THESIS TITLE

STUDIES ON WILD SORGHUM (*SORGHUM ARUNDINACEUM*) AS SILAGE MATERIAL

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By

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requirements for the degree of
MASTER OF PHILOSOPHY.

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DECLARATION

I hereby declare that, except for references to other people's work which have been duly cited, this work is the result of my own original research and that this thesis either in whole or in part has not been presented for another degree elsewhere.

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ABSTRACT

Three experiments were carried out at the Department of Animal Science, University of Ghana, Legon on the Accra plains between January and November, 1990 to examine

a) the factors influencing germination of "wild sorghum" (Sorghum arundinaceum) seeds

b) changes in the dry matter yield and nutrient composition of "wild sorghum" with growth

c) the effect of treatment and duration of preservation on the quality of "wild sorghum" silage.

Seeds of "wild sorghum" were used in establishing the field in Experiment 1. Seeds were collected at 3, 4, 5, 6, 7 and 8 weeks after inflorescence appearance and used for the germination test. For each of the seed sample collected, four scarification treatments, namely, mechanical, acid, hot water and dry heat were used. High germination rates were obtained for seeds collected between four and five weeks after inflorescence appearance and mechanical scarification was the only treatment which improved germination in this experiment. The germination obtained were 67.5% and 57.0% with seed harvested at four and five weeks after inflorescence appearance compared with the control which gave values of 47.5% and 27.5% respectively.

In Experiment 2, the plants were harvested beginning at six weeks post-planting and continued at two weeks intervals until the fourteenth week.

DMY of the whole plant significantly increased ($p<0.01$) with increasing maturity reaching 10.18 tha^{-1} in the fourteenth week. The proportions of dead leaves, stems and inflorescence stalk increased while the percentages of green leaves and leaf sheaths decreased with advancing growth ($p<0.01$). Crude protein content in the whole forage and those of the various morphological fractions decreased ($p<0.05$) with maturity. Cell wall constituents of the whole forage and those of the various fractions increased ($p<0.01$) with advancing growth period. IVDMD of the whole forage and the morphological fractions also decreased ($P<0.05$) with advancing growth. HCN content of the whole forage decreased ($P<0.05$) with advancing growth from an initial value of 530 mg kg^{-1} (Dm) to 222mg kg^{-1} (Dm) at the final harvest.

In Experiment 3, stem cuttings of "wild sorghum" collected from University of Ghana farms, Legon, were used in establishing the field. The regrowths ie. both secondary and tertiary growth were used for the ensilage. Herbage in both cases were harvested after ten weeks of regrowth. The harvested herbage were chopped to 2-3cm lengths for ensiling. Polyethylene bags were used as silos, each of the silos was then filled with one kilogram of the Sorghum for one of four treatments of the chopped herbage ie. (i) sorghum with nothing added (ii) sorghum with 0.5% formic acid (iii) sorghum with nothing added but wilted in the sun for six hours (iv) sorghum combined with _Leucaena leucocephala_ (leucaena) in the ratio of 7:3 and were duplicated. The materials were ensiled over a period of 28, 56, 84 and 112 days.

DMY of secondary and tertiary growths were 9.71 and 10.07 t ha^{-1}. Ensilage was generally good for all treatments. There was not much change in the silage quality within the four month ensiling period. Crude protein content did not change but ammonia nitrogen content increased with ensiling period. Both pH and the total volatile fatty acids (TVFA) increased with increasing ensiling period. Of the cell wall constituents only NDF significantly ($P<0.05$) decreased with ensiling period whereas the rest did not show any significant difference . IVDMD decrease with ensiling period. The use of formic acid as an additive improved the silage quality. Wilting increased the dry matter content. The inclusion of the legume leucaena to the "wild sorghum" at 30% increased the crude protein content from 6.12% to 24.01% and IVDMD from 47.17% to 59.55%. The legume inclusion also decreased the NDF content from 77.76% to 66.89%, ADF from 47.40% to 33.47%, cellulose from 36.27% to 25.81%, ADL content from 6.97% to 6.21% and HCN content from 354.8 to 252.0 mg (DM) Kg^{-1}. However there was not much difference in silage quality between "wild sorghum" combined with leucaena and

other treatments.

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CHAPTER ONE

INTRODUCTION

Ruminant livestock production is an important component of agriculture in the tropics generally and in Ghana particularly . The livestock industry provides a good Source of animal protein for man. However, the level of livestock production in Ghana is not adequate to support the animal protein requirement of the population. According to a Central International de agriculture Tropical (CIAT) (1981) report, the low productivity of ruminant livestock in developing countries is due mainly to severe malnutrition of the grazing animal. A major factor in increasing ruminant livestock productivity will be the improvement of the plane of animal nutrition.

Whereas ruminant livestock in Ghana are able to make positive growth during the rainy season, they tend to loose weight in the dry season when most of the forage plants are mature, dry, unpalatable and of low quality. The weight loss over the dry season on the Accra plains for example, has been estimated to be as high as 11% of the body weight (Rose Innes,1977). Consequently, many attempts have been made to overcome the dry season feeding problem either by the use of crop residues and agro-industrial by-products (Cameron and Gordon, 1969; Addae, 1988; Fleischer, 1989) or by the use of silage (Tuah, 1971; Larsen 1974, a, b; Larsen and Abbey, 1976).

The production of silage involves cutting, chopping, consolidating and anaerobic storage of a crop of high moisture content. The ensiled material can be fed to ruminant livestock in periods (dry season) when forage supplies are inadequate. The major aim, is therefore to preserve the forage by fermentation with minimal loss of nutrients. Well preserved silage has supported higher levels of animal production (Ekern et. al., 1975).

The suitability of silage making to large-scale production and its independence of the weather have led to a substantial increase in its popularity. However, the use of silage in ruminant feeding in Ghana is still unknown to the average farmer and limited to experimental farms and government stations. Even where practised, there is the difficulty of deciding whether to plant maize and/or sorghum which can conveniently be ensiled, because both crops are also consumed by man. On the contrary, the "wild sorghum" (Sorghum arundinaceum) which has a potential of being used as silage material has been growing wild and has not been studied. The crop is not consumed by man and the stems are not thick enough to be used for fuel as the sorghums in current use are (Ministry of Agriculture (MOA), 1991). The objective of this research therefore is to study the following:

(a) the factors that influence germination of the "wild sorghum" seeds ie. treatment of the "wild sorghum" seeds to remove dormancy.

(b) the changes in the dry matter yield and nutrient composition of the "wild sorghum" plant as growth advances.

(c) the effect of treatment and duration of ensiling on the quality of "wild sorghum" silage.

CHAPTER TWO

LITERATURE REVIEW

2.1 ESTABLISHMENT OF "WILD SORGHUM"

2.1.1 GERMINATION AND FACTORS AFFECTING SEED GERMINATION

Both seeds and vegetative plant parts are used in crop establishment. Where seeds are used, establishment depends greatly on seed germination and seedling emergence.

The more widespread use of improved varieties of forages depends upon the continuous availability of seed or planting material which is true to type, free from weeds, inexpensive to obtain, and which will reliably establish good pastures when planted (Food and Agriculture Organisation (F.A.O), 1979). Many tropical forage plants are wild plants which have not been domesticated and vigorously selected for good seed production characteristics (F.A.O,1979). Too often, plant breeders and agronomists have concentrated on increasing the forage yield and nutritive value but have given little attention of seed production which will determine how widely the new tropical variety is used by farmers (F.A.O,1990).

The germination phase is the period from imbibition of the seed and the emergence of the plumule and radicle up to the time when the seed reserves are exhausted and the seedling becomes autotrophic (Whiteman, 1980). The process of germination leads eventually to the development of the embryo into a seedling. The normal development and growth of the seedling involves both cell division and cell elongation (Mayer and Poljakoff-Mayber, 1982). Various internal and external factors are known to affect seed germination.

These include

1. Viability and life span of seeds
2. Moisture
3. Temperature
4. Light
5. Gases (oxygen)
6. Seed dormancy

2.1.1.1 VIABILITY AND LIFE SPAN OF SEEDS

Viability is the length of time a seed can retain its ability to germinate (Ellis *et*. *al*., 1985). The length of time for which seeds can remain viable is extremely variable and is partially genetic (Mayer and Poljakoff-Mayber, 1982) and partially determined by environmental factors (Ellis *et*. *al*., 1985)

A study by International crops research institute for the semi-arid tropics (ICRISAT) (1980) showed that the age of seed and storage conditions may have a large influence on seed vigour.

Generally, seeds remain viable for longer periods if they are dry because under this condition their metabolic activity is greatly reduced (Villiers, 1972) Although dry conditions seem essential for retention of viability, there are some seeds which remain viable when submerged in water (Villiers, 1972). Some seeds, such as those of lettuce, which store well under very dry condition, retain their viability even when they have imbibed water fully (Villiers, 1972). Various storage conditions are required to maintain viability for different seeds. Viability is retained for very long periods of time in seeds having a hard seed coat as in the leguminosae (Mayer and Poljakoff-Mayber, 1982).

2.1.1.2 MOISTURE

Provided temperature is suitable, the most important factor that influences germination is the presence of water. The weather conditions prior to and after sowing influence soil moisture conditions needed for seed germination. When the embryonic plant within the seed resumes growth, it requires the conversion of the insoluble food reserves by hydrolytic enzymes into soluble products before they can be transported to the growing regions of the young seedling, where active respiration and synthesis of new protoplasm and cell walls occurs (Loveless, 1986).

Germination begins with the uptake of water by the seed and is referred to as the process of imbibition (Mayer and Poljakoff-Mayber, 1982; Loveless, 1986). During imbibition, the desiccated colloidal contents of the seed are rehydrated, leading to swelling of the seed, and this process occurs regardless of wether or not the seed is alive (Ellis et. al.; 1985). As more water enters the seed by imbibition, the imbibitional forces for the intake of water decrease, but the hydrated cells develop osmotic forces which facilitate further intake (Loveless, 1986). Eventually the tissues regain the size and shape they had before the seed dried out during ripening, and active metabolism begins which is manifested by a sudden rise in the rates of respiration and protein synthesis, both of which are associated with the hydration of existing enzymes (Loveless, 1986)

2.1.1.3 TEMPERATURE

Different seeds vary in their temperature requirement for gemination. At relatively low or high temperatures the germination of seeds is adversely affected. Suitable soil temperature is an important factor in seedling establishment. F.A.O (1980) has reported 17°C as acceptable (Suitable) soil temperature for germination and establishment of grain sorghum (*Sorghum bicolor*)

2.1.1.4 LIGHT

Among cultivated plants, there is very little evidence for light as a factor influencing germination. In contrast, among wild plants much variability in the behaviour toward light is observed. Consequently seeds may be divided into the following,

(a) those which germinate only in continuous light

(b) those which germinate after being given a brief illumination.

(c) those which germinate only in the dark

(d) those which are indifferent to light during germination (Ellis *et*. *al*., 1985).

The duration of illuminations has also been shown to affect germination (Mayer and Poljakoff-Mayber, 1982).

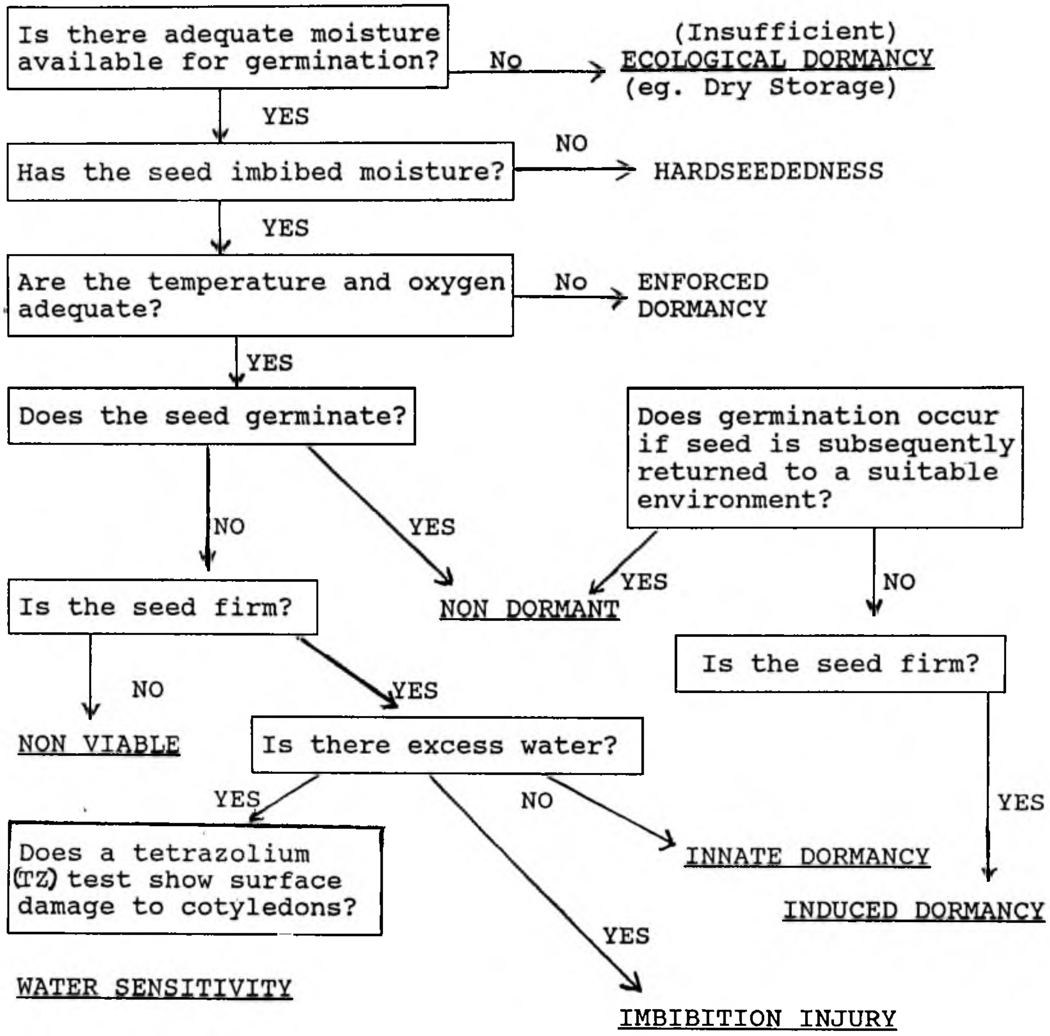
2.1.1.5 GASES

Germination requires energy which is met by aerobic respiration. Consequently, it is markedly affected by the composition of the ambient atmosphere -oxygen and carbon dioxide concentration (Mayer and Poljakoff-Mayber, 1982).

2.1.1.6 SEED DORMANCY

Seed dormancy is the condition in a viable seed which prevents it from germinating when supplied with the forelisted factors in adequate measure for germination. Dormancy provides a delay mechanism which enables dispersal from the parent stock before germination occurs.Thus the seed germinates at more opportune times or positions (Ellis *et*. *al*., 1985). Below is a schematic representation of the different categories of dormancy, together with their associated problems.

DIFFERENT CATEGORIES OF DORMANCY



Source : Ellis *et. al.*, (1985).

The different types of dormancy are as follows:-

(i) Innate dormancy (also known as primary, natural, inherent and endogenous dormancy) which describes the dormancy present immediately the new embryo ceases to grow when still attached to the parent plant. Such dormancy prevents the seed from germinating viviparously. The delayed germination after dispersal also ensures that some of the seeds germinate during the right season in the appropriate environment for plant growth.

(ii) Enforced dormancy (Environmental dormancy) describes the condition when viable seeds do not germinate because of some limitation in the environment such as absence of light and reduced temperature.

(iii) Induced dormancy (also known as secondary dormancy) is usually the result of seeds being supplied with water but exposed to an environment where some factor is unfavourable for germination eg. high temperature, low oxygen.

(iv) Seed coat Imposed dormancy describes the condition when hardseededness (due mainly to an impermeable seed coat or testa) can limit oxygen diffusion and act as mechanical barriers to radicle emergence.

2.1.1.8 TREATMENTS WHICH REMOVE DORMANCY

1. Removal or puncture of structures covering the seed. In many species, puncturing or scratching (Scarification) of seed coats may enable imbibed, dormant seeds to germinate (Grant,1979; Ellis *et. al*., 1985). In a number of species such treatment can be quite

effective in promoting germination.

Hamley (1932) was the first to investigate various ways of breaking dormancy in seeds with very hard seed coats or resistant to abrasion and/or covered with a wax-like layer. He showed that vigorous shaking of seeds of Melilotus alba, Trigonella arabica and Crotalaria aegyptica rendered the seeds permeable to water. This treatment is frequently called impaction.

Heating of seeds has been reported by Dell (1980) to allow entry of water thus facilitating germination.

In nature, the seed coat may be broken down or punctured by mechanical abrasion, microbial attack and passage through the digestive tract of animals. In mechanical scarification, the seed coat is abraded by passing over abrasive surfaces. Simple rubbing between emery paper covered boards is widely used for laboratory germination testing. Revolving-drum scarifiers are used for commercial quantities of seeds. A stationary drum in which seeds are agitated by compressed air is another mechanical scarification method used for commercial quantities of seed.

Chemical treatment is chiefly of two kinds: (i) removal of the waxy layer of seed coat of some seeds such as Brachiara decumbens by some suitable solvent such as alcohol. (ii) immersing of seed in concentrated acids such as sulphuric acid for 15 to 20 minutes depending on species (Whiteman, 1980). These various treatments of seeds - mechanical or chemical scarification, as described above may induce other effects such as changes in permeability to gases, sensitivity to light or temperature and even possible destruction or removal of inhibitory substances (Mayer and Poljakoff-Mayber, 1982).

Immersion of seed in water at 80°C for 10 minutes is effective in breaking dormancy for some species, for example leucaena (Gray, 1968).

2. Changing the gaseous atmosphere. An increase in partial pressure of oxygen around the intact seeds increases their respiratory activities, thus resulting in greater loss of seed dormancy (Ellis et. al., 1985). Similarly pre-treatment in the complete absence of oxygen (pure nitrogen) may also result in loss in dormancy (Ellis et. al., 1985). Other gases can also affect dormancy. For example high concentration of carbon dioxide (above 5%) may induce dormancy or result in loss in dormancy whilst lower (0.3-4.5%) concentrations usually tend to lead to loss of seed dormancy (Ellis et. al., 1985). The presence of hydrogen sulphide, carbon monoxide, phosphine, ethylene and certain anaesthetics (ethanol, methanol, acetone, chloroform, ethyl ether) have also been found to result in loss in dormancy (Ellis et. al., 1985).

3. Temperature

In many seeds alternating temperatures can be extremely effective in breaking dormancy. The alternating temperature changes may be either diurnal or seasonal. A major problem when considering alternating - temperature regimes is the number of attributes which could stimulate seed germination. These are:

(i) the length of each cycle

(ii) the minimum and maximum temperature in each cycle

(iii) the period of exposure to the minimum and maximum temperature.

(iv) the range between the minimum and maximum temperature

(v) the cumulative effect of the number of cycles.

(vi) the efficacy of cycles with respect to time from the onset of imbibition.

(vii) the rate of heating or cooling from one temperature to another.

(viii) the mean temperature (Ellis _et_. _al_., 1985)

Pre-chill treatment (stratification) that is subjecting seeds to low temperature, before transferring to a higher temperature is a normal method of breaking seed dormancy. Similarly, pre-treatment of imbibed seeds at a high temperature, with subsequent transfer to a lower temperature can be a powerful dormancy-breaking treatment (Ellis _et_. _al_., 1985).

High temperatures are also known to cause a change in the structure of the seed coats, thus causing a change in permeability (Mayer and Poljakoff-Mayber, 1982).

4. The influence of light

It is well known that light can have an influence on the expression of seed dormancy in many species. Generally light sensitive species can be divided into two categories depending on whether germination was promoted (ie. positively photoblastic species) or inhibited by light (ie negatively photoblastic species). The interaction between light and some other external conditions as well as the age of the seeds in relation to inhibiting germination is very complex (Mayer and Poljakoff-Mayber, 1982). The following results provide examples of positive interactions between the effects of light, nitrate and alternating temperatures on the germination of dormant seeds of _Rumex_ _Spp_.

5. Soaking in water before germination test.

Pre-soak treatment in water before the germination test sometimes has a enhances seed germination. Soaking the seeds of rice (_Oryza_ _sativa_) in water at 40°C for one to two days has been recommended by the International Seed Testing Association as a means of removing dormancy in rice (Ellis _et._ _al_., 1985).

In addition to removing germination inhibitors, pre-wash treatment may soften the seed coat or surrounding fruit structures, lessening the physical resistance to germination (Taylorson and Hendricks, 1977; Ellis _et_. _al_., 1985).

Table 2.1 The effect of light, nitrate and alternating temperature on the germination of dormant seeds of Rumex Spp

Treatment	Germination Environment	% Germination
1	25°C, dark, water	0
2	25°C, light, water	0
3	25°C, dark, 10^{-2}MKNO_3	0
4	25°C, light, 10^{-2}MKNO_3	0
5	25°C/1.5°C*, dark, water	1
6	25°C/1.5°C*, light, water	68
7	25°C/1.5°C*, dark, 10^{-2}MKNO_3	4
8	25°C/1.5°C*, light, 10^{-2}MKNO_3	100

*Diurnal alternating temperature regime 25°C for 8 hours, then 1.5 for 16 hours; Source: Roberts,(1973) as quoted by Ellis et. al. (1985).

