS_4	BS_1	BS_3	BS_5
	25.00	20.81	20.50	19.84	14.76
	a	b	b	b	c

Date of Harvest CV = 10.24

$SY = \frac{\sqrt{(4.27)}}{\sqrt{20}} = 0.46$

Range	2	3
q (5% level)	28.89	3.49
Wp (5% level)	1.33	1.61
Means (In Array)		
Date	D_1	D_2 D_3
	21.52	19.67 19.36
	a	b b

Means with the same letter are not significantly different (P>0.05)

APPENDIX 12

ANOVA FOR NEUTRAL DETERGENT FIBRE (NDF)

SV	df	SS	MS	F Observed	F TAB 5%
Block	3	25.35	8.45		
Species	3	3378.81	1126.27	54.10*	3.86
Error (a)	9	187.39	20.82		
Date	2	37.14	18.57	3.17	3.40
Date x Species	6	110.68	18.45	3.15	2.51
Error (b)	24	140.66	5.86		
Total	47	3880.02			

* Significant at 5% level; CV = 4.3%
CV = Coefficient of variation

STUDENT-NEWMAN-KEULS' TEST

$$SY = \frac{\sqrt{(20.82)}}{\sqrt{12}} = 1.32$$

Range	2	3	4	
q (5% level)	3.20	3.95	4.42	
Wp (5% level)	4.22	5.21	5.83	
Means (In Array)				
Species	BS_4	BS_1	BS_3	BS_2
	60.45	60.45	49.06	40.52
	a	a	b	c

Means with the same letter are not significantly different (P>0.05)

APPENDIX 13

ANOVA FOR ACID DETERGENT FIBER

SV	df	SS	MS	F Observed	F TAB 5%
Block	3	23.43	7.81		
Species	3	2034.80	678.27	51.42*	3.86
Error (a)	9	118.77	13.19		
Date	2	8.22	4.11	2.06	3.32
Date x Species	6	27.68	4.61	2.31	2.51
Error (b)	24	47.84	1.99		
Total	47	2260.74			

* Significant at 5% level; CV = 5.49%
CV = Coefficient of variation

STUDENT-NEWMAN-KEULS' TEST

$$SY = \frac{\sqrt{(13.19)}}{\sqrt{12}} = 1.05$$

Range	2	3	4
q (5% level)	3.20	3.95	4.42
Wp (5% level)	3.36	4.14	4.63

Means (In Array)

Species	BS_4	BS_1	BS_3	BS_2
	40.61	38.31	27.51	25.70
	a	a	b	b

Means with the same letter are not significantly different (P>0.05)

APPENDIX 14

ANOVA FOR CELLULOSE CONTENT

SV	df	SS	MS	F Observed	F TAB 5%
Block	3	14.39	4.80		
Species	3	659.21	219.74	35.61*	3.86
Error (a)	9	55.52	6.17		
Date	2	3.21	1.60	2.19	3.40
Date x Species	6	2.50	0.42	0.57	2.51
Error (b)	24	17.62	0.73		
Total	47	752.45			

* Significant at 5% level; CV = 6.58%
CV = Coefficient of variation

STUDENT-NEWMAN-KEULS' TEST

$$SY = \frac{\sqrt{(6.17)}}{\sqrt{12}} = 0.71$$

Range	2	3	4
q (5% level)	3.20	3.95	4.42
Wp (5% level)	2.29	2.83	3.16

Means (In Array)

Species	BS_4	BS_2	BS_1	BS_3
	25.00	18.47	16.57	15.42
	a	b	bc	c

Means with the same letter are not significantly different (P>0.05)

APPENDIX 15

ANOVA FOR HEMICELLULOSE CONTENT

SV	df	SS	MS	F Observed	F TAB 5%
Block	3	0.98	0.33		
Species	3	397.82	132.61	24.24*	3.86
Error (a)	9	49.24	5.47		
Date	2	23.10	11.55	1.94	3.40
Date x Species	6	61.34	10.22	1.72	2.51
Error (b)	24	142.62	5.94		
Total	47	675.09			

* Significant at 5% level; CV = 5.97%
CV = Coefficient of variation

STUDENT-NEWMAN-KEULS' TEST

$$SY = \frac{\sqrt{(5.47)}}{\sqrt{12}} = 0.67$$

Range	2	3	4
q (5% level)	3.20	3.95	4.42
Wp (5% level)	2.16	2.67	2.98

Means (In Array)

Species	BS_1	BS_3	BS_4	BS_2
	22.13	21.56	19.84	14.82
	a	a	a	b

Means with the same letter are not significantly different (P>0.05)

