EVALUATION OF SEED YIELD AND VIABILITY OF SOME FORAGE CROPS IN GHANA

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DECLARATION

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

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DEDICATION

Dedicated to the Glory of God and my uncle Mr. Alex Gyasi-Sarkodie who has seen me through my education.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

ABSTRACT

Three experiments were carried out at the University of Ghana Agricultural Research Station, Legon, from November, 1999 to November, 2000, to assess field establishment and seed yield of five forage crops at various harvest periods and how their germination can be enhanced to improve pasture production in the country. The studies also examined the influence of storage of the seeds at room temperature, fridge and cold room and duration of storage on seed viability. High seed yields were obtained for *Macroptilium lathyroides* and *Macroptilium atropurpereum*, which were 22.63 kg/ha and 22.40 kg/ha respectively when they were harvested at three weeks after flower opening. Yields of subsequent harvest were poor. The seed yields of *Cenchrus ciliaris* and *Panicum maximum* were significantly higher than that of *Andropogon gayanus*. Time of harvesting significantly (p,0.05) influenced seed yield in the forage legumes and the grasses being 13.33 kg/ha and 22.7 kg/ha in the 3rd week harvest respectively for *C. ciliaris* and *P. maximum* while that of *Andropogon guyanus* had 3.07 kg/ha. Germination percentage of *M. lathyroides* and *M. atropurpureum* seeds harvested at both three and four weeks after flowering ranged between 80.6% over the 4 months of storage under the various conditions. For the grasses *C. ciliaris* had germination percentage of between 18.2% and

30.7% while *A. gayanus* had between 5.4% and 13.2% over the study period with no germination for *P. maximum.*

Coldroom storage gave higher germination percentage and rate of germination for *M. atropurpureum. C. ciliaris* and A. gayanus while storage in fridge gave highest germination percentage for *M. lathyroides*. Seeds of *C. ciliaris* and *A. gayanus* harvested at five week after flowering had highest germination percentage under the various storage treatments.

A study to determine efficient methods of breaking seed dormancy in the legumes seeds revealed that mechanically scarified seeds of *M. lathyroides* and *M. atropurpureum* had highest germination percentages. With the grasses mechanically scarified seeds of *C. ciliaris* and *A. gayanus* had lower germination percentages. Soaking of seeds in water for 14 hours gave a high germination percentage for *C. ciliaris* compared to no treatment. *Panicum maximum* seeds did not germinate over the study period.

It is recommended that seeds of *M. lathyroides* and *M. atropurpureum* should be mechanically scarified before sowing to enhance higher germination. Since seed shattering occurred greatly after the third week of harvest, effort should be made to harvest these legume and grass seeds early to avoid loss of seeds during harvest.

It is also recommended that seeds of *M. atropurpureum, C. ciliaris* and *A. gayanus* Should be stored in a cold room in order to get higher germination percentage while *M. lathyroides* should be stored in a fridge. Vegetative propagation could be used to establish pastures from *A. gayanus* as low germination percentage was obtained from the seeds

Finally, it is recommended that further studies should be carried out on *P. maximum* to find effective ways of improving its germinability since the work done showed that none of the seeds germinated under the various dormancy breaking methods or storage conditions.

CHAPTER ONE

INTRODUCTION

Ruminant livestock depend on natural grassland, cut herbage, crop residues and agro-industrial by-products such as rice bran for their nutritional needs (Whiteman, 1980). However, there is a reduction in the area under natural grasslands for grazing as a result of growing human population with consequent demand for cropping, settlement, industrial and infrastructure development. Land use is thus being intensified for livestock production and this calls for the improvement of the dwindling natural grassland.

In Ghana, forage seeds are usually imported even though some forage seeds can be produced abundantly and cheaply in the country. Sown pastures and intensively grown fodder form an insignificant proportion of feed provision and these are mainly practised on government livestock production stations, research stations and a few elite farms and ranches.

There is the need for farmers to establish high yielding sown pastures on limited land area in order to get adequate feed for their animals. Widespread use of forage depends upon the availability of cheap seed material, which is true to type, viable, free from diseases and weeds and which will reliably establish good pastures when sown (Skerman, 1977; Humphreys and Riveros, 1986). Plant breeders and agronomists have concentrated on increasing the forage yield and nutritive value with little attention given to seed production, which will determine how widely the new variety would be used (FAO, 1990a).