6. Pre-applied and co-applied compounds in solution.

Very many compounds have been applied to seeds in an attempt to break dormancy. A pre-applied treatment refers to treatment of seeds with a compound in solution in water (unless otherwise stated) prior to transfer to the germination test environment.

A co-applied treatment is one in which a compound normally dissolved in water is applied to the seed in the germination environment.

With both methods of application, the concentration of the compound in solution is critical. When the concentration is very low there is no effect on germination and when too high, non-dormant seeds may be temporarily prevented from germinating or killed.

With the pre-applied method however higher concentrations are generally necessary to promote germination of dormant seeds compared to the co-applied method.

Among the chemicals most commonly applied to seeds and which have been reported to promote germination of dormant seeds in one or more species include hydrogen peroxide, ethyl alcohol, sodium hypochlorite, thiourea, mercaptoethanol, nitrates, nitrites, cyanide, azide, gibberelins, cytokinin (eg kinetin) and hydroxylamine (Ellis et. al., 1985)

In addition to the above there is also after - ripening in dry storage which removes dormancy.After-ripening or post-harvest maturation describes the loss in dormancy that gradually occurs when seeds are stored after harvest in the air-dry state. This technique is common in commercial seed practice.

2.1.2 MANAGEMENT OF ESTABLISHED FIELD

When seed reserves are exhausted the seedling becomes dependent on soil nutrients, and therefore deficiencies in the soil can depress establishment. Furthermore, excessive applications of fertilizer may depress or delay establishment (Whiteman, 1980). Under dry-land conditions, moisture rather than the supply of plant nutrients is usually the limiting factor (Herron, 1963; F.A.O., 1988). With adequate moisture supply throughout the growing period, sorghum responded to increasing nitrogen applications up a maximum of 130kg of N per hectare (Herron,1963).

2.2 GROWTH AND DEVELOPMENT

2.2.1 GROWTH HABIT OF SORGHUM

After emergence, the plant begins expanding its leaf surface and increases in dry weight as a result of photosynthesis (F.A.O,1988) The optimum temperatures for growth are between 27°C and 30°C (Quinsby et. al., 1958). The Sorghum plant is determinate, producing a sequence of leaves from the apical meristem until the apex becomes reproductive. Unlike most cereals, sorghum is perennial, and a new growth cycle can commence after grain maturity, which is achieved through tillering from dormant lateral buds on the old stem (Humphreys, 1981). The period from emergence to panicle initiation is referred to as growth stage 1

(GS1). Following initiation there is the growth of the panicle, unexpanded leaves and of the stem. The period from panicle initiation to anthesis is known as growth stage 2 (GS2). The remaining period from anthesis to grain maturity is known as growth stage 3 (GS3) (F.A.O, 1979).

2.2.2 DRY MATTER YIELD

Dry matter yield increases with advancing growth period for various species up to a ceiling yield (Wilman and Omaliko, 1978; Asiedu, 1980; F A O; 1988, Westselaar and Farquhaar, 1980; Fleischer, 1987). The increase in dry matter yield is accompanied by changes in the proportion of the various morphological fraction. Fleischer (1987) working on green panic (Panicum maximum var trichoglume cv Petrie) and Rhodes grass (Chloris gayana Kunth) observed that the proportion of stems and dead leaves increase in dry matter yield while those of green leaves and leaf sheaths decreased with advancing growth.

Stem elongation with subsequent increase in its proportion in the crop leads to increase in dry matter yield.

2.3 NUTRITIVE VALUE

2.3.1 DRY MATTER CONTENT

Generally the crop dry matter content increases with increase in its maturity (Minson, 1976). The dry-matter content can also affect dry matter intake but the evidence on this seems inconclusive. Forages consumed by animals should contain sufficient dry matter in order to satisfy other body requirements. Booysen (1975) has reported that animals must ingest daily sufficient dry matter in proportion to their liveweight.

2.3.2 CRUDE PROTEIN CONTENT

Crude protein content of herbage generally declines with advancing maturity (Spedding and Diekmahns, 1972; Fribourg, 1974; Asiedu,1980; Fleischer, 1987). This decline in crude protein content occurs in all the various morphological fractions of the forage (Lyttleton, 1973; Fleischer et. al., 1983; Fleischer et. al.,1984). The crude protein content of the various plant morphological fractions differ. The leaves generally have higher crude protein content levels than other fractions of the crop (Altimimi, 1978; Fleischer,1987).

Crude protein content of herbage is known to be affected by environmental factors. Fleischer et. al., (1983) have reported a decrease in crude protein content of green panic with increasing temperature. Again, Fleischer et. al., (1984) have reported a decrease in nitrogen content with increasing light intensity.

When the crude protein content in the herbage falls below 8% its palatability decreases and so voluntary feed intake by the animal will be less than might be expected (Laredo and Minson, 1973, 1975). Though the protein content of a pasture may be increased by applying nitrogen fertilizer, the time of harvest may modify the actual effect of fertilizer application (Lyttleton, 1973; Wilson, 1982).

2.3.3 PLANT CELL WALL CONSTITUENTS

The nutritive value of the fibrous fraction is influenced by the degree of lignification, while that of the soluble fraction bears no relation to lignification (Minson, 1976).

The cell wall constituents (neutral detergent fibre, acid detergent fibre, cellulose lignin) of the plant fractions and the whole forage increase with advancing growth (Hacker and Minson, 1981, Fleischer, 1987). Green leaves are lower in cell wall constituents than dead leaves, leaf sheath, inflorescence and stem (Asiedu, 1980; Fleischer, 1987).

Nitrogen fertilization influences the cell wall constituent in various plant species to different extents depending on the time of harvest. Fleischer et. al. (1983) working on green panic reported a decrease in fibre content with increasing nitrogen levels.

The high fibre content of tropical forages is known to lower feed intake by animals (Minson, 1972; Powell, 1984) and also decrease digestibility (Asiedu, 1980; Fleischer, 1987).

2.3.4 HYDROGEN CYANIDE (HCN) CONTENT

Many plants, including those of the genus Sorghum contain substances (Cyanogenic glycosides) which may breakdown, releasing hydrocyanic (prussic) acid (Gander, 1960, Fribourg, 1974; Hulse et. al., 1980). Sorghum contains the glycoside dhurrin, p-hydroxymandelonitrile-ß-D-glucoside (Reay and Conn, 1970) which upon hydrolysis in the rumen, yields glucose, parahydroxybenzaldehyde and HCN (Gander, 1960). When the HCN is liberated in the digestive tract by enzymatic or acid hydrolysis, it is absorbed by the blood where it inhibits the oxygen-activating enzyme, indophenol oxidase, and results in rapid respiratory paralysis (Reay and Conn,1970)

Concentration of cyanide potential in plants varies greatly with genotype, environment, age of plant, plant part, harvest management and fertilization. The aerial parts of the sorghum plant (leaf blades and actively - growing plant parts) are higher in HCN potential than stems and leaf sheaths (Akazawa et. al., 1960; Wolf and Washko, 1967).

Higher HCN concentrations have been found in sorghum fertilized with higher levels of nitrogen and plants harvested at younger growth stages than when nitrogen fertilization was lower and plants harvested were older (Jung et al., 1964). Phosphorous fertilization decreases HCN potential of plants while potassium has little effect (Patel and Wright, 1958).

Conservation of fodder as silage and hay tends to lower the HCN content (Amanig-Kwarteng, 1974; Aii, 1975).

The likelihood of hydrocyanic poisoning occurring with stored herbage has been reported by McCarty et al., (1971) as quoted by Noller and Rhykerd (1974) to be remote due to losses of HCN during ensiling. There is some indication that high HCN content induces decreased forage intake by cattle and sheep (Rabes et al., 1970).

2.3.5 DIGESTIBILITY

The digestibility of plant feed-stuffs, particularly roughage, is governed not only by the proportions of the chemical components but also by the morphological structures.

Digestibility is a measure of the proportion of the feed consumed which is digested and is potentially available to be metabolized by the animal. Digestibility decreases with increases in the lignin content which protects cellulose from degradation by rumen micro-organisms. Dry matter digestibility has been reported to decrease with advancing maturity (McLeod and Minson, 1974; Fleischer, 1987) and increasing ambient temperature during plant growth (Masuda, 1977; Wilson, 1982; Fleischer et al., 1983). Dry matter digestibility may also increase with nitrogen fertilization (Wilson, 1982, Fleischer et al., 1983).

Different plant parts vary in digestibility and those with lower cell wall constituents are usually the more digestible (Minson, 1972, Asiedu, 1980; Hacker and Minson, 1981; Fleischer, 1987).

2.4 SILAGE

The production of silage involves anaerobic storage of a crop of high moisture content. Silage can be fed to ruminant livestock in periods (dry season) when fresh forage supplies are inadequate (Tuah, 1971; Wilkinson, 1983).

The suitability of silage making to large-scale production, and its independence of the weather have led to a substantial increase in its popularity in the last twenty years in some parts of the world.

However, the use of silage had not been popular with farmers in West Africa and limited to experimental farms and government stations.

2.4.1 THE ENSILING PROCESS (FERMENTATION)

The ensiling process refers to changes which take place when forage is stored in a silo (Whittenbury et al., 1967) for it to undergo anaerobic fermentation (McDonald et. al., 1973a). There are two main methods of silage preparation - cold and warm methods. In the cold fermentation, the silo is rapidly filled and the temperature rise to about 27°C to 33°C whilst in the warm method, ensiling takes several days and the ensiled material is exposed to the air for sometime during which the temperature in the silo rises to over 50°C (McDonald and Whittenbury, 1973)

The silage formation process is associated with the production of short-chain organic acids from the fermentation of water soluble carbohydrates (McDonald, et al, 1973b; Ashbell et. al., 1985; Ashbell et. al., 1987) and the degradation of a proportion of the protein in the crop to non-protein nitrogenous compounds (Bergen, Cash and Henderson, 1974). Water soluble carbohydrate in the crop is fermented by homolactic bacteria to give lactic acid and heterolactic bacteria to give lactic acid, acetic acid, mannitol, ethanol, carbon dioxide (Moon et. al., 1981) and by yeast to give lactic acid, ethanol and carbon dioxide. These happen so that the growth of clostridia bacteria would be restricted so as to prevent the deamination of amino-acids and secondary fermentation of lactic acid to butyric acid (McDonald et. al., 1973a). The losses of nutrients associated with secondary fermentation and degradation of protein can cause depression in voluntary intake (Demarquilly and Jarrige 1970) and digestibility (Flynn, 1981). Crops with low contents of dry matter and water soluble carbohydrates are particularly prone to secondary fermentation. An adequate level of water soluble carbohydrate is required for fermentation to a stable, low-pH, lactic acid-dominated and well preserved silage (Wilkinson et. al., 1982). Tropical forages generally contain lower levels of water soluble carbohydrates than temperate species (Catchpoole and Henzell, 1971; Wilson and Ford, 1973; Noble and Lowe, 1974). This may be due to the ambient temperature under which they are grown or different pathways for the synthesis and assimilation of carbohydrates or both. However, tropical fodder crops such as maize, the sorghums and elephant grass have relatively high content of water soluble carbohydrates and are frequently ensiled (Tuah, 1971; F.A.O., 1990). Catchpoole (1972) has produced good quality silage with sorghum almum without additives. Furthermore certain tropical grasses such as Pennisetum purpureum, Panicum maximum are known to contain higher levels of water soluble carbohydrates than some temperate crops and hence produce better silage of fairly good quality (Wilson and Wilkins, 1973; Torsi, 1973 as quoted by Wilkinson (1983)). The effect of water-soluble carbohydrate on the pattern of silage fermentation in the silo is illustrated in Table 2.2.

During the first few hours of the ensiling process, the main changes are caused by aerobic respiration, which will continue, as long as oxygen is present until the plant sugars are depleted (McDonald and whittenbury, 1973). Sugars are oxidised to carbon dioxide and water, with the production of heat which may result in a considerable rise in temperature in the mass (Murdoch, 1960; Lisker et. al., 1987). The plant cell together with aerobic bacteria die when anaerobic conditions are established. High temperatures during the early stages of ensiling are reflected in increased unavailability of protein in the silage.

2.4.2 IMPROVING THE PRESERVATION OF SILAGE

The probability of achieving good preservation during ensilage may be as follows:

(a) Appropriate choice of crop ie. crops which have relatively high contents of water soluble carbohydrates.

(b) A period of field-wilting

(c) Treating the crop with additives so that fermentation quality is improved, and losses of nutrients are reduced.

Wilting which is usually done prior to the ensiling process has the effect of increasing the dry matter (DM) content of the crop, and reducing the incidence of secondary fermentation (Ashbell *et*. *al*., 1986).

Table 2.2 Effect of water-soluble carbohydrate (WSC) on pattern of fermentation.

ITEM	CROP		SILAGE					REFERENCE
	Dry-matter (%)	WSC (%/fresh wt)	A	B	C	D	E	
Temperate crops								
Lolium perenne	16.3	2.67	3.8	15.4	3.4	0.0	8.5	Wilson and Wilkins (1973)
Medicago sativa	16.3	0.73	6.4	6.5	6.5	2.9	24.4	
Tropical crops								
Pennisetum purpureum	29.1	3.67	3.7	5.0	2.0	0.0	8.6	Torsi * (1973)
Panicum maximum	27.8	1.74	4.6	1.9	3.1	0.1	21.2	

A = pH
B = Lactic acid (Percentage of DM)
C = Acetic acid (Percentage of DM)
D = Butyric acid (Percentage of DM)
E = Amonia-nitrogen (total nitrogen percentage)

* As quoted by Wilkinson (1983)

Suitable dry matter content for ensiling has been reported by McCullough (1978) to be between 28 and 34%. Wilting to more than 30% DM limits the development of Clostridium (Weisbach et. al, 1974). Wilting prior to ensiling causes an increase in pH, reduction in bacteria, reduction in lactic acid and butyric acid content of the ensiled material (Stirling, 1951; Ashbell et. al., 1986). Additional changes in freshly harvested forages effected by wilting include deamination or degradation of protein or amino-acids resulting in loss of protein. This is caused in freshly harvested crop by plant enzymes, and ceases at between 40 and 45% DM. Clostridial activity generally results in deamination in the silage and this can be limited by raising the DM above 30% before ensiling (Macpherson, 1952). Also respiratory losses of harvested forage prior to ensiling decrease as dry matter increases (Honig, 1979).

Ammonia-nitrogen and volatile acids (such as acetic acid) have been reported to be higher in wilted silage (Gordon, 1981, Ashbell et. al., 1986). Ashbell et. al., (1986), working with the wheat plant, obtained an 8.3% higher value of free amino-acid in wilted silage than in the unwilted.

Feed intake may be higher in wilted than in unwilted silages (Flynn and Wilson, 1978). Wilting can result in a decrease in digestibility. Ashbell et. al., (1986) have reported a 6% reduction in water soluble carbohydrate in wilted wheat plants which resulted in 2% unit decrease in digestibility.

Wilting, apart from improvement in fermentation quality, eliminates the production of effluent from the silo.

The use of additives such as formic acid or mixtures of acids and formaldehyde in ensiling have been shown to improve both fermentation quality and animal production (Waldo, 1977; Flynn and Wilson, 1978; Thomas, 1980). Animals given silages treated with additives show superior performance. In most cases the improved production responses are due to increase in intake. Addition of formic acid to unwilted silage resulted in improved digestibility of dry matter (Wilkins, 1978; Flynn and Wilson, 1978) and to wilted materials also led to improvement in live weight and milk production (Waldo, 1977). Other silage additives investigated include salts of acids such as ammonium formate (Drysdale and Barry, 1980) and sodium acrylate (Wilkinson et. al., 1980). These have an advantage over the free acids which can pose handling problems. Much as these appear promising they require further testing to establish their efficacy under a wide range of conditions. Some of the problems associated with the use of additives in the developing countries are high cost, non-availability of them at times as well as the hazards to the safety of unskilled farm workers. However, the use of molasses and urea, considered to be "safe", are recommended (Wilkinson, 1983). Molasses as an additive increases the content of fermentable carbohydrates while urea increases the content of nitrogen (which is commonly very low in silages made from tropical crops). The use of urea in silage has resulted in improvement in dry matter digestibility. The addition of urea at ensiling (0.5 per cent of the fresh crop weight) to forage maize of 29 per cent DM content and 0.85 per cent nitrogen in the DM resulted in an increase in DM digestibility from 51 to 58 per cent (Goncalves, 1978 as quoted by Wilkson (1983)). This increase has been attributed to the improved supply of fermentable nitrogen to the rumen microbial population. However with forage maize of higher nitrogen content (1.1-1.7 per cent of DM) urea had a little effect on digestibility (Demarquilly and Jarrige 1970).

Legumes are known to be high in crude protein content than grasses (Minson, 1975; F.A.O., 1988). The leaves of leucaena (*Leucaena leucocephala*) for example has been found by Takahashi and Ripperton (1949) as quoted by Skerman (1977) to have a crude protein content of 26.70%. Addition of leaves from leguminous trees and shrubs, such as leucaena, should increase the nitrogen content and hence cause an improvement in the digestibility of low quality grasses.

2.4.3. LOSSES IN STORAGE (LOSSES DURING ENSILAGE)

The extent of silage losses has very important economic implication. Losses occurring during storage are caused by seepage, spoilage, fermentation and high temperature (Dijkstra, 1957). Losses from silos involving liquid or effluent drainage (seepage) carries with it soluble nutrients, thus affecting the nutritive value of silage (Murdoch, 1961). Spoilage losses occurring mostly at the top and sides of the silo are caused by exposure of the material to the air for a long period of time or the entrapping of great quantities of air in the ensiling material. The spoiled material may be rotten, mouldy or odorous. Losses occurring during fermentation include breakdown of carbohydrates of the plant material during respiration, and degradation of protein by plant enzymes and bacteria action.

High temperatures cause great losses of carotene and the losses are greater in wilted silages than in unwilted silages. Analyzing 800 sets of data published between 1938 and 1960, Watson and Nash (1960), reported that the mean dry matter losses of silage under farm conditions were 16.1%. Zimmer (1976) also reported a loss of 19.4% DM.

Ashbell and Kashanchi (1987) worked with ensiled wheat and reported that mean losses in the middle of bunker silos ranged between 2.8 and 16%; that near the wall was between 10.1 and 22.7%. DM losses in the cover layer and near the wall ranged between 13.9 and 26.7% and from 20.4 to 75.8% respectively. Ashbell (1984) has observed losses of between 5.2 and 7.7% in wheat silage under laboratory conditions.

Typical losses of dry matter during the conservation of crops as silage in bunker silos under tropical or temperate conditions is shown in Table 2.3

From Table 2.3, it is apparent that there is not much difference in total losses between the various treatments.

Table 2.3 DM losses during the conservation of crops as a silage in bunker silos.

Loss %	Tropical	Temperate	
	Direct Cut A	Direct Cut B	Wilted C
IN FIELD			
Respiration	-	-	2
Mechanical	6	1	4
DURING STORAGE			
Respiration	-	1	1
Fermentation	7	5	5
Effluent	-	6	-
Surface wash	7	4	6
During removal From Storage	5	3	3
TOTAL	25	20	21

A = Forage Maize-From Pizarro and Vera (1980)

B = Ryegrass treated with formic acid at 2.5kg/ton fresh crop -from Wilkinson (1981).

C = Ryegrass, 36 hours wilt in field - From Wilkinson (1981).

2.4.4. TYPE OF SILO

There are different types of silos. These include the following:

1. Conventional upright (Tower) silos. It is a cylinder built above ground.
2. Gastight (oxygen-limiting) silos
3. Pit silos. It is shaped like the tower silo, but inverted into the ground. It resembles a well or cistern.
4. Horizontal (Trench) silos
5. Temporary silos which include
    - a) Enclosed
    - b) Open Stacks
    - c) Modified trench
    - d) Plastic or polyethylene bag (Ensminger, 1970).

Silos should be filled as rapidly as possible and crops should be consolidated during filling. Complete sealing and protection of the seal from damage are essential. In tropical conditions, the seal should be insulated to reduce the extent to which heat is absorbed into the silo in sunny weather.

Loss of Dry matter (DM) during Storage of forage in different types of silo under tropical conditions is shown in Table 2.4.

Losses of DM comprise loss of digestible nutrients. Thus with limited loss in DM, there is little difference between the digestibility of the crop at harvest and that of the ensiled product (Zimmer, 1976).

Table 2.4 Loss of DM during storage of forage in different types of Silo under tropical conditions

	Types of Silo		
	Tower	Trench	Clamp
Loss of DM (%)			
Per day in store	0.03	0.06	0.22
Average(150 days)	4.5	9	35

Source: Pizarro and Vera (1980)

2.4.5 EVALUATION OF SILAGE QUALITY

Silage quality is assessed by three main characteristics. These are physical, chemical and microbiological. The physical characteristics normally employed on farms are odour, feel, appearance, texture and taste (Moore, 1966; Tuah, 1971). The physical characteristics are very easy to evaluate, but do not give any picture of nutritive value of the silage. The chemical characteristics used are pH, residual acidity, volatile acidity, content of volatile bases, ammonia and ratio of true to crude protein.