APPENDIX 16

ANOVA FOR LIGNIN CONTENT

SV	df	SS	MS	F Observed	F TAB 5%
Block	3	1.89	0.63		
Species	3	1120.89	373.63	128.3*	3.86
Error (a)	9	26.17	2.91		
Date	2	9.14	4.57	3.47	3.40
Date x Species	6	19.63	3.27	2.48	2.51
Error (b)	24	31.63	1.32		
Total	47	1209.35			

* Significant at 5% level; CV = 6.85%
CV = Coefficient of variation

STUDENT-NEWMAN-KEULS' TEST

$$SY = \frac{\sqrt{(2.91)}}{\sqrt{12}} = 0.49$$

Range	2	3	4	
q (5% level)	3.20	3.95	4.42	
Wp (5% level)	1.57	1.94	2.17	
Means (In Array)				
Species	BS_1	BS_4	BS_3	BS_2
	19.56	13.49	10.41	6.32
	a	b	c	d

Means with the same letter are not significantly different (P>0.05)

APPENDIX 17

ANOVA FOR CALCIUM CONTENT

SV	df	SS	MS	F Observed	F TAB 5%
Block	3	0.988	0.329		
Species	4	84.545	21.136	40.88*	3.26
Error (a)	12	6.211	0.517		
Date	2	1.906	0.953	2.39	3.32
Date x Species	8	2.754	0.344	0.86	2.27
Error (b)	30	11.984	0.399		
Total	59	108.391			

* Significant at 5% level; CV = 10.48
CV = Coefficient of variation

STUDENT-NEWMAN-KEULS' TEST

$$SY = \frac{\sqrt{(0.517)}}{\sqrt{12}} = 0.208$$

Range	2	3	4	5	
q (5% level)	3.08	3.77	4.20	4.51	
Wp (5% level)	0.639	0.783	0.872	0.936	
Means (In Array)					
Species	BS_2	BS_4	BS_3	BS_5	BS_1
	5.560	3.628	3.280	2.455	2.207
	a	b	b	c	c

Means with the same letter are not significantly different (P>0.05)

APPENDIX 18

ANOVA FOR PHOSPHORUS CONTENT

SV	df	SS	MS	F Observed	F TAB	
					5%	1%
Block	3	0.021	0.007			
Species	4	0.040	0.010	2.0NS	3.26	5.41
Error (a)	12	0.065	0.005			
Date	2	0.024	0.012	2.0NS	3.32	5.39
Date x Species	8	0.044	0.005	0.83NS	2.27	3.17
Error (b)	30	0.184	0.006			
Total	59	0.378				

NS: Means not significantly different at both 5% and 1% levels

CV for species = 19.64%
CV for Date = 43.08%
CV = Coefficient of variation

APPENDIX 19

ANOVA FOR MAGNESIUM CONTENT

SV	df	SS	MS	F Observed	F TAB 5%
Block	3	0.093	0.031		
Species	4	0.920	0.230	16.04*	3.26
Error (a)	12	0.172	0.014		
Date	2	0.007	0.004	0.86	3.32
Date x Species	8	0.046	0.006	3.44	2.27
Error (b)	30	0.125	0.004		
Total	59	1.364			

* Significant at 5% level; CV = 12.33
CV = Coefficient of variation

STUDENT-NEWMAN-KEULS' TEST

$$SY = \frac{\sqrt{(0.014)}}{\sqrt{12}} = 0.034$$

Range	2	3	4	5
q (5% level)	3.08	3.77	4.20	4.51
Wp (5% level)	0.107	0.130	0.145	0.156

Means (In Array)

Species	BS_2	BS_3	BS_1	BS_4	BS_5
	0.6392	0.5908	0.4975	0.3942	0.3025
	a	ab	bc	c	d

Means with the same letter are not significantly different (P>0.05)

APPENDIX 20

ANOVA FOR POTASSIUM CONTENT

SV	df	SS	MS	F Observed	F TAB 5%
Block	3	0.02	0.01		
Species	4	17.16	4.29	47.66*	3.26
Error (a)	12	1.08	0.09		
Date	2	0.04	0.02	0.30	3.32
Date x Species	8	0.051	0.06	0.85	2.27
Error (b)	30	2.03	0.07		
Total	59	20.84			

* Significant at 5% level; CV = 3.5
CV = Coefficient of variation

STUDENT-NEWMAN-KEULS' TEST

$SY = \frac{\sqrt{(0.09)}}{\sqrt{12}} = 0.09$

Range	2	3	4	5
q (5% level)	3.08	3.77	4.20	4.51
Wp (5% level)	0.27	0.33	0.36	0.39

Means (In Array)

Species	BS_4	BS_2	BS_1	BS_3	BS_5
	2.79	1.78	1.62	1.55	1.21
	a	b	b	b	c

Means with the same letter are not significantly different (P>0.05)