Quality standards for grass silage produced from temperate pastures in the Netherlands is shown in Table 2.5.

It can be referred from Table 2.5 that good quality silage should have pH less than 4.2, butyric acid less than 0.2% and ammonia nitrogen, less than 8.0%. However the quality standards for evaluating good quality tropical silages differs from above. The quality of tropical forage silages is assessed on the basis of acetic acid and butyric acid contents and not lactic acid and butyric acid contents since tropical forage silage produce acetic acid instead of lactic acid (Catchpoole and Henzell, 1971).

Table 2.5 Quality Standards for Silage

Standard	Quality of Silage		
	Good	Median	Poor
PH	<4.2	4.3 - 4.5	>4.5
Butyric acid (%)	<0.2	0.2 - 0.5	>0.5
Ammonia N (%)	<8.0	9 - 15	>15

Source : F.A.O. (1990)

CHAPTER THREE

EXPERIMENT ONE

FACTORS INFLUENCING GERMINATION OF "WILD SORGHUM" SEEDS

3.1 INTRODUCTION

The success of pasture establishment depends greatly on seed germination and seedling emergence. Many of the tropical fodder crops are relatively wild plants which have not been domesticated and vigorously selected for good seed production characteristics and hence their poor germination. Humpherys (1981) has attributed the poor germination of most tropical "wild Seeds" to seed dormancy. Thus there is the need to treat seeds before planting so as to break dormancy and also provide better chance of good pasture establishment (F.A.O., 1990). The various treatments which remove seed dormancy have already been discussed in the literature (see chapter 2).

The objective of this study is to examine the percentage germinability of "wild sorghum" seeds as influenced by harvesting time and different methods of scarification.

3.2 MATERIALS AND METHODS

LOCATION OF EXPERIMENT

The study was conducted at the Department of Animal Science, University of Ghana, Legon, Accra.

Meteorological observations in the experimental year are shown in Table 3.1.

Table 3.1 Meteorological observations in the experimental year

Meteorological attribute	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average
Rainfall (mm)	0.00	7.80	3.20	103.60	17.60	99.40	14.30	6.70	78.40	48.30	48.30	77.40	646.8	53.9
Temp. Min. °C	23.80	23.80	25.40	24.50	24.00	23.80	22.60	22.40	22.90	23.40	24.00	23.20	-	23.70
Max. °C	33.30	33.90	34.50	32.90	31.40	30.30	27.80	29.00	30.10	31.20	32.20	31.70	-	31.50
Mean relative umidity	75	75	71	80	84	84	87	84	83	81	81	78	-	80
vapotransiration (mm)	130.80	142.20	146.10	137.20	153.70	110.50	130.80	134.60	129.50	134.60	137.20	138.40	1625.60	135.50

Source: Ghana Meteorological Services Dept. (1990)

The average temperature during the experimental period was about 28°C. Rainfall in the year of the experiment was about 88% of the normal (Walker, 1962; Jenik and Hall, 1976). The relative humidity was about 75%. The relative humidity was uniformly high during the night and early morning ie 92% decreasing to 68% in the afternoon (Ghana Meteorological Services Dept. 1990).

Planting material

Seeds of *Sorghum arundinaceum* collected from the Legon farms University of Ghana, were used as planting material.

Land preparation and establishment

The land was ploughed and harrowed. Seeds were first nursed and seedlings were transplanted two weeks later onto a plot measuring 3.0mx3.0m. Planting was done at 0.25m apart within the row and 0.50 m between rows.

Agronomic Practices

There was regular manual weed control using cutlass and hoe especially during the initial stages of growth. Two weeks after planting, fertilizer was applied at the rate of 20kg N and 20kg P_2O_5 per hectare using the ringing method. Since rainfall was inadequate initially, the field was irrigated from a nearby stand pipe.

Harvesting

Inflorescence appeared about eight weeks post planting. Seeds were collected at 3,4,5,6,7 and 8 weeks after inflorescence appearance and used for the germination test.

For each of the collected seed samples, four different scarification treatments were applied

(i) Mechanical scarification- The seeds were rubbed between emery paper.

(ii) Acid scarification - The seeds were immersed for 5 minutes in concentrated sulphuric acid and thereafter thoroughly washed in running water.

(iii) Hot water treatment - The seeds were immersed in hot water (80°C) for 10 minutes.

(iv) Dry heat treatment - The seeds were heated in an oven at a temperature of 80°C for 12 hours.

20 treated seeds of the "wild sorghum" were then placed on moist filter paper in a petri dish. Water was sprinkled on the seeds daily and germination counts made daily for each treatment over a period of four weeks.

STATISTICAL ANALYSIS

Statistical analysis was done using the computer. The statistical programme for social sciences (SPSS) was used in the analysis of variance. Duncan multiple range test (DMRT) was used to separate means.

3.3. **RESULTS**

The percentage germination of "wild sorghum" seeds as influenced by harvesting time and scarification treatment is shown in Table 3.2.

Table 3.2 Percentage germination of "wild sorghum" seeds as influenced by harvesting time and scarification treatment.

Treatment	Harvesting time (week of growth)							
	11	12	13	14	15	16	Mean	S.E.
No control	22.5	47.5	27.5	17.5	7.5	2.5	20.83 b	4.56
Mechanical scarification	32.5	67.5	57.5	25	17.5	5	34.17 a	6.74
Acid scarification	5	7.5	5	2.5	2.5	0	3.75 ed	0.90
Hot water	12.5	22.5	17.5	10	5	0	11.25 dc	2.31
Dry water	10	30	22.5	15	2.5	0	14.58 cb	3.45
Mean	16.59 cb	35 a	26.00 ba	15.50 dc	7.00 ea	1.50 f		
S. E.	3.34	7.00	5.95	2.93	2.26	1.07		

Both the time of harvest and scarification method had significant ($P<0.01$) effect on the percentage germination. The highest percentage of germination was observed, for each treatment, between 12th and 13th weeks of growth, thereafter lower values were recorded with advancing age. At the eleventh week of growth, ie, three weeks after inflorescence appearance, the germination of harvested seeds were significantly ($P<0.01$) lower than values obtained between the twelfth and thirteenth weeks of growth. Apart from mechanical scarification which significantly ($P<0.01$) increased the percentage germination compared to the untreated, the latter was significantly ($P<0.05$) higher than all the other scarification methods. Acid scarification gave the lowest germination values among all the treatment methods. However, no significant effect ($P>0.05$) was established between acid scarification and hot water treatment. Hot water treatment was not significantly ($P>0.05$) different from the dry heat treatment.

3.4 DISCUSSION

The increasing germination up to a point in time and decreasing thereafter with advancing growth is in agreement with the result of other workers (Miyamoto *et al*, 1961; Ballard, 1962; Whiteman, 1980; Ellis *et al*, 1985). According to Ballard (1962) the grass embryo is capable of continued development shortly after pollination and even immature grains, if removed from the parent plants, have some capacity for germination. Thus germination steadily increases until full value is achieved at morphological ripeness. Thereafter it decreases with advancing growth period since the seed becomes drier then (Whiteman, 1980; Ellis et al., 1985). Thus, in this study it might be said that the sorghum seed probability have reached morphological ripeness between the twelfth and the thirteenth week of growth or 4-5 weeks after inflorescence appearance.

Comparatively lower germination values with some scarification methods have been reported in the literature (Clark et. al, 1968; Bewly and Black, 1978). Although seed treatment generally promotes germination, the actual method used would depend on the type or cultivar of seed and the feasibility of the treatment (Whiteman, 1980; Grant and Clatworthy, 1984). Mechanical scarification has been shown to improve germination (Villiers, 1972; Mayer and Poljakoff-Mayber, 1982; Ellis et al., 1985). In fact mechanical scarification is known to increase permeability to moisture and gases thereby improving germination (Milthorpe and Moorby, 1986). It may also increase the seed's sensitivity to temperature and light as well as remove or destroy some of the inhibitory substances (Ellis et. al., 1985) thus improving germination. Whiteman (1980) and Humpherys (1981) have however pointed out that temperature may not be a limitation to germination in the tropics.

Acid scarification is somewhat unreliable (Whiteman, 1980; Grant and Clatworthy, 1984) as there is a tendency for it to kill some seeds (Ellis et al., 1985). This perhaps explains the very low germination of sorghum seeds with acid scarification in this study.

Ellis et al. (1985) also observed inhibition injury and subsequently destruction of the seed embryo of forage sorghum (Sorghum vulgare) when immersed in warm water. Furthermore

Rudrapel and Basu (1980) also observed soaking injury resulting from rapid inhibition when soybean was immersed in warm water. These observations perhaps explain the lower germination values of the hot water treatment compared with the untreated.

Whereas heating results in temperature increase which may cause change in seed coat permeability resulting in enhanced germination (Holm, 1973; Mayer and Poljakoff-Mayber, 1982), it also could cause dehydration and subsequent destruction of the seed embryo thus decreasing germination (Hegarthy, 1970; Milthorpe and Moorby, 1986). Hence, the low germination of the dry heat treatment compared with the untreated.

From the above therefore, to obtain viable seeds of "wild sorghum" of very high germination rate, the seeds should be collected at between four to five weeks after inflorescence appearance. Germination of such seeds would be enhanced by mechanical scarification.

CHAPTER FOUR

EXPERIMENT TWO

CHANGES IN THE DRY MATTER YIELD AND NUTRITIVE VALUE OF "WILD SORGHUM" (SORGHUM ARUNDINACEUM) WITH GROWTH.

4.1 INTRODUCTION

Ruminant livestock production in the tropics can be increased through better nutrition ie. production and feeding of adequate amounts of high-quality forage. Maize and sorghum which are of high nutritive value are used as fodder crops in the United States and other developed nations. However, in Ghana, there is the difficulty in deciding whether to plant maize and / or sorghum as fodder crops for livestock, because they are also consumed by man. On the contrary, "wild sorghum" which has the potential as fodder crop has been growing wild and has not been studied in terms of dry matter yield and nutritive value in relation to growth.

The objective of this study was therefore, to examine the changes that occur in the dry matter yield as the plant grows and to estimate the nutritive value of "wild sorghum".

4.2 MATERIALS AND METHODS

Location, period of experiment, climatic conditions, preparation of site and establishment, management of plots (agronomic practices) were the same as described in experiment one.

4.2.1 HARVESTING

Harvesting, which began on the sixth week after planting, was repeated at two weeks intervals up to the fourteenth week of rowth. At harvest crops were cut with cutlass at ground level. The ut herbage was collected in sacks and the total net fresh weight aken. Sub-sampled herbage (above-ground shoot) was then separated nto green leaves, dead leaves, leaf sheaths, stems and nflorescence stalk, weighed and later dried in an oven at a emperature of 70°C for 48 hours for dry matter content etermination and subsequently dry matter yield. All the dried ample were then ground to pass through a 1mm-sieve with a Wiley ill. The ground samples were then stored in labelled sample olythene bags for subsequent analyses.

.2.4 CHEMICAL ANALYSES

The ground samples were analyzed for

. Crude Protein - Total nitrogen (TN) was determined by the jeldahl method and crude protein (CP) was calculated by ultiplying TN by 6.25.

. Neutral detergent fibre (NDF), acid detergent fibre (ADF), ellulose and Acid Detergent lignin (ADL) according to the method f Goering and Van Soest (1970).

. *In vitro* dry matter digestibility - was determined according o the method of Minson and McLeod (1972).

. Hydrogen cyanide (HCN) was determined according to A.O.A.C 1975).

.2.5 STATISTICAL ANALYSIS

The statistical analysis was the same as described in xperiment one.

4.3. RESULTS

4.3.1 DRY MATTER YIELD

The Dry matter yield of whole forage and its component morphological parts with growth are shown in Fig 4.1

There was a significant ($P<0.01$) increase in dry matter yield with advancing maturity.

Total dry matter yield of the whole plant was ranged from 0.25t DM ha^{-1} at the first harvest (at the sixth week of growth) to 2.67t DM ha^{-1} and 9.54t DM ha^{-1} at the 10th and 12th weeks of growth respectively, followed by only a slight increase to 10.18t DM ha^{-1} thereafter.

Green leaves increased gradually from 0.21t DM ha^{-1} at the sixth week of growth to 1.88t DM ha^{-1} by the twelfth week of growth and decreased to 1.25t DM ha^{-1} by the final harvest. Dead leaves appeared at the twelfth week of growth and increased from a low value of 0.27t DM ha^{-1} to a high value of 1.01t DM ha^{-1} by the final harvest. The leaf sheath followed a similar growth pattern like the green leaves increasing from a low value of 0.04t DM ha^{-1} at the sixth week of growth to 1.36t DM ha^{-1} by the twelfth week of growth, and decreased to 1.07t DM ha^{-1} by the final harvest. The stem appeared at the eighth week of growth and increased from a low value of 0.43t DM ha^{-1} to 6.07t DM ha^{-1} by the final harvest. The inflorescence also appeared at the eight week of growth and increased from a low value of 0.02t DM ha^{-1} to a high value of 1.39t DM ha^{-1} by the twelfth week of growth, and by the final harvest it had decreased to 0.77t DM ha^{-1}.

Fig. 4·1 CHANGES IN DRY MATTER YIELD OF WHOLE FORAGE AND ITS COMPONENT MORPHOLOGICAL PARTS WITH GROWTH (t ha-1)

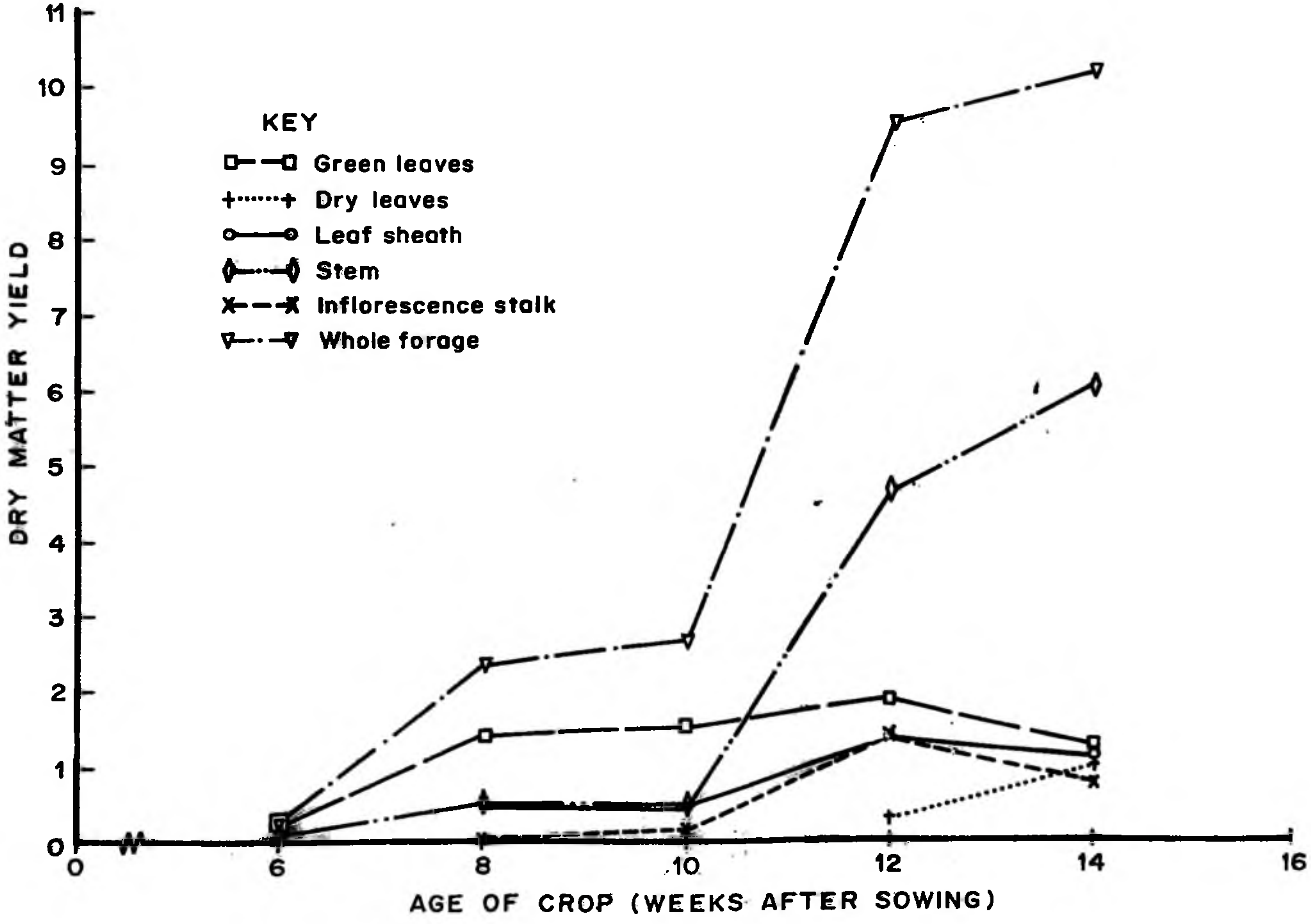
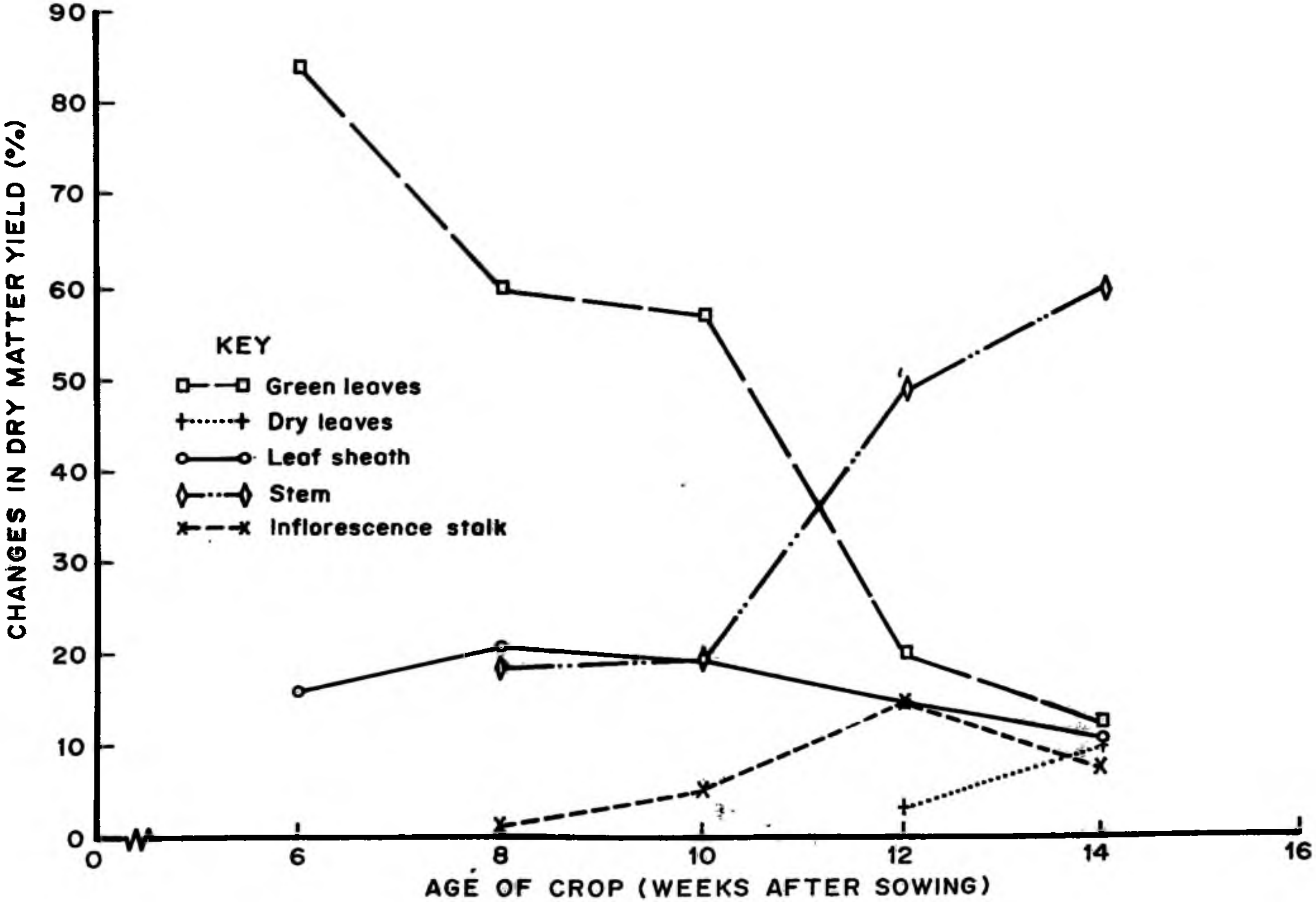


Fig. 4·2 CHANGES IN DRY MATTER YIELD OF MORPHOLOGICAL PLANT PARTS EXPRESSED AS PERCENTAGES OF THE WHOLE FORAGE WITH GROWTH



The changes in dry matter yield of morphological plant parts expressed as percentage of whole forage with growth is shown in Fig.4.2.

Green leaf percentage decline from 84 at the 6th week to a final harvest value of 10 at the 14th week. There was an increase in the proportion of leaf sheath from 16% to 21% between the sixth and eight week of growth followed by a decline and by the final harvest it had fallen to 11%. The proportion of stem also increased with advancing growth period so that by the final harvest it formed about 59% of the whole forage. The inflorescence increase from 1% at the 8th week to 14% by the twelfth week of growth, and thereafter decreased to 8% by the final harvest.

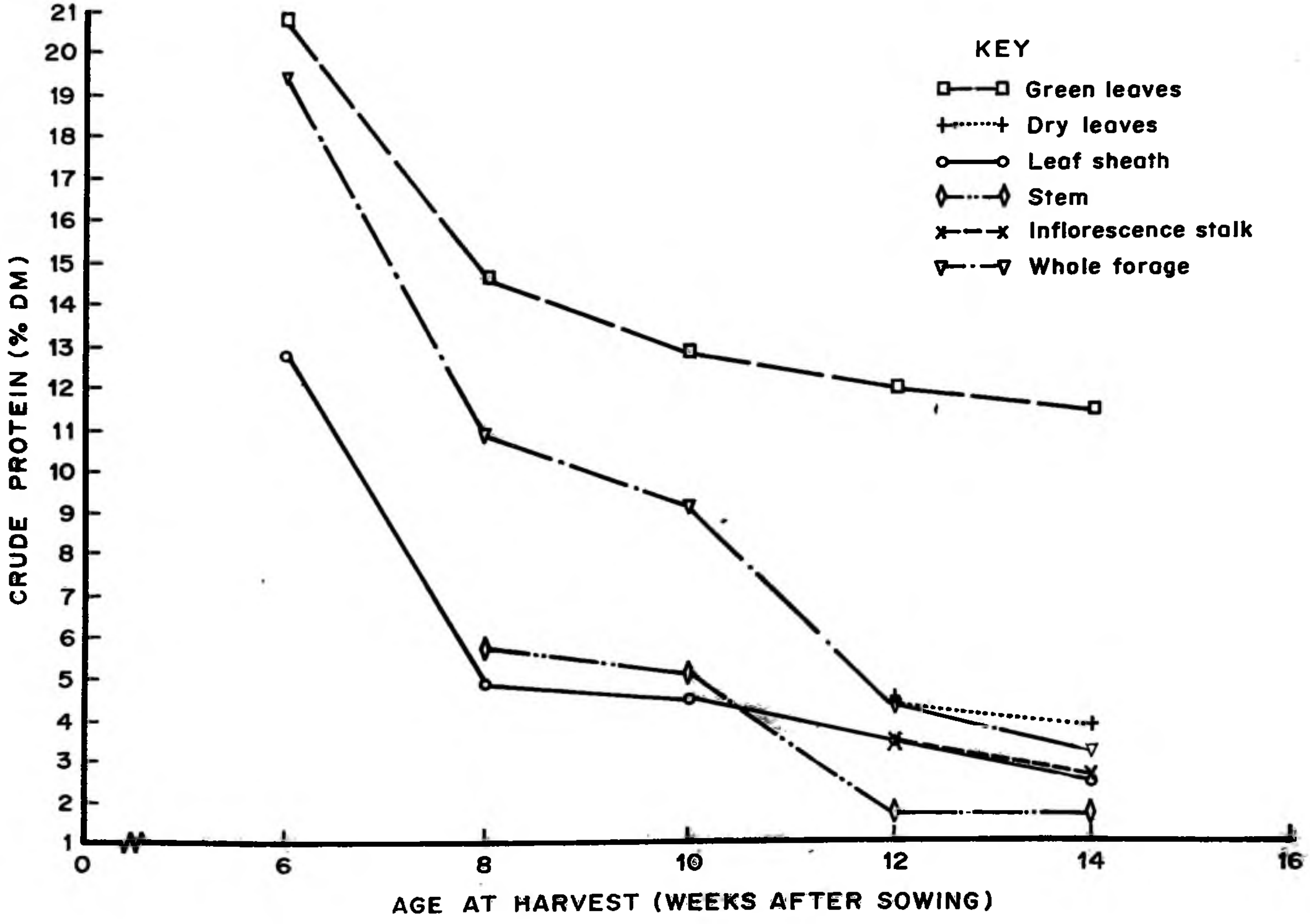
4.3.2 CRUDE PROTEIN CONTENT

The Crude protein content of the whole forage and its component morphological parts are illustrated in Fig 4.3.

The crude protein content significantly ($P<0.05$) decreased with age in both the whole forage and the component morphological fractions. At the initial harvest the whole forage had a very high value of 19.40% which decreased continuously and by the final harvest it had decreased to a low value of 3.13%.

There was a sharp decline in crude protein content of green leaves from 20.69% to 14.58%' between the first and second harvests, and by the final harvest it had declined to 11.45%.

Fig. 4·3 CHANGES IN PERCENTAGE CRUDE PROTEIN OF THE WHOLE FORAGE AND ITS COMPONENT MORPHOLOGICAL PLANT PARTS WITH GROWTH



Dead leaves which appeared at the twelfth week of growth decreased only slightly from a value of 4.38% to 3.77% by the final harvest. The leaf sheath followed a similar trend like green leaves, a sharp drop from 12.75% at Sixth week to 4.17% at eight week, and thereafter a continuous decline to 2.41 by the final harvest.

The stem showed a slight decrease from 5.64% at the eight week to 5.02% at the tenth week of growth after which it decreased rapidly to 1.60% by the final harvest. The inflorescence stalk showed a small decrease from 3.41% at the twelfth week to 2.62 at the final harvest.

On the average the green leaves had the highest mean crude protein value of 14.29% among the morphological fractions while the inflorescence stalk had the lowest value of 3.02%.

4.3.3 CELL WALL CONSTITUENTS

(1) Neutral Detergent Fibre (NDF)

The changes in percentage NDF of the whole forage and its component morphological parts with growth are shown in Table 4.1

The NDF content Significantly ($P<0.05$) increased with advancing growth period. The whole plant NDF increased from 61.38% at the first harvest to 83.36% by the final harvest. The greatest increase from 70.77% to 82.56% occurred between the tenth and twelfth week of growth. Green leaves increased significantly $P<0.05$)from 61.01% at initial harvest to 68.24% at eighty week of growth, thereafter increased gradually and by the final harvest it has increased to 74.68%

Table 4.1 Changes in neutral detergent fibre content of the whole forage and its component morphological parts with growth (percentage of dry matter)

	Harvest Period (week of growth)						
	6	8	10	12	14	Mean	S.E
Whole Forage	61.38	67.78	70.77	82.56	83.36	73.17	4.28
Green Leaves	61.01	68.24	73.92	74.08	74.68	70.39	2.62
Dead Leaves	-	-	-	76.31	76.84	76.58	6.27
Leaf sheath	63.34	72.32	77.50	80.24	80.77	74.83	3.24
Stem	-	64.70	73.21	85.34	85.90	77.29	5.12
Inflore-scense stalk	-	-	-	85.96	87.93	86.95	0.99

Dead leaves showed only a slight increase from an initial value of 76.31% to a final value of 76.84%.

The leaf sheaths showed a similar trend like green leaves, increasing gradually from an initial value of 63.34% to a final value 80.77%.

The stem increased from 64.70% at the second harvest to 85.90% by the final harvest. The greatest increase from 73.21% to 85.34% occurred between the tenth and twelfth week of growth. The inflorescence stalk showed an increase of 85.96% at twelfth week to 87.93% by the final harvest.

(ii) Acid Detergent Fibre (ADF)

The changes in ADF content of the whole forage and its component morphological parts with age are shown in Table 4.2 The ADF content significantly ($P<0.05$) increased with advancing age. With the whole forage, there was an increase in ADF value from 32.51% at initial harvest to 52.24% by the final harvest. The most rapid increase occurred between the tenth and twelfth week of growth (increasing from 38.72% to 50.50%).

There was a significant ($P<0.05$) increase in green leaves from 31.43% between the sixth and eight week of growth, and thereafter a gradual increase until a final harvest value of 40.82%.

Dead leaves which appeared at the twelfth week of growth had an initial ADF value of 43.63% which decrease to 42.95% by the final harvest. The leaf sheath followed a pattern similar to that of the green leaf though it had higher values.

Table 4.2 Changes in acid detergent fibre content of the whole forage and its component morphological parts with growth (Percentage of dry matter).

	Harvest Period (week of growth)						
	6	8	10	12	14	Mean	S.E
Whole Forage	32.51	37.46	38.72	50.50	52.24	42.29	3.86
Green Leaves	31.43	37.98	39.26	40.19	40.82	37.94	1.70
Dead Leaves	-	-	-	43.63	42.95	43.29	0.34
Leaf sheath	38.19	40.79	46.16	53.40	52.80	46.27	3.07
Stem	-	33.88	39.87	52.20	55.13	45.27	5.03
Inflore-scense stalk	-	-	-	50.80	57.39	54.10	3.3

The stem increased from 33.88% at eight week to 39.87% at tenth week of growth, and then rapidly increased to 52.20% by the twelfth week, and to 55.14% by the final harvest.

There was an increase in the ADF content of the inflorescence stalk from 50.80% at twelfth week of growth to 57.39% by the final harvest.

(iii) Cellulose

The cellulose content of the whole forage and its component morphological parts with growth is shown in table 4.3.

The whole forage increased in cellulose content from 24.60% at initial harvest to 43.74% by final harvest. The most rapid increase occurred between the tenth and twelfth week of growth ie from 31.09% to 43.19%. The green leaves increased from 23.05% at initial harvest to 35.35% by the twelfth week of growth, and thereafter decreased to 34.10% by the final harvest. However these two values were not significantly different (P>0.05) from each other. Dead leaves showed only a slight increase from, 31.85% to 32.96% by the final harvest.

The leaf sheaths continuously increase in cellulose content from an initial value of 28.98% to 41.64% at the twelfth week of growth, followed by a slight decrease to 41.12% by the final harvest.

TABLE 4.3 Changes in cellulose content of whole forage and its component morphological parts with growth.

	Percentage of DM					Mean	S.E
	Growth Period (Weeks)						
	6	8	10	12	14		
Whole Forage	24.60	29.20	31.09	43.19	43.74	34.36	3.86
Green Leaves	23.05	26.57	30.26	35.35	34.10	29.86	2.30
Dead Leaves	-	-	-	31.85	32.96	32.41	0.56
Leaf Sheath	28.98	32.98	37.14	41.64	41.12	36.37	2.42
Stem	-	35.16	35.66	48.15	47.35	41.58	3.57
Inflorescence Stalk	-	-	-	40.96	46.85	43.91	2.95

The stem had an initial cellulose content of 35.16 % which increased to 48.15% by the twelfth week and thereafter decreased slightly to 47.35% by the final harvest.

The inflorescence stalk significantly (P<0.05) increased from 40.96% at twelfth week of growth to 46.85% by the final harvest.

iv) Acid detergent lignin (ADL).

Table 4.4 shows the acid detergent lignin content of the whole forage and its component morphological part with growth.

The ADL content increased Significantly (P<0.01) with advancing age. The ADL content of the whole plant forage increased gradually from an initial value of 2.39% to 3.48% by the tenth week, followed by a rapid increase to 6.06% at twelfth week of growth and finally to 6.85% by the final harvest. Green leaves also had increasing ADL values with advancing age except between the tenth and twelfth week of growth where there was a slight drop from 3.69% to 3.52%. However this decrease was not significant (P>0.05). Dead leaves showed an increase from 4.32% at twelfth week of growth to 5.09% by the final harvest. Leaf sheaths increased from an initial value of 2.54% to a final value of 6.19%. The most rapid increase occurred between the tenth and twelfth week of growth ie from 3.12% to 5.44%. Stem showed a continuous increase from 1.57% to 7.66% by the final harvest. The inflorescence stalk increased from 8.21% at twelfth week of growth to 10.41% by the final harvest.

Table 4.4 Changes in ADL content of the whole forage and its component morphological parts with growth.

	Percentage of DM						
	Growth Period (Weeks)					Mean	S.E
	6	8	10	12	14		
Whole Forage	2.39	2.72	3.48	6.06	6.85	4.30	0.91
Green Leaves	2.36	2.97	3.69	3.52	4.11	3.33	0.30
Dead Leaves	-	-	-	4.32	5.09	4.71	0.39
Leaf Sheath	2.54	3.13	3.12	5.44	6.19	4.08	0.72
Stem	-	1.57	4.16	6.81	7.66	5.05	1.38
Inflore-scence Stalk	-	-	-	8.21	10.41	9.31	1.10

4.3.4 IN VITRO DRY MATTER DIGESTIBILITY

Table 4.5 shows the changes in *in vitro* dry matter digestibility of the whole forage and its component morphological parts with growth IVDMD of the whole forage and its component morphological parts significantly ($P<0.05$) decreased with advancing age. IVDMD of the whole forage decreased from 67.99% at the initial harvest to 38.50% by the final harvest. Green leaves had an initial high value of 68.60% but decreased gradually and by the final harvest it had decline to 44.17%. Dead leaves which appeared at the twelfth week of growth had value of 39.15% which decreased to 36.23% at final harvest. Leaf sheath followed a continuous decline pattern like green leaves, however their values were lower than those of the green leaves. The stem also continuously declined in IVDMD from an initial value of 68.80% to a final value of 39.86%. The inflorescence stalk, also decreased from 31.19% at the twelfth week to 30.47% at fourteenth week of growth. Green leaves gave the highest IVDMD values than all morphological plant fractions. However, the stem gave higher value than green leaves between the eighth and tenth weeks of growth. The inflorescence stalk recorded the lowest value.

4.3.5 HYDROGEN CYANIDE(HCN) CONTENT

The changes in HCN content in whole forage "wild sorghum" with advancing maturity is showed in the table 4.9.

The HCN content significantly ($P<0.05$) decreased with advancing age. The HCN content of the plant decrease

e from an initial value of 530 mg $kg(Dm)^{-1}$ to a final value of 222 mg $kg(Dm)^{-1}$.

Table 4.5 In vitro dry matter digestibility (IVDMD) of the whole forage and its morphological fractions as affected by growth.

	Percentage of DM						
	Growth Period (Weeks)					Mean	S.E
	6	8	10	12	14		
Whole Forage	67.99	63.92	54.26	41.47	38.50	53.23	4.79
Green Leaves	68.60	63.95	55.37	49.12	44.17	56.24	3.69
Dead Leaves	-	-	-	39.15	36.23	37.69	0.84
Leaf Sheath	64.79	62.73	52.94	41.07	32.96	50.90	5.02
Stem	-	68.80	66.54	41.55	39.86	54.19	6.05
Inflore-scence Stalk	-	-	-	31.19	30.47	30.83	0.21

Table 4.6 Changes in HCN content of whole forage *Sorghum arundinaceum* with growth.

Growth Period (Week)	HCN Content mg/kg DM Basis
6	530
8	471
10	346
12	310
14	222

4.4. DISCUSSION

4.4.1. DRY MATTER YIELD

The decline in dry matter yield after the ceiling yield is in agreement with reports in the literature (Wilman and Omaliko, 1978; Asiedu, 1980; Westselaar and Farquhaar,1980; Fleischer, 1987). The increase in dry matter yield with advancing growth period up to a ceiling yield followed by a decline has been observed with maize (Fleischer, 1987) and grain sorghum (Naga white) (Egyir, 1990). The observed changes in the proportion of the morphological fractions is similar to that observed with grasses (Fleischer, 1987) maize (Fleischer *et al*., 1990) and sorghum (Egyir, 1990). These changes may have been due to the shift in the source-sink relations in the distribution of photosynthates as reported by Wareing and Patrick (1975). The rapid increase in dry matter yield between the twelfth and fourteenth week was probably due to the increased proportion of stem during elongation and thickening of this growth stage. Leaf senescence which is very high when growth is rapid perhaps contributed to the decline in dry matter yield after the ceiling yield (Westselaar and Farquhaar, 1980).

4.4.2. CRUDE PROTEIN CONTENT

The decline in crude protein content in the whole forage and the various morphological fractions has been reported by others (Lyttleton, 1973, Fleischer 1987). Such trends are partly due to the increase in size of the plant during which photosynthates are mainly diverted into the production of low nitrogen containing structural fractions of which the leaf sheaths, stems and inflorescence stalk form the bulk (Lyttleton, 1973; Fleischer et al, 1990). The variation in the morphological plant parts are similar to that observed with other plants (Fleischer, 1987; Fleischer et al.,1990; Egyir, 1990).

4.4.3. CELL WALL CONSTITUENTS

Increase in cell wall constituents with advancing growth period is consistent with reports in the literature (Hacker and Minson, 1981; Wilson, 1982; Fleischer, 1987; Fleischer et al., 1990). As the plant matures it increases in size and therefore requires greater structural support hence those fractions with this function increases in proportion (Esau, 1965; Fleischer, 1987). Green leaves had very low cell wall constituents compared to the other morphological fractions because of its general function as the major photosynthetic tissue and hence tends to have less fibrous and lignified cell but rather more parenchymatous cells with thin walls (Loveless, 1986).

4.4.4. IN VITRO DRY MATTER DIGESTIBILITY (IVDMD)

The findings of decreased IVDMD with increasing growth period were in agreement with that reported in the literature (McLeod and Minson, 1974; Fleischer, 1987; Fleischer et al., 1990; Egyir, 1990). The decrease is not only due to the increase in cell wall constituents but also increase in the proportion of the various structural morphological fraction (Fleischer et al., 1990). Again the variations among the various morphological fractions have also been reported by Hacker and Minson (1981). Generally as the lignin content increases with advancing growth, digestibility decreases (Raymond, 1969; Hacker and Minson, 1981).

The stem at its first appearance had an IVDMD value higher than that of the green leaves partly because at this point it is relatively physiologically immature and partly also because it is shielded from the direct impact from the surrounding temperature (Minson and McLeod, 1970; Wilson, 1982; Fleischer *et al*., 1983).

4.4.5. HYDROGEN CYANIDE (HCN) CONTENT

The observation of a decrease in HCN content with advancing growth has also been observed with grain sorghum by Aii (1975).

Generally, as the plant matures the cyanogenic compounds are either broken down or metabolized into other compounds (Akazawa *et al*., 1960) thereby resulting in lower values (Watts and Breyer-Brendwijk, 1962).

CHAPTER FIVE

EXPERIMENT THREE

EFFECT OF TREATMENT AND DURATION OF PRESERVATION ON THE QUALITY OF SORGHUM SILAGE

5.1 INTRODUCTION

A major constraint to livestock production in the tropics, and in Ghana for that matter, is the unavailability of good quality forage especially during the dry season.

One way of overcoming this problem of dry season feeding is to produce silage (Tuah, 1971; Larsen 1974, a, b; Larsen and Abbey, 1976). Well preserved silages have supported high levels of animal production.

5.2 MATERIAL AND METHODS

Location, period of experiment, climatic conditions, preparation of site and establishment, management of plots (agronomic practices) were the same as described in experiment one.

5.2.1 ENSILING THE CROP

The Secondary and tertiary growths which were harvested 10 weeks after regeneration from tillers were used for the ensilage. Herbage in both cases were harvested after ten weeks of regrowth.
Harvesting from three of the sub-plots were carried out and the mean fresh weight to the nearest kilogram taken. Sub-samples were dried at 70^0C for 48 hours, weighed and their dry matter yields determined.

Silage Preparation

The harvested herbage to be ensiled was chopped to 2-3cm lengths manually using a cutlass. Polythene bags measuring 40cm X 25cm and about 1mm in thickness were used as silos. A bag was placed inside a second bag to give the silo strength and to prevent puncturing by chopped pieces of the ensiling material. Each of the silos was then filled with one of the four treatments of the chopped forages. These were done in duplicates.

The four treatments were as follows:

1. Unwilted sorghum with nothing added
2. Unwilted sorghum with formic acid forming 0.5%
3. Sorghum with nothing added but wilted in the sun for six hours.
4. Unwilted sorghum combined with leucaena (made up largely of leaves and immature stems) in the ratio of 7:3.

Each silo was filled with 1 kg of the chopped forages. The materials were ensiled over a period of 28, 56, 84 and 112 days. Thus the design was a 4 x 4 factorial one. The filled and sealed silos were weighed prior to ensiling. The polythene bags were protected from rodent attack by storing in a drum. The ensiled material for each treatment was re-weighed at the end of storing period.

Sample preparation for analysis

At each storage period, silos for the various treatments were opened and sub-samples were taken and dried in an oven at 70°C for 48 hours for determination of dry matter content and dry matter yield. The rest of the fresh silages was stored in a freezer for the determination of pH, ammonia-nitrogen and total volatile fatty acids

(TVFA). The dried samples were ground and stored in tightly sealed polythene bags for subsequent analysis.