APPENDIX 21

ANOVA FOR SODIUM CONTENT

SV	df	SS	MS	F Observed	F TAB 5%
Block	3	0.165	0.055		
Species	4	0.003	0.251	5.83*	3.26
Error (a)	11	0.475	0.043		
Date	2	0.087	0.043	1.10	3.40
Date x Species	8	0.368	0.046	1.18	2.36
Error (b)	24	0.946	0.039		
Total	52	2.986			

* Significant at 5% level; CV = 57.60
CV = Coefficient of variation

STUDENT-NEWMAN-KEULS' TEST

$$SY = \frac{\sqrt{(0.043)}}{\sqrt{12}} = 0.059$$

Range	2	3	4	5
q (5% level)	3.08	3.77	4.20	4.51
Wp (5% level)	0.211	0.259	0.289	0.311

Means (In Array)

Species	BS_5	BS_3	BS_1	BS_2	BS_4
	0.4258	0.1208	0.1117	0.0933	0.080
	a	b	b	b	b

Means with the same letter are not significantly different (P>0.05)

APPENDIX 22

ANOVA FOR ZINC CONTENT

SV	df	SS	MS	F Observed	F TAB 5%
Block	3	1027.85	342.61		
Species	4	14887.62	3721.90	8.96*	3.26
Error (a)	12	4983.15	415.26		
Date	2	221.16	110.58	0.45	3.32
Date x Species	8	4124.39	515.55	2.14	2.27
Error (b)	30	7241.69	241.39		
Total	59	32485.88			

* Significant at 5% level; CV = 28.72%
CV = Coefficient of variation

STUDENT-NEWMAN-KEULS' TEST

$$SY = \frac{\sqrt{(415.26)}}{\sqrt{12}} = 5.882$$

Range	2	3	4	5
q (5% level)	3.08	3.77	4.20	4.51
Wp (5% level)	18.125	22.195	24.698	26.517

Means (In Array)

Species	BS_4	BS_1	BS_3	BS_5	BS_2
	64.41	38.21	31.31	22.16	21.28
	a	b	b	b	b

Means with the same letter are not significantly different (P>0.05)

APPENDIX 23

ANOVA FOR COPPER CONTENT

SV	df	SS	MS	F Observed	F TAB 5%
Block	3	392.36	130.77		
Species	3	763.22	254.41	2.15NS	3.86
Error (a)	9	1065.66	118.41		
Date	2	314.07	157 03	1.40NS	3.23
Date x Species	6	725.38	120.90	1.08NS	2.51
Error (b)	24	2697.25	112.39		
Total	47	5957.92			

NS: Means not significant at 5% level

CV for species = 17.21
CV for Date = 136.54
CV = Coefficient of variation

APPENDIX 24

ANOVA FOR MANGANESE CONTENT

SV	df	SS	MS	F Observed	F TAB 5%
Block	3	1129.56	376.52		
Species	4	32407.56	8101.89	6.19*	3.26
Error (a)	12	15714.13	1309.51		
Date	2	894.44	447.22	2.85	3.32
Date x Species	8	1298.57	162.32	1.04	2.27
Error (b)	30	4699.85	156.66		
Total	59	56144.11			

* Significant at 5% level; CV = 32.10%
CV = Coefficient of variation

STUDENT-NEWMAN-KEULS' TEST

$$SY = \frac{\sqrt{(1309.51)}}{\sqrt{12}} = 10.45$$

Range	2	3	4	5	
q (5% level)	3.08	3.77	4.20	4.51	
Wp (5% level)	32.19	39.41	43.86	47.09	
Means (In Array)					
Species	BS_2	BS_3	BS_4	BS_1	BS_5
	76.40	76.02	59.09	57.59	12.73
	a	a	a	a	b

Means with the same letter are not significantly different (P>0.05)

APPENDIX 25

ANOVA FOR *IN VITRO* DRY MATTER DIGESTIBILITY

SV	df	SS	MS	F Observed	F TAB 5%
Block	3	4.51	1.50		
Species	4	2803.94	700.98	37.63*	3.26
Error (a)	12	223.54	18.63		
Date	2	13.51	6.75	1.30	3.32
Date x Species	8	76.04	9.51	1.83	2.27
Error (b)	30	155.81	5.19		
Total	59	3277.35			

* Significant at 5% level; CV = 3.83%
CV = Coefficient of variation

STUDENT-NEWMAN-KEULS' TEST

$$SY = \frac{\sqrt{(18.63)}}{\sqrt{12}} = 1.25$$

Range	2	3	4	5
q (5% level)	3.08	3.77	4.20	4.51
Wp (5% level)	3.84	4.70	5.23	5.62

Means (In Array)

Species	BS_5	BS_2	BS_3	BS_4	BS_1
	62.90	61.37	59.44	53.39	44.21
	a	a	a	b	c

Means with the same letter are not significantly different (P>0.05)