5.2.7 CHEMICAL ANALYSIS

Silages were analyzed for the following:-

a. Crude protein

b. pH

c. Ammonia-Nitrogen - This was determine using Markham (1942) method for estimation of rumen ammonia nitrogen.

d. Total volatile fatty acids (organic acids). This was determined by using Markham (1942) distillation.

e. Fibre

f. *In Vitro* Dry matter digestibility

g. Hydrogen cyanide (HCN).

5.2.8 STATISTICAL ANALYSIS

The statistical analysis was the same as described in experiment one.

5.3 RESULTS

5.3.1 DRY MATTER YIELD

The dry matter yield of the secondary growth was 9.71 tha^{-1} and this value was lower than the 10.07 t ha^{-1} value for the tertiary growth. However the difference was not statistically significant ($p>0.05$).

Table 5.1 Chemical composition of "wild sorghum", leucaena and their combination prior to ensiling

		Components								
Treatment		Dry matter %	Crude protein (% of DM)	NDF (% of DM)	ADF (% of DM)	Hemi-cellulose (% of DM)	Cellulose (% of DM)	ADL (% of DM)	IVDMD (% of DM)	HCN mg kg $(DM)^{-1}$
Sorghum	a	20.65	5.85	76.60	45.60	31.01	35.95	6.90	49.18	362.0
	b	28.16	6.38	78.92	49.21	29.69	36.58	7.04	45.16	347.5
	c	24.41	6.12	77.76	47.41	30.35	36.27	6.97	47.17	354.8
Leucaena	a	25.34	32.87	36.27	21.46	14.81	14.90	5.31	68.36	-
	b	33.31	36.35	39.07	22.81	16.26	14.38	6.03	64.11	-
	c	29.33	34.61	37.67	22.14	15.54	14.64	5.67	66.24	-
70% sorghum + 30% leucaena leucocephala	a	27.41	22.18	65.41	32.76	32.65	25.47	6.11	60.87	256.2
	b	29.64	25.83	68.37	35.17	33.20	26.14	6.31	58.23	247.8
	c	28.52	24.01	66.89	33.47	32.93	25.81	6.21	59.55	252.0

a = Secondary growth
b = Tertiary growth
c = Average of regrowths

5.3.2 CHEMICAL ANALYSIS OF "WILD SORGHUM" AND leucaena PRIOR TO ENSILING

Table 5.1 shows the chemical analysis of "wild sorghum", leucaena and their combination prior to ensiling.

The dry matter contents of the secondary growth harvests were significantly lower ($P<0.01$) than those obtained for tertiary growth harvest.

The DM contents of sorghum combined with leucaena and of sole leucaena though not significantly different from each other ($P>0.05$), were higher than that of sorghum alone.

Leucaena leaves had the highest crude protein content of 34.61%, which was significantly ($P<0.01$) different from sorghum combined with leucaena and sole sorghum. Sorghum had the lowest C.P value of 6.12% and was significantly lower ($P<0.01$) than the 24.01% obtained for sorghum combined with leucaena. All the crude protein values obtained in the secondary growth were lower than those of the tertiary growth. However, differences were not statistically significant ($P>0.05$).

Sole Sorghum had the highest NDF value of 77.76% which was significantly ($P<0.01$) higher than those of Sorghum combined with leucaena (66.89%) and sole leucaena (37.67%). The NDF values obtained for the secondary growth were significantly lower ($P<0.01$) than those of the tertiary growth.

The ADF values obtained showed a trend similar to the NDF. The value obtained for sole sorghum ie 47.41%, was significantly ($P<0.01$) higher than those of the sorghum combined with leucaena (33.47%) and sole leucaena (22.14%).

The hemi-cellulose value of sole sorghum (30.35%) was statistically ($P>0.05$) similar to that of sorghum combined with leucaena (32.93%). These values were significantly ($P<0.01$) higher than that of sole leucaena (15.54%). The hemi-cellulose values obtained for the secondary growth were statistically ($P>0.05$) similar to those of the tertiary growth.

Sole sorghum had the highest cellulose content of 36.27% which was significantly ($P<0.01$) higher than the values obtained for sorghum combined with leucaena (25.81%) and sole leucaena (14.64%). There was no statistical ($P>0.05$) difference between the secondary and tertiary regrowths, though the latter had higher cellulose content with the exception of leucaena.

The lignin content of sole legume (6.97%) was statistically ($P>0.05$) similar to that of sorghum combined with leucaena (6.21%) but these values were significantly higher than that of the sole leucaena. The lignin content were lower in the secondary growth compared with the tertiary growth. However, differences was not statistically significant ($P>0.05$)

Leucaena had the highest in vitro dry matter digestibility (66.24%) which was significantly ($P<0.01$) higher than those of sorghum combined with leucaena (59.55%) and sole Sorghum (47.17%). The value obtained for sorghum combined with leucaena was also significantly ($P<0.01$) higher than those Sole Sorghum. The secondary growth had higher digestibility values than tertiary growth.

Sorghum had the highest HCN content of 354.80mg(DM)kg^{-1} which was significantly($P<0.01$) higer than that of Sorghum combined with leucaena (252.0mg(DM)kg^{-1}. All the HCN values obtained in the secondary growth were significantly ($P<0.01$) higher than those obtained in tertiary growth.

5.3.3. CHEMICAL ANALYSIS OF ENSILED MATERIALS AS INFLUENCED BY DURATION OF PRESERVATION AND TREATMENTS

5.3.3.1 DRY MATTER CONTENT.

The changes in dry matter content of ensiled material as influenced by duration of ensilage and treatments are shown in Table 5.2. There was no significant ($P>0.05$) difference among the various storage days. However, significant ($P<0.05$) differences were observed among the various treatments. Wilted sorghum silage gave significantly ($P<0.01$) higher dry matter content of 38.02% than any of the other treatments. There was however no significant ($P>0.05$) difference among the silages of sole sorghum, sorghum treated with formic acid and sorghum combined with leucaena. For all the various treatments the secondary growth gave significantly lower ($P<0.05$) dry matter content than the tertiary growth.

The ensiled sole sorghum recorded 6.6% loss in dry matter whereas sorghum combined with leucaena recorded a higher loss (21%).

5.3.3.2 CRUDE PROTEIN CONTENT

Table 5.6 shows the protein content of ensiled material as influenced by duration of ensilage and treatments.

There was no statistical difference ($P>0.05$) between the ensiling periods. However, significant ($P<0.01$) differences were established among the various treatments. Sorghum combined with leucaena had the highest crude protein content (23.46%) which was significantly ($P<0.01$) different from all other treatments.

TABLE 5.2 Dry matter content of ensiled material as influenced by duration of ensilage and treatments.

Treatment		Percentage					
		Duration of ensilage (Days)					
		28	56	84	112	Mean	S.E.
Unwilted sorghum with nothing added	a	19.80	18.29	18.24	18.28		
	b	28.22	27.89	27.99	23.65		
	c	24.01	23.09	23.12	20.96	22.80 a	1.66
Unwilted Sorghum with formic acid forming 0.5%	a	20.11	18.71	19.99	20.72		
	b	26.67	29.21	26.90	26.45		
	c	23.39	23.96	23.45	23.59	23.60 a	1.45
Sorghum wilted in the sun for 6 hours	a	37.01	37.39	33.66	31.59		
	b	40.63	42.05	43.36	38.44		
	c	38.82	39.72	38.51	35.02	38.02 b	1.42
Unwilted Sorghum (70%) Combined with Leucaena(30%)	a	20.98	20.47	16.93	17.49		
	b	27.49	26.96	27.58	25.54		
	c	24.24	23.72	22.26	21.52	22.93 a	1.59
Mean		27.61	27.62	26.83	25.27		
S. E.		2.74	3.06	3.11	2.49		

a = Secondary growth
b = Tertiary growth
c = Average of regrowths

Means with the same letters are not significantly different at 5% level of testing.

Table 5.3. Crude protein content of ensiled material as influenced by duration of ensilage and treatments

Treatment		Percentage of DM					
		Duration of ensilage (Days)					
		28	56	84	112	Mean	S.E.
Unwilted sorghum with nothing added	a	6.14	6.01	6.18	6.38		
	b	6.27	6.19	6.48	7.02		
	c	6.21	6.10	6.33	6.70	6.33b	0.11
Sorghum with formic acid forming 0.5%	a	5.84	5.98	5.69	5.45		
	b	6.36	6.25	6.30	6.10		
	c	6.10	6.12	6.00	5.78	6.00b	0.11
Sorghum wilted in the sun for 6 hours	a	5.26	5.24	5.07	4.99		
	b	6.04	6.03	6.26	6.45		
	c	5.65	5.64	5.67	5.72	5.69b	0.21
Unwilted sorghum (70%) combined with leucaena (30%)	a	22.60	22.28	24.11	23.29		
	b	24.35	25.20	23.84	22.00		
	c	23.48	23.74	23.98	22.65	23.46a	0.39
Mean		0.36	10.40	0.49	10.21		
S.E.		2.87	2.93	2.95	2.73		

a = Secondary growth

b = Tertiary growth

c = Average of regrowths

All means which have the same letters are not significantly different at 5% level of testing.

Table 5.4 pH of ensiled material as influenced by duration of ensilage and treatments

Treatment		Ensiling period (Days)				Mean	S.E.
		28	56	84	112		
Unwilted sorghum with nothing added	a	5.01	4.82	5.03	5.27		
	b	4.91	4.87	5.12	5.08		
	c	4.96	4.85	5.08	5.18	5.01 b	0.05
Sorghum with formic acid forming 0.5%	a	4.08	4.12	4.10	4.28		
	b	4.13	4.36	4.39	4.45		
	c	4.11	4.24	4.25	4.37	4.24 a	0.05
Sorghum wilted in the sun for 6 hours	a	4.96	4.97	5.07	5.15		
	b	5.03	4.92	5.16	5.19		
	c	5.00	4.95	5.11	5.17	5.11 b	0.06
Unwilted sorghum (70%) combined with leucaena (30%)	a	5.06	5.24	5.08	5.16		
	b	5.09	5.01	5.38	5.34		
	c	5.08	5.12	5.23	5.25	5.17 b	0.05
Mean		4.78	4.79	4.92	5.04		
S. E.		0.15	0.13	0.15	0.15		

a = Secondary growth
b = Tertiary growth
c = Average of regrowths

* Means with the same letters are not significantly different at 5% level of testing.

The secondary growth had a lower protein content than the tertiary growth though the differences were not statistically significant ($P>0.05$).

5.3.3.3 pH

The pH content of ensiled material as influenced by duration of ensilage and treatments is shown in Table 5.3.

There was no statistical difference in pH content between the various ensiling periods. With regards to the various treatments however, significant ($P<0.01$) differences were established. Sorghum combined with leucaena gave the highest pH value of 5.17. Although this value obtained was higher than those obtained for the untreated sorghum untreated (5.01) and wilted sorghum (5.06), the differences were not significant ($P>0.05$). The above pH values were however, significantly ($P<0.05$) different from sorghum with formic acid (4.24). There was no statistical difference ($P>0.05$) between the secondary and tertiary growth values.

5.3.3.4 TOTAL ORGANIC ACIDS

Table 5.4 shows the total organic acids of ensiled material as influenced by duration of ensilage and the various treatments.

The total organic acids content significantly ($P<0,01$) increased with increasing ensiling periods. All the ensiling periods significantly ($P<0.01$) differs from one another.

The 28 - day storage duration gave the lowest value of $0.82\times10^{5}\mu m$(DM) kg^{-1}, followed by 56 days which gave a value of 1.20 $10^{5}\mu m$(DM) kg^{-1}, then 84 days storing time recording a value of 1.51 $10^{5}\mu m$(DM) kg^{-1} and finally 112 days storing time recording the highest value of $1.90mm10^{5}\mu m$(DM) kg^{-1}.

TABLE 5.5 Total organic acids of ensiled material as influenced by duration of ensilage and treatments (1×10^5 μM (DM) kg^{-1})

Treatment		Percentage Duration of ensilage (Days)					
		28	56	84	112	Mean	S.E.
Unwilted sorghum with nothing added	a	0.58	1.06	1.26	1.75		
	b	0.45	1.08	1.36	1.80		
	c	0.52	1.07	1.31	1.78	1.17a	0.17
Unwilted sorghum with formic acid forming 0.5%	a	0.91	1.18	1.50	1.76		
	b	0.98	1.24	1.37	1.84		
	c	0.95	1.21	1.44	1.80	1.35a	0.12
Sorghum wilted in the sun for 6 hours	a	1.01	1.41	1.88	2.16		
	b	1.23	1.44	1.94	2.31		
	c	1.12	1.43	1.91	2.24	1.67b	0.16
Unwilted sorghum (70%) combined with leucaena (30%)	a	0.52	1.02	1.34	1.75		
	b	0.88	1.16	1.45	1.83		
	c	0.70	1.09	1.40	1.79	1.24a	0.16
Mean		0.82a	1.19b	1.51c	1.90d		
S.E.		0.10	0.06	0.09	0.08		

a = Secondary growth
b = Tertiary growth
c = Average of regrowths

All means which have the same letter are not significantly different at 5% level of testing.

Sorghum wilted in the sun for 6 hours recorded the highest organic acid content which was significantly ($P<0.01$) different from all the other treatments. However, no significant ($P>0.05$) difference were observed among sorghum untreated, sorghum with formic acid and sorghum combined with leucaena.

Silages prepared from the secondary growth contained lower organic acid values than those from the tertiary growth.

5.3.3.5 AMMONIA-NITROGEN

The ammonia- nitrogen content of ensiled material as influenced by duration of ensilage and treatments is shown in Table 5.5.

There was significant ($P<0.01$)difference for the different ensiling times as well as the treatments.

The ammonia-nitrogen content significantly($P<0.01$) increased as the storing period increased. There was an increase from 127.82mg(DM) $100g^{-1}$ to 150.54mg (DM) $100g^{-1}$ at between the 28 and 56 days of ensiling, the increased further to 167.91mg (DM) $100g^{-1}$ at 84 days of ensiling period it had increased to 173.49mg (DM) $100g^{-1}$. The increase between the 84 days and the final ensiling period was not significant ($P>0.05$).

Sorghum combined with leucaena gave the highest ammonia-nitrogen content of 254.34mg (DM) $100g^{-1}$ which was significantly ($P<0.01$) different from that of any other treatment. Sorghum wilted had a higher value of 144.82 mg(DM) $100g^{-1}$ than sorghum unwilted (120.34 mg(DM) $100g^{-1}$). However, no significant difference was established between these two values. Sorghum with formic acid had the lowest value of 100.26 mg(DM) $100g^{-1}$ which was significantly ($P<0.01$)

different from the value of sorghum wilted, but similar to that of sorghum untreated.

Silages prepared from the secondary growth gave higher values than those from the tertiary growth. However, there was no statistical (P>0.05) difference between these two regrowths.

5.3.3.6 CELL WALL CONSTITUENTS

NEUTRAL DETERGENT FIBRE

Table 5.7 shows neutral detergent fibre (NDF) of ensiled material as influenced by duration of ensilage and treatments.

Both duration of ensilage and treatments showed significant effect (P<0.01). The NDF content significantly (P<0.05) decreased as the storage time increased. At the initial storage period a value of 73.61% was obtained which decrease to 69.66% by 84 days of ensiling and then a slight increase to 69.78% by the final ensiling period. There was however no significant (P>0.05) difference between the 84 days of ensiling and the final ensiling period. There was no significant (P>0.05) difference among the NDF values of sorghum untreated, sorghum with formic acid and sorghum wilted but these were significantly (P<0.01) greater than that of sorghum combined with leucaena.

Silages prepared from the secondary growth gave lower values than the tertiary growth. However, the difference were not statistically significant (P>0.05).

TABLE 5.6 Ammonia-nitrogen content of ensiled material as influenced by duration of ensilage and treatments.

Treatment		mg (DM) 100g^{-1}					
		Duration of ensilage (Days)					
		28	56	84	112	Mean	S.E.
Unwilted sorghum with nothing added	a	107.26	116.21	141.06	143.39		
	b	104.86	108.61	118.68	122.61		
	c	106.06	112.41	129.87	133.00	120.3bc	5.23
Unwilted sorghum with formic acid forming 0.5%	a	88.80	93.05	116.51	115.86		
	b	79.40	99.63	95.62	113.24		
	c	84.10	96.34	106.07	114.55	100.26c	4.85
Sorghum wilted in the sun for 6 hours	a	123.87	144.88	160.35	172.42		
	b	119.66	134.36	146.58	153.43		
	c	121.77	139.62	153.47	164.43	144.82b	6.44
Unwilted sorghum (70%) combined with leucaena(30%)	a	205.63	270.53	299.95	303.62		
	b	193.07	237.02	264.53	260.35		
	c	199.35	253.78	282.24	281.99	254.34a	14.23
Mean		127.82 c	150.54 b	167.91 a	173.49 a		
S.E.		16.48	23.52	26.15	25.08		

a = Secondary growth
b = Tertiary growth
c = Average of regrowths

All means which have the same letters are not significantly different at 5% level of testing.

Table 5.7. Neutral detergent fibre of ensiled material as influenced by duration of ensilage and treatments

Treatment		Percentage of DM Duration of ensilage (Days)					
		28	56	84	112	Mean	S.E.
Unwilted sorghum with nothing added	a	76.31	74.98	73.88	73.85		
	b	78.34	77.28	76.24a	73.07		
	c	77.33	76.13	75.06	73.46	75.50b	0.8216
Unwilted sorghum with formic acid forming 0.5%	a	75.06	73.77	73.72	71.49		
	b	76.51	73.50	73.83	74.21		
	c	75.79	73.64	73.78	72.85	74.01b	0.6261
Sorghum wilted in the sun for 6 hours	a	74.36	72.73	70.95	71.50		
	b	76.86	72.03	71.76	72.40		
	c	75.61	72.38	71.36	71.95	72.82b	0.9516
Unwilted Sorghum (70%) comb. with leucaena (30%)	a	65.13	62.37	61.09	61.89		
	b	66.32	62.62	60.55	59.86		
	c	65.73	62.50	60.82	60.87	62.48a	1.1515
Mean		73.61 a	71.16 ab	70.26 b	69.78 b		
S.E.		2.31	2.40	2.53	2.66		

a = Secondary growth

b = Tertiary growth

c = Average of regrowths

All means which have the same letters are not significant different at 5% level of testing.

Table 5.8 Acid detergent fibre of ensiled material as influenced by duration of ensilage and treatments

Treatment		Percentage of DM					
		Duration of ensilage (Days)					
		28	56	84	112	Mean	S.E.
Unwilted sorghum with nothing added	a	49.93	46.62	46.92	46.93		
	b	49.35	51.34	47.81	49.21		
	c	49.64	48.98	47.37	48.07	48.51a	0.60
Unwilted sorghum with formic acid forming 0.5%	a	47.89	46.75	46.89	46.07		
	b	47.80	45.81	46.33	44.75		
	c	47.85	46.28	46.61	45.41	46.54bc	0.37
Sorghum wilted in the sun for 6 hours	a	47.83	44.94	46.02	45.10		
	b	48.92	50.40	46.05	48.39		
	c	48.38	47.67	46.04	46.75	47.21ac	0.70
Unwilted sorghum (70%) comb. with leucaena (30%)	a	33.25	31.92	33.11	32.60		
	b	37.22	37.39	38.55	35.89		
	c	35.24	34.66	35.83	34.25	34.99d	0.91
Mean		45.27	44.40	43.96	43.62		
S.E.		2.24	2.32	1.86	2.14		

a = Secondary growth

b = Tertiary growth

c = Average of regrowths

All means which have the same letters are not significantly different at 5% level of testing.

ACID DETERGENT FIBRE

Table 5.8 shows the acid detergent fibre (ADF) of ensiled material as influenced by duration of ensilage and treatments.

There was no statistical difference (P>0.05) among the various ensiling periods. However, there was significant (P<0.01) differences among the treatments. Sorghum untreated had an ADF content of 48.51% which was significantly (P<0.01) higher than those of sorghum with formic acid and sorghum combined with leucaena (46.54% and 34.99% respectively). There was however, no statistical difference (P>0.05) between sorghum untreated and sorghum wilted. Sorghum combined with leucaena had the lowest value and this was significantly (P<0.01) different from all the other treatment.

Silages prepared from the secondary growth were generally lower in ADF content than those from the tertiary growth, except sorghum with formic acid. Though the silage prepared from tertiary growth (sorghum with formic acid) gave slightly lower values compared with its secondary growth, the difference was however, not statistically significant (P>0.05).

CELLULOSE

The cellulose content of silage as influenced by duration of ensilage and treatments is shown in Table 5.9.

No significant (P>0.05) difference was observed among the various ensiling period. There was however, significant (P<0.01) effect among the treatments. Sorghum combined with leucaena had a significantly (P<0.01) lower cellulose value than any other treatment. There was no statistical difference (P>0.05) among the cellulose contents of sorghum untreated, sorghum with formic acid

Table 5.9 Cellulose content of silage as influenced by duration of ensilage and treatments.

Treatment		Percentage of DM					
		Duration of ensilage (Days)					
		28	56	84	112	Mean	S.E.
Unwilted sorghum with nothing added	a	36.92	35.16	37.20	36.41		
	b	38.37	38.89	36.36	35.49		
	c	37.65	37.03	36.78	35.95	36.85a	0.46
Unwilted sorghum with formic acid forming 0.5%	a	36.90	37.05	36.73	35.60		
	b	36.76	34.31	35.61	36.58		
	c	36.83	35.68	36.17	36.09	36.19a	0.33
Sorghum wilted in the sun for 6 hours	a	37.41	34.25	35.42	33.95		
	b	38.44	37.04	36.58	34.79		
	c	37.93	35.65	36.00	34.37	35.99a	0.57
Unwilted sorghum (70%) comb. with leucaena (30%)	a	26.90	26.53	24.61	24.90		
	b	28.68	27.02	25.26	25.04		
	c	27.79	26.78	24.94	24.97	26.12b	0.50
Mean		35.05	33.78	33.47	32.85		
S.E.		1.61	1.63	1.87	1.74		

a = Secondary growth
b = Tertiary growth
c = Average of regrowths

All means which have the same letters are not significantly different at 5% level of testing.

Table 5.10 Acid detergent lignin of silage as influenced by duration of ensilage and treatments

Treatment		Percentage of DM					
		Duration of ensilage (Days)					
		28	56	84	112	Mean	S.E.
Unwilted sorghum with nothing added	a	6.92	6.83	7.02	6.62		
	b	7.21	7.11	7.07	7.03		
	c	7.07	6.97	7.05	6.83	6.98ab	0.07
Unwilted sorghum with formic acid forming 0.5%	a	6.78	7.60	7.04	6.90		
	b	7.08	7.08	7.06	6.91		
	c	6.93	7.34	7.05	6.91	7.06 b	0.09
Sorghum wilted in the sun for 6 hours	a	6.53	6.60	6.70	6.78		
	b	6.93	7.08	6.83	7.00		
	c	6.73	6.84	6.77	6.89	6.81 b	0.07
Unwilted sorghum (70%) comb. with leucaena (30%)	a	6.16	6.05	6.04	5.98		
	b	6.37	6.43	6.33	6.11		
	c	6.27	6.24	6.19	6.05	6.18 c	0.06
Mean		6.75	6.85	6.76	6.66		
S.E.		0.13	0.17	0.14	0.14		

A = Secondary growth

b = Tertiary growth

c = Average of regrowths

All means which have the same letters are not significantly different at 5% level of testing.

and sorghum wilted.

There was no significant (P>0.05) difference between the regrowths, though generally the silages prepared from secondary growth contain lower cellulose values than those from tertiary growth.

ACID DETERGENT LIGNIN

Table 5.10 shows the acid detergent lignin (ADL) of silage as influenced by duration of ensilage and treatment.

There was no significant (P>0.05) difference among the various storage days, but significant (P<0.01) difference was established among the treatments. Sorghum untreated, sorghum with formic acid and sorghum wilted all had values which were significantly (P<0.01) higher than that of sorghum combined with leucaena sorghum with formic acid gave the highest value of 7.06% which was not significantly (P>0.05) different from sorghum untreated (6.98%), but significantly (P<0.01) higher than the value of sorghum wilted (6.81%).

All the ADL values obtained for secondary growths were lower than those recorded in the tertiary growths. However, differences were not statistically significant (P>0.05).

Table 5.11 In vitro dry matter digestibility (IVDMD) of silage as influenced by duration of ensilage and treatments.

Treatment		Percentage of DM					
		Duration of ensilage (Days)					
		28	56	84	112	Mean	S.E.
Unwilted sorghum with nothing added	a	46.78	43.60	40.41	39.23		
	b	40.64	39.38	38.39	38.61		
	c	43.71	41.49	39.40	38.97	40.89	1.02
Unwilted sorghum with formic acid forming 0.5%	a	46.47	40.91	41.61	42.35		
	b	44.54	39.20	38.20	37.47		
	c	45.51	40.06	39.91	39.91	41.34	1.10
Sorghum wilted in the sun for 6 hours	a	44.16	41.62	35.22	35.67		
	b	41.49	38.88	39.57	39.68		
	c	42.83	40.25	37.46	37.38	39.54	1.07
Unwilted sorghum (70%) comb. with leucaena (30%)	a	49.35	44.21	42.68	44.81		
	b	47.18	42.82	41.08	39.79		
	c	48.27	43.52	41.88	42.30	44.00	1.11
Mean		45.08 a	41.33 b	39.65 b	39.71 b		
S.E.		1.05	0.74	0.83	1.00		

a = Secondary growth

b = Tertiary growth

c = Average of regrowth

All means which have the same letters are not significantly different at 5% level of testing.

5.3.3.7 IN VITRO DRY MATTER DIGESTIBILITY (IVDMD)

Table 5.11 shows the *in vitro* dry matter digestibility (IVDMD) of silage as influenced by duration of ensilage and treatments.

Sorghum combined with leucaena had the highest IVDMD of 44% which was however not significantly (P>0.05) different from the other treatments. It was followed by sorghum with formic acid giving a value of 41.34% compared with the sorghum untreated (40.89%) and the lowest digestibility value was obtained by sorghum wilted (39.55%). There were significant (P<0.01) difference among the ensiling periods. The 28 days ensiling period recorded the highest digestibility value of 45.08% which significantly (P<0.05) decreased to 39.65% by the 84 days ensiling period and then a slight increase to 39.71% by the final ensiling period. No significant (P>0.05) differences were established among the 56,84 and 112 days of ensiling.

Silages prepared from the secondary growth generally gave higher digestibility values than those from the tertiary growth. However, differences were not statistically significant (P>0.05).

5.3.3.8 HCN CONTENT

Table 5.12 shows the HCN content of silage as influenced by duration of ensilage and treatments. Both duration of ensilage and various treatments showed statistical differences (P<0.01). The HCN content significantly (P<0.01) decreased with increasing ensiling period for all treatments. The material ensiled for 28 days had the highest HCN contents which were not significantly (P>0.05) different from those stored for 56 days, but significantly (P<0.01) different from samples stored for 84 and 112 days.

Table 5.12 Hydrogen cyanide(HCN) content of silage as influenced by duration of ensilage and treatments

Treatment		mg(DM)kg^{-1}					
		Duration of ensilage (Days)					
		28	56	84	112	Mean	S.E.
Unwilted sorghum with nothing added	a	298.10	267.80	217.50	190.60		
	b	309.30	249.80	206.15	172.60		
	c	303.70	258.80	211.83	181.60	238.98a	17.77
Unwilted sorghum with formic acid forming 0.5%	a	293.00	254.60	244.60	180.00		
	b	301.70	245.80	211.10	181.40		
	c	297.35	250.20	227.85	180.70	239.03a	18.46
Sorghum wilted in the sun for 6 hours	a	255.80	216.00	193.10	141.50		
	b	242.10	208.70	172.20	130.30		
	c	248.95	212.35	182.65	135.90	194.96a	15.88
Unwilted sorghum (70%) comb. with leucaena (30%)	a	202.80	167.00	129.20	102.40		
	b	190.70	156.60	120.70	95.20		
	c	196.75	161.80	124.95	98.80	145.58b	14.13
Mean		26169 b	220.79 bc	186.82 c	149.25 a		
S.E.		16.42	14.64	15.35	13.21		

a = Secondary growth

b = Tertiary growth

c = Average of regrowth

All means which have the same letters are not significantly different at 5% level of testing.

No statistical difference ($P>0.05$) was also observed among samplesensiled for between 56 and 84 days. All the materials ensiled for 112 days had the lowest HCN values. The initial mean HCN content (ie at 28 days) was 261.69 mg (DM) kg^{-1} which decrease as the ensiling period increases and by the end of 112 day ensiling period the HCN content has decreased to 149.25 mg (DM) kg^{-1}. Sorghum combined with leucaena gave the lowest HCN content of 145.58mg (DM)kg^{-1} which was significantly ($P<0.01$) lower than those of other treatments. Although there was no significant ($P>0.05$) difference among sorghum untreated (238.98mg DM kg^{-1}), sorghum with formic acid (239.03mg DM kg^{-1}) and sorghum wilted (194.96mg kg^{-1}), sorghum wilted gave a lower value compared with sorghum untreated and sorghum with formic acid.

The HCN content of silages prepared from secondary growth were generally higher than those of the tertiary growth. However, differences were not statistically significant ($P>0.05$).

5.4 DISCUSSION

5.4.1 DRY MATTER YIELD

Dry matter yield generally declines over successive cuts (regrowths) within the season, (Fletcher,1976). However in this study the tertiary growth period occurred in the rainy season, when soil moisture content was very high, and hence availability of nutrients to plants was high. This, together with the additional application of fertilizer at the rate of 20 $kgNha^{-1}$ and 20kg P_20_5 ha^{-1}, contributed to the higher dry matter yield of the tertiary growth than the secondary growth. On the contrary the secondary growth occurred when the season was relatively drier with irregular irrigation hence inadequate soil moisture at that time, thus the slightly lower yield.

5.4.2 CHEMICAL ANALYSIS OF SORGHUM AND LEUCAENA PRIOR TO ENSILING

5.4.2.1 DRY MATTER CONTENT

The higher dry matter yield obtained with the tertiary growth reflected in high dry matter content of all tertiary growth treatments compared with secondary growth treatments.

5.4.2.2 CRUDE PROTEIN

The additional application of nitrogen fertilizer and the favourable soil conditions during the rainy season in addition to the residual soil nitrogen (Tinker, 1979; Fleischer et. al., 1984) explains the higher crude protein values obtained with the tertiary growth compared to the secondary growth. Legumes are generally known to contain high levels of protein than grasses (Minson 1976; 1977) and leucaena in particular under favourable conditions have relatively high crude protein content (NRC, 1984). Thus mixing sorghum with leucaena resulted in increasing crude protein values compared to the other treatments.

5.4.2.3 CELL WALL CONSTITUENTS

The leucaena that was used was made up largely of leaves and immature stems. These parts of the plant usually have lower cell wall constituents (Norton, 1981). Thus the lower fibre content of the leucaena contributed to lower values of NDF, ADF, Cellulose and lignin of sorghum mixed with leucaena than the other treatments. Though both secondary and tertiary growth were harvested after the same length of growth period (ie, ten weeks of regrowth) for the ensiling, the tertiary growth matured faster and produced higher dry matter yield than the secondary growth. Increased dry matter yield is associated with increased in cell wall constituents (Hacker and Minson, 1981).

This explains the higher values of NDF, ADF, cellulose and lignin obtained with the tertiary growth compared with the secondary growth.

5.4.2.4 IN VITRO DRY MATTER DIGESTIBILITY (IVDMD)

Whole forage crops or their component morphological parts low in cell wall constituents are reported to be relatively high in IVDMD (Minson, 1972; Asiedu, 1980; Hacker and Minson, 1981; Fleischer,1987). The high digestibility value of leucaena as observed in this experiment is consistent with reported literature (Le Houerou, 1980; NCR, 1984) and is associated with the low values of NDF, ADF, Cellulose, and lignin. The combination of this legume with sorghum resulted in a higher digestibility value than the other sole sorghum treatments.

The lower cell wall constituents of the secondary growth compared with the tertiary growth, contributed to the higher digestibility values of the secondary growth.

5.4.2.5 HYDROGEN CYANIDE (HCN) CONTENT

Though the leaves of leucaena are said to produce some hydrocyanic acid (Quisumbing 1947 as quoted by Watts and Breyer-Brandwijk 1962), leucaena does not appear to contain any cyanogenic glycoside that will break down to release hydrocyanic (prussic) acids (Watt and Breyer-Brandwijk 1962; Skerman, 1977). This therefore explains the lower value of HCN content with the sorghum mixed with leucaena compared with the other treatments.

Sorghum wilted in the sun for six hours also had lower value of HCN content than either untreated sorghum or sorghum treated with formic acid. This is contrary to the result of Aii (1975) who observed only a 4% decrease in HCN content when forage sorghum was exposed to the sun for six hours compared to a decrease of 12% obtained in this experiment. On the contrary, Aii (1975) drying the forage sorghum in a drought oven had reported a decrease of about 46% of the HCN content which is higher than the observation made in this experiment. The differences between these results might be due to differences in ambient temperature in which the crops were exposed during wilting.

5.4.3 CHEMICAL ANALYSIS OF ENSILED MATERIAL AS INFLUENCED BY ENSILING PERIOD AND TREATMENTS

5.4.3.1 DRY MATTER CONTENT

The decrease in values of dry matter content in the ensiled material compared with the material prior to ensiling may be due to losses in non-structural carbohydrate contents during the ensiling process. During wilting, plants lose sugars due to aerobic respiration as well as loss in plants lose protein due to deamination by plant enzymes (Ashbell *et*. *al*., 1986). These losses contributed to the high dry matter loss with the wilted sorghum compared with the unwilted sorghum in this study.

Leucaena contains a very high level of crude protein and its combination with the sorghum resulted in the high loss of dry matter due to extensive deamination of total nitrogen to ammonia-nitrogen.

The addition of formic acid perhaps gave an opportunity to improve fermentation quality, and losses of nutrients reduced, thus giving the lowest dry matter loss among all the treatments.

5.4.3.2 pH

Water soluble carbohydrates influence silage quality by determining the pH level. Tropical forages generally contain low levels of water soluble carbohydrates (Catchpole and Henzell, 1971; Wilson and Ford, 1973) and this perhaps might have contributed to high pH values (above 5.0%) obtained in this study. However, sorghum treated with formic acid gave the lowest pH value of 4.24 which falls within the range recommended for good quality silage (Minson, 1977; Ashbell et. al., 1986; Skerman and Riveros, 1990). Again Lingvall (1972) had pH values of 4.9 for sorghum untreated and 4.4 for sorghum treated with formic acid which is similar to the observation in this study. Wilson and Wilkins (1973) had observed a decrease in pH from 5.8 (untreated) to 4.6 by the addition of formic acid. The use of formic acid (additive) improved the fermentation quality, thus contributing to the low pH compared with other treatments. An increase in pH in wilted sorghum silage compared with the unwilted silage was consistent with the results of previous workers (Minson, 1977; Skovborg and Andersen, 1979, Ashbell et. al., 1986). It might be due to the degradation of protein and amino-acids to ammonia-nitrogen. The sorghum mixed with leucaena produced high level of ammonia-nitrogen and this perhaps contributed to the high pH obtained with this particular type of silage compared with other treatments. Tasaki et. al., (1970) also ensiled legumes mixed with grasses in the ratio of 3:7 and ensiling observed high pH but the level of pH attained depended on the type of legume used.

5.4.3.3 TOTAL ORGANIC ACIDS

The conversion of non-structural carbohydrate by bacteria during the ensiling process to various organic acids contributed to the increasing trend of total organic acids with increasing ensiling periods. Wilting, resulting in an increase in dry matter content tend to limit clostridial activity (secondary fermentation) and hence improve fermentation quality. The observation of high level of organic acids in the wilted sorghum compared with other treatments in this study is contrary to reports by other workers (Stirling, 1951; Murdoch, 1960; Donaldson and Edwards, 1976; Ashbell et. al., 1986) that wilted herbage contains less products of fermentation and the amount of organic acid were low. Perhaps relative increase in the extent of secondary fermentation might have contributed to the increase in organic acid with the wilted sorghum. Skovborg and Andersen (1979) had observed a slight rise in organic acid content (especially butyric acid) with wilted grass silage, in conformity with to the findings in this study.

5.4.3.4 AMMONIA-NITROGEN CONTENT

Silage ammonia-nitrogen content increased with increasing ensiling period. This finding is similar to that of Ashbell et. al., (1986) and may be due to the degradation of protein and amino-acids by bacteria. The high ammonia-nitrogen content of the sorghum mixed with leucaena may be related to the high level of protein in the leucaena and its subsequent degradation to ammonia and other products. Schaadt and Johnson (1970) had observed an increase in ammonia-nitrogen content with silage of high nitrogen content.

5.4.3.5 CRUDE PROTEIN CONTENT

Minson (1976; 1977) have reported higher levels of protein in legume than grasses. Thus the higher crude protein content of the sorghum mixed with leucaena was not surprising in view of the high protein content of the legume. The crude protein in silage from the wilted sorghum though not significantly different from the unwilted sorghum was slightly lower. Degradation by plant enzymes due to the drying in the sun might have contributed to the decrease in protein content.

5.4.3.6 CELL WALL CONSTITUENTS

High protein containing forages usually tend to have lower fibre content (Whiteman, 1980), in conformity with to the observation made in this experiment. Thus the inclusion of the legume leucaena high in crude protein content (Minson, 1976; 1977) but lower in cell wall constituents contributed to the lower NDF, ADF, cellulose and lignin content of ensiled sorghum mixed with Leucaena compared with the other treatment involving sorghum alone. The decline in NDF with advancing storage period was perhaps due to breakdown of hemicellulose by microbes since this decrease was not observed with the other cell wall constituents.

5.4.3.7 IN VITRO DRY MATTER DIGESTIBILITY (IVDMD)

Forages with low cell wall constituents are generally known to have higher digestibility values (Milford and Minson, 1966; Minson, 1972; Laredo and Minson, 1973; Asiedu 1980; Hacker and Minson, 1981;

Fleischer, 1987), in conformity with to the observation made in this experiment. The finding of high digestibility value for sorghum mixed with leucaena was therefore not surprising in view of the low fibre ie. low cell wall constituents of the leucaena. Digestibility decreases as lignin content increases (Mcleod and Minson, 1974). A similar observation was made in this experiment. The sole sorghum treatments which were higher in lignin content than the sorghum mixed with leucaena, had lower digestibility values. The loss in dry matter content with increasing ensiling period may have contributed to the decreasing digestibility with advancing ensiling period for all the treatments.

5.4.3.8 HYDROGEN CYANIDE (HCN) CONTENT

The finding of decreased HCN content with the ensiled material compared with the fresh material was in agreement with the observation by McCarthy et. al., (1971) as quoted by Noller and Rhykerd (1974), Amaning-Kwarteng (1974) and Aii (1975) that the likelihood of hydrocyanic acid poisoning occurring with stored feeds is rather remote due to losses of HCN during ensiling.

The losses of HCN during ensiling also contributed to the decreasing HCN content with increasing ensiling period for all treatments. Absence of HCN in leucaena contributed to the lower cyanide content for all the ensiled material of sorghum mixed with leucaena compared with the other treatments.

CHAPTER SIX

GENERAL DISCUSSION

Ruminant livestock production in Ghana is grossly inadequate to support the animal protein requirement of the growing population (M.O.A., 1990). This low productivity is largely due to the poor nutrition of the animals especially during the dry season. A solution to overcome the dry season feeding problem could be the use of silage. Silage making requires finding suitable forage material. One plant that has a potential of being used as a silage material but has not received attention is "wild sorghum" (*Sorghum arundinaceum*).

One of the main objectives of this work was to find the most appropriate time that seeds of "wild sorghum" should be harvested from the field and which scarification method, if there is the need to, should be adopted. This will aid in establishing pasture field of "wild sorghum". The study showed that seeds should be collected at four to five weeks after inflorescence appearance at which time very high germination percentage is possible. The percentage germination could further be enhanced by mechanical scarification. The percentage germination declines after five weeks post inflorescence emergence till final harvest.

The aim of experiment 2 was to establish the most appropriate time of harvesting "wild sorghum" from the field for feeding livestock. The study indicated that the best time to harvest the crop was between 10-12 weeks of growth at which period both the dry matter yield and nutritive value will be reasonably high. The study showed that, for the primary growth, together with the two regrowths a total harvestable dry matter yield of 30t ha^{-1} could be obtained over the growing season of thirty two weeks. This is about six to seven times the yield from the natural grassland (Caldwell, 1975; Loomis and Geralkis, 1975). This yield could conveniently be harvested and ensiled and would be able to support a relatively higher number of livestock over the dry season in Ghana which is about five months. However, the "wild sorghum" harvested between 10-12 weeks of growth had a crude protein content of 5-6% (DM basis) and in vitro dry matter digestibility of about 47%. The crude protein content was below the minimum threshold level of 7%, below which intake decreases (Milford and Minson, 1965). This however could be overcome by combining the "wild sorghum" with leaves and immature stems of leucaena which raised the crude protein level to about 29%. The HCN content of "wild sorghum" at 12 weeks of growth was 310mg kg $(DM)^{-1}$. This value is higher than 200mg kg $(DM)^{-1}$ which is considered as the minimum lethal dose for livestock (Blood and Henderson 1963), thus threatening the potential usefulness of the crop as animal feed. However, combining the crop with leucaena reduces the level of HCN considerably to 230mg kg $(DM)^{-1}$.

In experiment 3 the objective was to find out whether "wild sorghum" could be ensiled and how the quality could be improved by adding leucaena and also whether the quality could be maintained over the duration of ensilage. The result of this study showed that "wild sorghum" could be ensiled and that the quality of the silage would be improved by adding leucaena. Even though the grass-legume combination of 7:3 was arbitrary chosen in this study, the proportion of the legume was intentionally made lower than the grass because legumes generally increase the protein level but have a low dry matter yield. On the other hand, though the level of protein in over the growing season of thirty two weeks. This is about six to seven times the yield from the natural grassland (Caldwell, 1975; Loomis and Geralkis, 1975). This yield could conveniently be harvested and ensiled and would be able to support a relatively higher number of livestock over the dry season in Ghana which is about five months. However, the "wild sorghum" harvested between 10-12 weeks of growth had a crude protein content of 5-6% (DM basis) and in vitro dry matter digestibility of about 47%. The crude protein content was below the minimum threshold level of 7%, below which intake decreases (Milford and Minson, 1965). This however could be overcome by combining the "wild sorghum" with leaves and immature stems of leucaena which raised the crude protein level to about 29%. The HCN content of "wild sorghum" at 12 weeks of growth was 310mg kg $(DM)^{-1}$. This value is higher than 200mg kg $(DM)^{-1}$ which is considered as the minimum lethal dose for livestock (Blood and Henderson 1963), thus threatening the potential usefulness of the crop as animal feed. However, combining the crop with leucaena reduces the level of HCN considerably to 230mg kg $(DM)^{-1}$.

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The study also showed that there was not much change in silage quality during the four months of storage.

Thus after improving germination of "wild sorghum" seeds, it can be grown in the rainy season, ensiled, and the silage used in feeding livestock throughout the dry season.

CHAPTER SEVEN

CONCLUSIONS AND RECOMMENDATIONS

EXPERIMENT ONE

High germination percentages were obtained with seeds collected at between four and five weeks after inflorescence appearance. This was further improved by mechanical scarification such that the germination percentages obtained by mechanical scarification were 67.5 and 57 with seeds harvested at four and five weeks after inflorescence appearance. Though, these values were the highest obtained among the other treatments used in this experiment, other dormancy-breaking agents are known to give hundred percent germination.

It is therefore recommended that further studies be carried out towards improving the germinability by looking at other seed dormancy-breaking agents as already discussed in the literature. From observations made in this research, it is recommended that seeds of "wild sorghum" must be harvested at between four to five weeks after inflorescence appearance in order to obtain very high germination. The germination must further be enhanced by mechanical scarification.

EXPERIMENT TWO

With regards to the DM yield, there was an increase with advancing growth period up to a ceiling yield followed by a decline. The highest DM yield of 10.18 t ha^{-1} was recorded at fourteenth week of growth. However, at this stage of growth the crude protein content and DM digestibility were low and the fibre content was high. At the initial stages of growth ie between the sixth and eight weeks of growth, though the crude protein values (20.69 and 14.58%) and DM digestibility (68 and 64%) were very high and the fibre contents were very low, the DM yields were also very low (0.25 and 2.34 t ha^{-1}). Also at these stages the hydrocyanic acid (HCN) contents were relatively high (530 and 471 mg (DM) kg^{-1}). However, the dry matter yield, crude protein and dry matter digestibility at the twelfth week of growth which were 9.54 t ha^{-1}, 4.26% and 41% respectively seemed encouraging. The fibre contents were also relatively low. The HCN content has also decreased to 310 mg(DM) kg^{-1}.

It is therefore recommended that the best time to harvest the crop for feeding animals should be the twelfth week of primary growth or about ten weeks of subsequent growth at which times both dry matter yield and nutritive value can be reasonably high.

EXPERIMENT THREE

The dry matter yields of 9.71tha^{-1} and 10.07tha^{-1} obtained for both secondary and tertiary growth, each of which lasted ten week on the field are encouraging. These were used for silage production preparation ensiling. Silage production was generally good for all treatments. There was not much change in the silage quality within the four months duration of preservation. There was not much difference in the nutritive value between the fresh material and the ensiled material. The use of formic acid as an additive improved the silage quality. Wilting increased the dry matter content. The addition of leucaena, a legume to the "wild sorghum" at 30% increased the crude protein content from 6.12% to 24.01% and the DM digestibility from 47.17% to 59.55%. The legume inclusion also decreased the neutral detergent fibre (NDF) content from 77.76% to

66.89%, acid detergent fibre (ADF) from 47.41% to 33.47%, cellulose content from 36.27% to 25.81%, acid detergent lignin content from 6.97 to 6.21% and hydrogen cyanide content from 354.8 to 252.0 mg(DM)kg^{-1}. Therefore though silage made from sorghum combined with leucaena generally appears very good in quality the protein content seemed too high for cattle utilization. Consequently, it is recommended that legumes such as leucaena must be included in "wild sorghum" silage at the rate of 30% or less to improve the nutritive value.

It is also recommended that crop must be grown in the rainy season and preserved as silage which can last for a period of four months without much change and thus can be used in the feeding of livestock throughout the dry season. It is further recommended that the work done so far be extended to include animal studies to ascertain intake, *in vivo* digestibility and performance.

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APPENDIX

BLE 1
The % germination of "wild sorghum" seeds as influenced by harvesting time and scarification treatment

Treatment		Harvesting time (week of growth)							
		11	12	13	14	15	16	Mean	S.E
No	I	25	45	20	15	10	5	20.83	
reatment	II	20	50	35	20	5	0		4.56
	AV	22.5	47.5	27.5	17.5	7.5	2.5	b	
echanical	I	35	65	60	30	10	10	34.17	
	II	30	70	55	20	25	0		6.74
carification	AV	32.5	67.5	57.5	25	17.5	5	a	
ACID	I	5	5	5	5	0	0	3.75	
	II	5	10	5	0	5	0		0.90
carification	AV	5	7.5	5	2.5	2.5	0	ed	
Hot	I	10	20	15	10	5	0	11.25	
water	II	15	25	20	10	5	0		2.31
treatment	AV	12.5	22.5	17.5	10	5	0	dc	
Dry	I	10	35	25	20	5	0	14.58	
water	II	10	25	20	25	0	0		3.45
treatment	AV	10	30	22.5	15	2.5	0	cb	
Mean		16.59	35	26.00	15.50	7.00	1.50		
		cb	a	ba	dc	ea	f		
S . E		3.34	7.00	5.95	2.93	2.26	1.07		

BLE 2

he dry matter yield of whole forage and its component morphological parts with growth (t DM ha^{-1})

Plant part	Harvest period (week of growth)				
	6	8	10	12	14
Green leaves	0.21	1.40	1.52	1.88	1.25
Dead leaves	-	-	-	0.27	1.01
Leaf sheath	0.04	0.49	0.51	1.36	1.09
Stem	-	0.43	0.50	4.64	6.07
Inflorescence	-	0.02	0.14	1.39	0.77
Whole forage	0.25	2.34	2.16	9.54	10.18

TABLE 3
Changes in dry matter yield of morphological plant parts expressed as % of whole forage with growth

Plant part	Harvest period (week of growth)				
	6	8	10	12	14
Leaves	84	60	57	20	12
Dead leaves	-	-	-	3	10
Stem	-	18	19	49	59
Leaf sheeth	16	21	19	14	11
Inflorescence	-	1	5	14	8

Table 4: Percentage crude protein content of the whole forage and component morphological plant parts with growth.

Plant part		Harvest Period(week of Growth)						
		6	8	10	12	14	Mean	S.E
Whole forage	I	20.08	10.67	9.03	4.14	3.06		
	II	18.72	10.85	9.11	4.40	3.19	9.34	2.90
	Av	19.40	10.76	9.07	4.26	3.13		
Green leaves	I	20.72	13.94	12.67	11.79	12.04		
	II	20.66	15.22	12.85	12.11	10.86	14.29	1.69
	Av	20.69	14.58	12.76	11.96	11.45		
Dead Leaves	I				4.34	3.75		
	II	-	-	-	4.42	3.75	4.08	0.31
	Av				4.38	3.77		
Leaf Sheath	I	12.73	4.70	4.57	3.42	2.37		
	II	12.77	4.71	4.39	3.43	2.54	5.56	1.84
	Av	12.75	4.71	4.48	3.43	2.41		
Stem	I		5.61	4.98	1.57	1.58		
	II	-	5.66	5.04	1.67	1.61	3.47	1.08
	Av		5.64	5.02	1.62	1.60		
Inflorescence Stalk	I				3.44	2.53		
	II	-	-	-	3.38	2.71	3.02	0.40
	Av				3.41	2.62		

Table 5: Percentage neutral detergent fibre content of the whole forage and component morphological plant parts with growth.

Plant part		Harvest period(week of growth)						
		6	8	10	12	14	Mean	S.E
Whole forage	I	60.21	66.89	70.34	83.48	83.34	73.17	4.28
	II	62.55	68.67	71.20	81.64	83.37		
	Av	61.38	67.78	70.77	82.56	83.36		
Green leaves	I	60.24	68.25	73.96	73.12	76.56	70.39	2.62
	II	61.78	68.23	73.88	75.03	72.80		
	Av	61.01	68.24	73.92	74.08	74.68		
Dead leaves	I				75.42	76.81	76.58	0.27
	II	-	-	-	77.20	76.87		
	Av				76.31	76.84		
Leaf sheath	I	63.29	73.47	77.52	80.23	79.36	74.83	3.24
	II	63.39	71.17	77.48	80.24	82.18		
	Av	63.34	72.32	77.50	80.24	80.77		
Stem	I		64.63	73.20	86.37	84.83	77.29	5.12
	II	-	64.77	73.21	84.31	86.97		
	Av		64.70	73.21	85.34	85.90		
Inflorescence Stalk	I				85.88	87.94	86.95	0.99
	II	-	-	-	86.04	87.91		
	Av				85.96	87.93		

Table 6: Percentage Acid Detergent Fibre content of the whole forage and its component morphological plant parts with growth.

Plant part		Harvest period(week of growth)						
		6	8	10	12	14	Mean	S.E
Whole forage	I	31.49	37.43	38.70	51.07	53.17		
	II	33.53	37.49	38.73	49.93	51.31	42.29	73.17
	Av	32.51	37.46	38.72	50.50	52.24		
Green leaves	I	31.48	36.97	38.20	40.17	39.75		
	II	31.38	38.98	40.32	40.21	41.89	37.94	2.62
	Av	31.43	37.98	39.26	40.19	40.82		
	I				43.62	41.07		
Dead leaves	II	-	-	-	43.63	44.83	43.27	0.27
	Av				43.63	42.95		
	I	38.17	40.36	46.13	53.31	53.21		
Leaf sheath	II	38.20	41.22	46.18	53.48	52.39	46.27	3.24
	Av	38.19	40.79	46.16	53.40	52.80		
	I		33.86	38.89	53.27	54.83		
Stem	II	-	33.89	40.85	51.13	55.43	45.27	5.12
	Av		33.88	39.87	52.20	55.13		
Inflorescence	I				50.34	57.42		
Stalk	II	-	-	-	51.26	57.36	54.10	0.99
	Av				50.80	57.39		

ABLE 7

% Cellulose content of the whole forage and its component morphological arts with growth

Plant part		Harvesting time (week of growth)						
		6	8	10	12	14	Mean	S.E
Whole forage	I	23.91	28.75	31.02	43.16	42.76	34.36	3.86
	II	25.29	29.65	31.16	43.22	44.71		
	AV	24.60	29.20	31.09	43.19	43.74		
Green leaves	I	22.84	26.54	30.28	34.88	34.13	29.86	2.30
	II	23.26	26.60	30.23	35.62	34.07		
	AV	23.05	26.57	30.26	35.25	34.10		
Dead leaves	I	-	-	-	31.83	32.94	32.41	0.56
	II				31.86	32.98		
	AV				31.85	32.96		
Leaf sheath	I	28.97	32.99	37.09	41.56	41.20	36.37	2.42
	II	28.98	32.96	37.18	41.72	41.04		
	AV	28.98	32.98	37.14	41.64	41.12		
Stem	I	-	35.18	35.63	48.14	46.42	41.58	3.57
	II		35.13	35.69	48.15	48.28		
	AV		35.16	35.66	48.15	47.35		
Inflorescence stalk	I	-	-	-	40.95	45.87	43.91	2.95
	II				40.97	47.82		
	AV				40.96	46.85		

TABLE 8
% Acid detergent lignin content of the whole forage and its components morphological parts with growth

Plant part		Harvesting time (week of growth)						
		6	8	10	12	14	Mean	S.E
Whole	I	2.43	2.70	3.17	6.01	6.88		
	II	2.35	2.73	3.79	6.11	6.82	4.30	0.91
forage	AV	2.39	2.72	3.48	6.06	6.85		
Green	I	2.32	2.99	3.72	3.48	4.02		
	II	2.40	2.94	3.66	3.55	4.20	3.33	0.30
leaves	AV	2.36	2.97	3.69	3.52	4.11		
Dead	I				4.47	5.06		
	II	-	-	-	3.17	5.12	4.71	0.39
Leaves	AV				4.32	5.09		
Leaf	I	2.51	3.07	3.10	5.31	6.22		
	II	2.57	3.19	3.13	5.57	6.16	4.08	0.72
sheath	AV	2.54	3.13	3.12	5.44	6.19		
	I		1.63	4.15	6.80	7.54		
Stem	II	-	1.51	4.17	6.82	7.78	5.05	1.38
	AV		1.57	4.16	6.81	7.66		
Inflorescence	I				8.24	10.43		
	II	-	-	-	8.18	10.39	9.31	1.10
stalk	AV				8.21	10.41		

TABLE 9

Changes *in vitro* dry matter digestibility of the whole forage and its component morphological parts with growth

Plant part		Harvesting time (week of growth)						
		6	8	10	12	14	Mean	S.E
Whole	I	67.31	64.92	54.40	39.43	39.23		
	II	68.67	62.91	54.11	42.51	37.77	53.23	
forage	AV	67.99	63.92	54.26	41.47	38.50		
Green	I	68.21	66.61	55.15	46.88	45.69		
	II	68.99	61.29	55.58	51.35	42.65	56.24	
leaves	AV	68.60	63.95	55.37	49.12	44.17		
Dead	I				37.11	37.52		
	II	-	-	-	41.18	34.94	37.69	
Leaves	AV				39.15	36.23		
Leaf	I	62.59	65.07	51.09	40.35	32.35		
	II	66.99	60.38	54.78	41.75	33.56	50.90	
Sheath	AV	64.79	62.73	52.94	41.07	32.96		
	I		68.36	69.81	40.98	40.99		
Stem	II	-	69.23	63.27	42.11	38.73	54.19	
	AV		68.80	66.54	41.55	39.86		
Inflorescence	I				30.88	30.70		
	II	-	-	-	31.50	30.24	30.83	
stalk	AV				31.19	30.47		

ABLE 10: Changes in hydrogen cyanide (HCN) content of "wild sorghum" (sorghum arundinaceum) with growth

Growth period (week)		HCN content mg/kg DM bases
6	I	531.8
	II	528.2
	AV	530.0
8	I	466.2
	II	475.8
	AV	471.0
10	I	350.0
	II	342.8
	AV	346.4
12	I	312.2
	II	308.6
	AV	310.3
14	I	218.2
	II	226.3
	AV	222.3

able 11. Percentage dry matter (DM) content of material prior to ensiling and silage (secondary growth)

Treatment	Fresh herbage (MAT*)	Ensiling material storage period (days)			
		28	56	84	112
Unwilted sorghum with nothing added	20.13	20.38	17.78	17.84	17.89
	20.73	19.21	18.80	18.63	18.67
	20.43	19.80	18.29	18.24	18.28
Unwilted sorghem with formic acid (0.5%)	20.14	20.28	17.40	18.73	20.98
	21.60	19.94	20.02	21.24	20.45
	20.87	20.11	18.71	19.99	20.72
Sorghum wilted in the sun for six hours	45.20	35.96	38.07	33.34	30.66
	45.71	38.06	36.71	33.97	32.51
	45.46	37.01	37.39	33.66	31.59
Unwilted sorghum (70%) combined with leucaena (30%)	28.45	21.92	21.80	17.00	16.22
	26.37	20.03	19.13	16.86	18.76
	27.41	20.98	20.47	16.93	17.49
Leucaena	25.43				
	25.39				
	25.41				

MAT = MATERIAL

Table 12. Percentage dry matter (DM) content of material prior to ensiling and silage (tertiary growth)

Treatment	Fresh material	Ensiling material storage period (days)			
		28	56	84	112
Unwilted sorghum with nothing added	29.71	30.01	29.21	28.95	24.67
	28.80	26.43	26.56	27.02	22.63
	29.25	28.22	27.89	27.99	23.65
Unwilted sorghum with formic acid (0.5%)	27.07	26.78	30.20	27.88	26.43
	27.04	26.56	28.22	25.92	26.47
	27.06	26.67	29.21	26.90	26.45
Sorghum wilted in the sun for six hours	48.32	39.64	42.76	43.39	38.99
	45.25	41.62	41.34	43.32	37.88
	46.79	40.63	42.05	43.36	38.44
Unwilted sorghum (70%) combined with leucaena (30%)	29.43	27.60	28.28	26.64	24.93
	29.85	27.38	25.63	28.52	26.14
	29.64	27.49	26.96	27.58	25.54
Leucaena	34.27				
	32.35				
	33.31				

able 13. % crude protein content (DM basis) of material prior to ensiling and silage (secondary growth)

Treatment	Fresh herbage	Ensiling material storage period (days)			
		28	56	84	112
Unwilted sorghum with nothing added	6.02 5.94 5.98	6.01 6.26 6.14	6.02 5.99 6.10	5.87 6.48 6.18	6.21 6.55 6.38
Unwilted sorghum with formic acid (0.5%)	5.72 5.70 5.71	5.81 5.86 5.84	6.07 5.88 5.98	5.47 5.90 5.69	5.50 5.42 5.45
Sorghum wilted in the sun for six hours	5.02 5.22 5.12	5.32 5.19 5.26	5.27 5.20 5.24	4.98 5.16 5.07	5.01 4.96 4.99
Unwilted sorghum (70%) combined with leucaena (30%)	22.28 22.08 22.18	23.12 22.07 22.60	22.87 21.69 22.28	24.34 23.87 24.11	23.22 23.35 23.29
Leucaena	31.86 33.88 32.87				

Table 14. % Crude protein content (DM basis) of material prior to ensiling and silage (tertiary growth)

Treatment	Before ensiling	Ensiling material storage period (days)			
		28	56	84	112
Unwilted sorghum with nothing added	6.39 6.29 6.34	6.30 6.29 6.27	6.21 6.16 6.19	6.40 6.56 6.48	6.99 7.05 7.02
Unwilted sorghum with formic acid (0.5%)	6.34 6.47 6.41	6.50 6.22 6.36	6.20 6.29 6.25	6.29 6.30 6.30	6.08 6.12 6.10
Sorghum wilted in the sun for six hours	5.97 5.95 5.96	5.99 6.08 6.04	6.03 6.02 6.03	6.18 6.44 6.26	6.40 6.50 6.45
Unwilted sorghum (70%) combined with leucaena (30%)	26.90 24.76 25.83	24.30 24.39 24.35	25.19 25.20 25.20	23.86 23.82 23.84	22.47 21.53 22.00
Leucaena	36.40 36.30 36.35				

Table 15: pH content of ensilage material as infleunced by ensiling periods and treatments (secondary growth)

Treatment	Storage periods (days)			
	28	56	84	112
Unwilted sorghum with nothing added	5.06 4.96 5.01	4.83 4.81 4.82	5.03 5.03 5.03	5.30 5.24 5.27
Unwilted sorghum with formic acid (0.5%)	4.06 4.10 4.08	4.12 4.11 4.12	4.03 4.17 4.10	4.28 4.28 4.28
Sorghum wilted in the sun for six hours	4.85 5.01 4.96	4.96 4.98 4.97	5.10 5.03 5.07	5.28 5.43 5.32
Unwilted sorghum (70%) combined with leucaena (30%)	5.09 5.03 5.06	5.26 5.22 5.24	5.02 5.14 5.08	5.18 5.14 5.16

Table 16: pH content of ensilage material as influenced by ensiling periods and treatments (tertiary growth)

Treatment	Storage periods (days)			
	28	56	84	112
Unwilted sorghum with nothing added	5.09 5.81 4.91	4.86 4.87 4.87	5.02 5.21 5.12	5.14 5.02 5.08
Unwilted sorghum with formic acid (0.5%)	4.00 4.25 4.13	4.26 4.45 4.36	4.39 4.38 4.39	4.40 4.49 4.45
Sorghum wilted in the sun for six hours	5.06 5.00 5.03	4.92 4.91 4.92	5.16 5.16 5.16	5.36 5.50 5.43
Unwilted sorghum (70%) combined with leucaena (30%)	5.21 4.97 5.09	5.05 4.97 5.01	5.23 5.53 5.38	5.26 5.42 5.34

Table 17: Total organic acids (secondary growth silage) $1 \times 10^5 \mu M/kg$ (DM basis)

Treatment	Storage periods (days)			
	28	56	84	112
Unwilted sorghum with nothing added	0.53 0.62 0.58	1.09 1.03 1.06	1.36 1.15 1.26	1.68 1.82 1.75
Unwilted sorghum with formic acid (0.5%)	0.99 0.82 0.91	1.20 1.16 1.18	1.58 1.42 1.50	1.83 1.69 1.76
Sorghum wilted in the sun for six hours	1.03 0.98 1.01	1.45 1.36 1.41	1.93 1.82 1.88	2.01 2.31 2.16
Unwilted sorghum (70%) combined with leucaena (30%)	0.47 0.56 0.52	1.07 0.96 1.02	1.46 1.22 1.34	1.64 1.84 1.75

Table 18: Total organic acids (tertiary growth silage) 1 X 10^5 µM/kg (DM basis)

Treatment	Storage periods (days)			
	28	56	84	112
Unwilted sorghum with nothing added	0.41 0.48 0.45	1.06 1.09 1.08	1.34 1.38 1.36	1.78 1.81 1.80
Unwilted sorghum with formic acid (0.5%)	0.99 0.97 0.98	1.21 1.26 1.24	1.58 1.15 1.37	1.85 1.85 1.84
Sorghum wilted in the sun for six hours	1.37 1.09 1.23	1.45 1.43 1.44	1.92 1.96 1.94	2.31 2.30 2.31
Unwilted sorghum (70%) combined with leucaena (30%)	0.89 0.86 0.88	1.13 1.18 1.16	1.54 1.36 1.45	1.82 1.84 1.83

Table 19. Ammonia -nitrogen (secondary growth) mg/100g silage (DM basis)

Treatment	Storage periods (days)			
	28	56	84	112
Unwilted sorghum with nothing added	107.24 107.28 107.26	125.76 106.66 116.21	140.03 142.09 141.06	164.28 122.50 143.39
Unwilted sorghum with formic acid (0.5%)	86.82 90.78 88.80	94.21 91.89 93.05	124.50 108.52 116.51	125.76 105.95 115.86
Sorghum wilted in the sun for six hours	126.80 120.94 123.87	141.44 148.32 144.88	158.39 162.31 160.35	179.51 165.33 172.42
Unwilted sorghum (70%) combined with leucaena (30%)	205.68 205.57 205.63	273.83 267.23 270.53	294.32 305.58 299.95	305.68 301.56 303.62

Table 20. Ammonia -nitrogen (tertiary growth) mg/100g silage (DM basis)

Treatment	Storage periods (days)			
	28	56	84	112
Unwilted sorghum with nothing added	117.24	108.62	127.31	122.64
	92.48	108.60	110.85	122.58
	104.86	108.61	118.68	122.61
Unwilted sorghum with formic acid (0.5%)	80.04	96.43	94.87	108.23
	78.76	102.83	96.37	118.25
	79.40	99.63	95.62	113.24
Sorghum wilted in the sun for six hours	120.83	136.87	144.84	157.60
	118.49	131.85	148.32	155.26
	119.66	134.36	146.58	156.43
Unwilted sorghum (70%) combined with leucaena (30%)	186.70	239.35	281.38	254.88
	199.44	234.69	247.68	265.82
	193.07	237.02	264.53	260.35

TABLE 21

% Neutral detergent fibre content (DM basis) of material prior to ensiling and silage (secondary growth)

Treatment	Before ensiling	Ensiled material			
		Storage period (days)			
		28	56	84	112
Unwilted sorghum with nothing added	75.94	75.28	74.99	72.86	72.84
	77.92	77.34	74.96	74.90	74.86
	76.93	76.31	74.98	73.88	73.85
Unwilted sorghum with formic acid (0.5%)	76.50	73.01	72.74	73.66	72.53
	76.04	77.11	74.80	73.78	70.45
	76.27	75.06	73.77	73.72	71.49
Sorghum wilted in the sun for six hours	77.35	74.27	72.84	70.96	71.52
	77.34	74.45	72.62	70.94	71.48
	77.35	74.36	72.73	70.95	71.50
Unwilted sorghum (70%) combined with lencaena (30%)	65.20	64.12	63.28	62.31	60.92
	65.61	66.13	64.46	59.87	62.86
	65.41	65.13	62.37	61.09	61.89
Leucaena	34.23				
	38.31				
	36.27				

Table 22. % Neutral detergent fibre NDF (DM basis) of material prior to ensiling and silage (tertiary growth)

Treatment	Before ensiling	Ensiling material storage period (days)			
		28	56	84	112
Unwilted sorghum with nothing added	79.01 79.41 79.21	79.35 77.33 78.34	77.68 76.88 77.28	70.87 72.15 71.51	73.24 72.89 73.07
Unwilted sorghum with formic acid (0.5%)	77.63 79.60 78.62	76.43 76.59 76.51	72.73 74.27 73.50	73.64 74.02 73.83	73.11 75.30 74.21
Sorghum wilted in the sun for six hours	79.64 81.14 80.39	77.58 76.14 76.86	75.47 68.58 72.03	70.88 72.63 71.76	72.81 71.99 72.40
Unwilted sorghum (70%) combined with leucaena (30%)	68.30 68.42 68.37	66.41 66.20 66.32	61.84 63.39 62.62	59.87 61.23 60.55	61.47 58.25 59.86
Leucaena	39.37 38.77 39.07				

TABLE 23

% Acid detergent fibre (ADF) content (DM basis) of material prior to ensilin and silage (tertiary growth)

Treatment	Before ensiling	Ensiled material			
		Storage period (days)			
		28	56	84	112
Unwilted sorghum with nothing added	44.55	49.81	47.19	46.95	47.74
	45.87	50.06	46.05	46.99	46.16
	45.21	49.93	46.62	46.92	46.93
Unwilted sorghum with formic acid (0.5%)	47.06	47.28	46.77	47.08	46.34
	44.90	48.51	46.73	46.71	45.79
	45.98	47.89	46.75	46.89	46.07
Sorghum wilted in the sun for six hours	44.51	47.42	44.57	45.67	45.32
	48.27	48.24	44.30	46.37	44.87
	46.39	47.83	44.44	46.02	45.10
Unwilted sorghum (70%) combined with lencaena (30%)	30.82	32.84	31.58	34.45	32.16
	34.70	33.66	32.26	31.77	33.04
	32.76	33.25	31.92	33.11	32.60
Leucaena	21.45				
	21.46				
	21.46				

TABLE 24

% Acid detergent fibre (ADF) content (DM basis) of material prior to ensil and silage (tertiary growth)

Treatment	Before ensiling	Ensiled material			
		Storage period (days)			
		28	56	84	112
Unwilted sorghum with nothing added	47.24	47.06	52.66	48.36	50.06
	52.09	51.63	50.01	47.25	48.36
	49.67	49.35	51.34	47.81	49.21
Unwilted sorghum with formic acid (0.5%)	49.12	47.54	44.76	46.25	43.87
	48.35	48.05	46.86	46.41	45.63
	48.74	47.80	45.81	46.33	44.75
Sorghum wilted in the sun for six hours	44.69	48.26	47.76	46.24	46.90
	49.96	49.58	53.03	45.86	49.87
	47.33	48.92	50.40	46.05	48.39
Unwilted sorghum (70%) combined with lencaena (30%)	34.89	33.85	40.19	40.85	34.26
	35.45	40.58	34.59	36.24	37.52
	35.17	37.22	37.39	38.55	35.89
Leucaena	23.26				
	22.35				
	22.81				

TABLE 25

% Cellulose content (DM basis) of material prior to ensiling and silage (secondary growth)

Treatment	Before ensiling	Ensiled material			
		Storage period (days)			
		28	56	84	112
Unwilted sorghum with nothing added	36.90	37.43	36.33	34.74	36.44
	34.80	36.42	33.98	39.65	36.38
	35.85	36.92	35.16	37.20	36.41
Unwilted sorghum with formic acid (0.5%)	35.38	36.27	36.36	34.82	35.07
	36.70	37.52	37.65	38.63	36.13
	36.04	36.90	37.05	36.73	35.60
Sorghum wilted in the sun for six hours	32.21	37.54	34.03	33.38	33.07
	36.20	37.28	34.47	37.45	34.83
	34.21	37.41	34.25	35.42	33.95
Unwilted sorghum (70%) combined with lencaena (30%)	25.56	26.98	25.53	24.06	26.08
	25.37	26.82	27.52	25.16	23.72
	25.47	26.90	26.53	24.61	24.90
Leucaena	15.89				
	13.90				
	14.90				

TABLE 26

% Cellulose content (DM basis) of material prior to ensiling and silage (tertiary growth)

Treatment	Before ensiling	Ensiled material			
		Storage period (days)			
		28	56	84	112
Unwilted sorghum with nothing added	36.80	37.54	39.16	35.48	34.73
	36.72	39.20	38.82	37.23	36.24
	36.75	38.37	38.89	36.36	35.49
Unwilted sorghum with formic acid (0.5%)	36.42	35.70	32.66	35.21	37.28
	36.38	37.82	35.96	36.01	35.87
	36.40	36.76	34.31	35.61	36.58
Sorghum wilted in the sun for six hours	34.85	38.51	36.85	34.92	36.01
	36.39	38.36	37.23	38.23	33.56
	35.62	38.44	37.04	36.58	34.79
Unwilted sorghum (70%) combined with leucaena (30%)	25.82	27.62	28.39	24.63	26.04
	26.46	29.73	25.64	25.89	24.03
	26.14	28.68	27.02	25.26	25.04
Leucaena	13.58				
	15.18				
	14.38				

TABLE 27

% ADL content (DM basis) of material prior to ensiling and silage (secondary growth)

Treatment	Before ensiling	Ensiled material			
		Storage period (days)			
		28	56	84	112
Unwilted sorghum with nothing added	6.77	7.48	6.53	6.94	6.38
	6.79	6.35	7.14	7.09	6.86
	6.79	6.92	6.83	7.02	6.62
Unwilted sorghum with formic acid (0.5%)	7.00	6.69	8.07	7.10	7.34
	7.02	6.87	7.12	6.98	6.47
	7.01	6.78	7.60	7.04	6.90
Sorghum wilted in the sun for six hours	6.58	6.58	6.92	6.75	7.08
	6.38	6.47	6.27	6.64	6.47
	6.48	6.53	6.60	6.70	6.78
Unwilted sorghum (70%) combined with leucaena (30%)	6.16	6.28	6.12	6.02	5.64
	6.06	6.04	5.98	6.06	6.32
	6.11	6.16	6.05	6.04	5.98
Leucaena	4.78				
	5.84				
	5.31				

TABLE 28

% Acid detergent lignin ADL (DM basis) of material prior to ensiling and silage (tertiary growth)

Treatment	Before ensiling	Ensiled material			
		Storage period (days)			
		28	56	84	112
Unwilted sorghum with nothing added	6.78 7.13 7.00	7.18 7.25 7.21	7.44 6.77 7.11	6.99 7.15 7.02	7.05 7.01 7.03
Unwilted sorghum with formic acid (0.5%)	7.17 6.95 7.07	7.11 7.04 7.08	7.28 6.87 7.08	7.18 6.94 7.06	6.87 6.94 6.91
Sorghum wilted in the sun for six hours	6.47 6.94 6.71	6.70 7.16 6.93	7.22 6.94 7.08	6.87 6.78 6.83	6.99 7.01 7.00
Unwilted sorghum (70%) combined with leucaena (30%)	6.43 6.18 6.31	6.29 6.44 6.37	6.67 6.18 6.43	6.23 6.42 6.33	5.97 6.24 6.11
Leucaena	5.99 6.07 6.03				

TABLE 29

In Vitro dry matter digestibility (IVDMD) of silage as influenced by duration of ensilage and treatments (secondary growth)

Treatment	Percentage			
	Ensiling period (Days)			
	28	56	84	112
Unwilted sorghum with nothing added	46.20 47.36 46.78	43.49 43.71 43.60	41.37 39.45 40.41	39.61 38.84 39.23
Unwilted sorghum with formic acid forming 0.5%	47.04 45.90 46.47	40.01 41.81 40.91	38.73 44.48 41.61	44.26 40.43 42.35
Sorghum wilted in the sun for six hours	43.41 44.90 44.16	43.66 39.57 41.62	35.21 35.22 35.22	36.32 35.01 35.67
Unwilted sorghum (70%) comb. with leucaena (30%)	48.12 50.57 49.35	43.39 45.03 44.21	44.29 41.07 42.68	45.15 44.47 44.81

TABLE 30

In Vitro dry matter digestibility (IV DMD) of silage as influenced by duration of ensilage and treatments (tertiary growth)

Treatment	Percentage			
	Ensiling period (Days)			
	28	56	84	112
Unwilted sorghum with nothing added	39.54 41.74 40.64	40.92 37.83 39.38	38.42 38.36 38.39	38.12 39.09 38.61
Unwilted sorghum with formic acid forming 0.5%	46.34 42.73 44.54	39.88 38.51 39.20	40.15 36.24 38.20	37.70 37.24 37.47
Sorghum wilted in the sun for six hours	42.72 40.25 41.49	36.83 40.93 38.88	38.61 40.52 39.57	39.16 40.19 39.91
Unwilted sorghum (70%) comb. with leucaena (30%)	47.00 47.37 47.18	42.96 42.67 42.82	40.21 41.94 41.08	40.93 38.64 39.79

TABLE 31

HCN content (DM basis) of materials prior to ensiling and silage (secondary growth) mg (Dm) kg^{-1}

Treatment	Before ensiling	Ensiled material			
		Storage period (Days)			
		28	56	84	112
Unwilted sorghum with nothing added	361.1	302.7	263.4	218.3	193.7
	367.3	293.5	272.1	216.6	187.4
	364.2	298.1	267.75	217.5	190.6
Unwilted sorghum with formic acid (0.5%)	358.7	287.6	257.8	253.6	188.6
	360.8	298.3	251.3	235.6	171.3
	359.8	293.0	254.6	244.6	180.0
Sorghum wilted in the sun for six hours	312.1	256.7	216.7	199.7	143.2
	317.5	254.8	215.3	186.5	139.8
	314.8	255.8	216.0	193.1	141.5
Unwilted sorghum (70%) comb. with lencaena (30%)	268.7	198.4	165.2	125.6	108.3
	243.6	207.3	168.7	132.7	96.5
	256.2	202.8	167.0	129.2	102.4

TABLE 32

HCN content (DM basis) of materials prior to ensiling and silage (tertiary growth) mg/kg (Dm basis)

Treatment	Before ensiling	Ensiled material			
		Storage period (Days)			
		28	56	84	112
Unwilted sorghum with nothing added	351.5	312.0	248.3	199.7	173.8
	352.8	306.5	251.2	212.6	174.3
	352.15	309.3	249.8	206.15	172.6
Unwilted sorghum with formic acid (0.5%)	343.7	304.7	239.7	207.4	182.4
	341.6	298.6	251.8	214.7	180.3
	342.7	301.7	245.8	211.1	181.4
Sorghum wilted in the sun for six hours	297.8	237.6	196.5	167.4	130.8
	316.2	246.5	220.8	176.9	129.7
	307.0	242.1	208.7	172.2	130.3
Unwilted sorghum (70%) comb. with lencaena (30%)	253.7	188.6	153.2	110.8	98.3
	241.8	192.7	160.0	130.6	92.0
	247.8	190.7	156.6	120.7	95.2

TABLE 33 Analysis of variance for percentage germination of "wild sorghum" as influenced by duration of ensilage and treatments.

Source	Sum of squares	D.F.	Mean square	F Ratio	Prob.
Cols (HT)*	7477.083	5	1495.417	76.362	1.000E-13
Rows (T)*	6285.833	4	1571.458	80.245	0.000E+00
Interaction	3054.167	20	152.708	7.798	3.919E-07
Error	587.500	30	19.583	-	-
Total	17404.583	59	-	-	-

* HT-HARVEST TIME

* T-TREATMENTS

TABLE 34 Regression equation for HCN content of whole forage (sorghum arundinaceum)

Regression equation: $Y = 764.30 - 38.85 * X$

where Y = Growth period

X = HCN content

Significant of slope: $T = 11.62634$

$df = 3$

$p = 1.366769E - 0.3$

The slope of this line is significantly different than 0.

Confidence limits on the slope can be calculated as

$- 38.85 +/- T(3) * 3.34$

TABLE 35 Analysis of variance for dry matter content of silage influenced by duration of ensilage and treatments.

Source	Sum of squares	D.F.	Mean square	F Ratio	Prob.
Cols (DS)*	29.391	3	9.797	.327	.8060
Rows (T)*	1336.709	3	445.570	14.862	6.908E+05
Interaction	16.188	9	1.799	0.060	0.9999
Error	479.689	16	29.981	-	-
Total	1861.977	31	-	-	-

*DS - Duration of ensilage

*T - Treatment

TABLE 36 Analysis of variance for crude protein content of silage as influenced by duration of ensilage and treatments.

Source	Sum of squares	D.F.	Mean Square	F Ratio	Prob.
Cols (DS)*	0.329	3	0.110	0.177	0.9104
Rows (T)*	1830.798	3	610.266	986.642	2.000E-14
Interaction	2.254	9	0.250	0.405	0.9143
Error	9.896	16	.619	-	-
Total	1843.277	31	-	-	-

DS* - Duration of ensilage

T* - Treatment

TABLE 37 Analysis of variance for crude protein content of silage as influenced by duration of ensilage and treatments.

Source	Sum of squares	D.F.	Mean square	F Ratio	Prob.
Cols (DS)*	0.359	3	0.083	0.322	0.8094
Rows (T)*	4.576	3	1.525	5.885	6.615E-03
Interaction	2.611	9	0.290	1.119	0.4037
Error	4.147	16	0.259	-	-
Total	11.693	31	-	-	-

DS* - Duration of ensilage

T* - Treatment

TABLE 38 Analysis of variance for total organic acids of silage as influenced by duration of ensilage and treatments.

Source	Sum of squares	D.F.	Mean square	F Ratio	Prob.
Cols (DS)*	5.060	3	1.687	177.119	1.720E-
Rows (T)*	1.187	3	0.396	41.550	8.876E-
Interaction	0.136	9	0.015	1.589	0.2007
Error	0.156	16	9.5219E-03	-	-
Total	6.535	31	-	-	-

DS* - Duration of ensilage

T* - Treatment

TABLE 39 Analysis of variance for ammonia-nitrogen content of silage as influenced by duration of ensilage and treatments.

Source	Sum of squares	D.F.	Mean square	F Ratio	Prob.
Cols (DS)*	10138.229	3	3379.410	16.504	3.739E-05
Rows (T)*	113354.408	3	37784.803	184.532	1.240E-12
Interaction	3095.479	9	0.250	0.405	0.1743
Error	3279.168	16	204.761	-	-
Total	129864.285	31	-	-	-

DS* - Duration of ensilage

T* - Treatment

TABLE 40 Analysis of variance for NDF values of silage as influenced by duration of ensilage and treatments.

Source	Sum of squares	D.F.	Mean square	F Ratio	Prob.
Cols (DS)*	80.860	3	26.953	21.910	6.546E-06
Rows (T)*	801.709	3	267.236	217.228	3.400E-13
Interaction	10.712	9	1.190	0.967	0.4997
Error	19.683	16	1.230	-	-
Total	912.964	31	-	-	-

DS* - Duration of ensilage

T* - Treatment

TABLE 41 Analysis of variance for ADF values of silage as influenced by duration of ensilage and treatments.

Source	Sum of squares	D.F.	Mean square	F Ratio	Prob.
Cols (DS)*	12.306	3	4.102	0.823	0.5001
Rows (T)*	942.840	3	314.280	63.062	4.403E-09
Interaction	9.000	9	1.000	0.201	0.9904
Error	79.739	16	4.984	-	-
Total	1043.885	31	-	-	-

DS* - Duration of ensilage

T* - Treatment

TABLE 42 Analysis of variance for cellulose of silage as influenced by duration of ensilage and treatments.

Source	Sum of squares	D.F.	Mean square	F Ratio	Prob.
Cols (DS)*	20.633	3	6.878	5.229	0.0105
Rows (T)*	630.628	3	210.209	159.835	3.930E-12
Interaction	8.563	9	0.951	0.723	0.6821
Error	21.043	16	1.315	-	-
Total	680.866	31	-	-	-

DS* - Duration of ensilage

T* - Treatment

TABLE 43 Analysis of variance for ADL content of silage as influenced b duration of ensilage and treatments.

Source	Sum of squares	D.F.	Mean square	F Ratio	Prob.
Cols (DS)*	0.132	3	0.044	0.980	0.4268
Rows (T)*	3.749	3	1.250	27.788	1.397E-06
Interaction	0.267	9	0.030	0.659	0.7328
Error	0.720	16	0.045	-	-
Total	4.868	31	-	-	-

DS* - Duration of ensilage

T* - Treatment

TABLE 44 Analysis of variance for *in vitro* dry matter digestibility of silage as influenced by duration of ensilage and treatments.

Source	Sum of squares	D.F.	Mean square	F Ratio	Prob.
Cols (DS)*	155.495	3	51.832	8.906	1.056E-03
Rows (T)*	83.486	3	27.829	4.782	0.0145
Interaction	9.515	9	1.057	0.182	0.9932
Error	341.616	16	5.820	-	-
Total	341.616	31	-	-	-

DS* - Duration of ensilage

T* - Treatment

TABLE 45 Analysis of variance for HCN content of silage as influenced b duration of ensilage and treatments

Source	Sum of squares	D.F.	Mean square	F Ratio	Prob.
COLS (DS)*	55206.464	3	18402.155	175.181	1.830E-12
ROWS (T)*	47551.823	3	15850.608	150.891	6.080E-12
INTERACTION	827.768	9	91.974	0.876	0.5651
ERROR	1680.746	16	105.047	-	-
TOTAL	105266.801	31	-	-	-

DS* - Duration of ensilage T* - Treatment