One of the problems of pasture production has been its high cost and often the unavailability of forage seeds. A reliable source of inexpensive seeds would help farmers to establish large areas of land for grazing leading to increase animal production in the country (Hare, 1985). Unfortunately forage seed production is one area not much researched into in Ghana. Seed is both important in commercial agriculture as a basic commodity for the propagation of crops and perpetuation of germ plasm (Larbi, 1979).

There is therefore the need to research into the possibility of producing forage seeds cheaply and abundantly in this country for the livestock farmers, to increase forage availability for the livestock industry. The quality of seed produced especially with respect to viability is equally important.

The main objectives of this study were to:

(a) assess the seed yield of some forage legumes and grasses at different times of harvesting.

(b) compare the viability of the seeds under different methods of seed storage, and

(c) determine efficient methods of breaking seed dormancy in these species.

CHAPTER TWO

LITERATURE REVIEW

2.1 Importance of forage seeds

The availability of cheap seeds of high purity and viability helps in establishing pastures (Whiteman, 1980) and to extend the use of improved pastures (Loch, 1984; Skerman, 1977). Leguminous forage seed crops can be sown to provide green manure to replenish organic matter in the soil, add nitrogenous material to the soil and protect soil during periods of high erosion hazards (Skerman, 1977). Seeds help in perpetuating the specie of the organism from generation to generation. Some wild birds depend on forage seeds for their survival.

2.2 Factors influencing productivity and survival of forage seed crops

2.2.1 Climatic factors

The main climatic factors that affect the productivity and survival of forage seed crop are rainfall, temperature, light intensity, day length, humidity and wind (Hare, 1985).

2.2.1.1. Rainfall

For most tropical forage seed crops, a wet season of about four months duration is needed for optimum production (Hare, 1985). An extended wet season or the occurrence of rainfall during the dry season introduces unfavourable conditions, for example, disease problems such as *Rhizoctonia* in *Macroptilium atropurpureum* (Siratro) and *Botrytis* head blight on *Stylosanthes spp*.

A lower limit of 800 mm and an upper limit of 2000 mm of rainfall during the growing season of the seed crop provide a secure income from seed production (Hare, 1985). Reliable well defined wet and dry seasons are needed for optimum seed production (Hopkinson and Eagles, 1980).

During the dry season, rainfall should not exceed 300-400 mm. This is very important for day neutral and quantitative short day crops as too much dry season rainfall will not promote vigorous flowering (Hare, 1985)

Hopkinson (1977) observed that Siratro performs best under a fairly short wet-season and with a winter climate modified by irrigation. With Siratro and Centro, some amount of soil moisture stress is necessary to promote vigorous reproductive activity. Both crops will revert to vegetative growth if there is too much moisture during flowering (Hare, 1985).

2.2.1.2 **Temperature**

Temperature conditions affect vegetative growth, floral initiation, growth and differentiation of the inflorescence, blooming, pollen germination, seed setting and seed maturation (Humphreys and Riveros, 1986).

The maximum temperature for photosynthesis in the tropical grass varies between 35° C to 40° C depending on species and plant age (Whiteman, 1980). Seed setting in tropical plants is adversely affected by low temperatures well above frosting. In most cases high temperatures do not limit seed production of the short day plants during the period of short days.

2.2.1.2. **Light intensity**

Tropical grasses have a greater capacity for growth than temperate grasses under higher light intensity. This is further enhanced by the absence of photorespiration and the maximum efficient C_4 carboxylic system used. Alberda (1962) concluded that provided the supply of water and mineral nutrients is adequate, the rate of pasture growth is principally determined by light intensity after the canopy is formed. Sites, which have a high light intensity receipt, may therefore be expected to have a high seed production potential (Humphreys and Riveros, 1986). Seed yield depends on both high early crop growth, which determines flower numbers and a continued photosynthesis during grain filling (Humphreys and Riveros,1986). Flower opening is more intense in bright sunlight (Hare, 1985). Solar radiation receipt rather than temperature governs pasture growth rate when pasture is in linear phase of growth, that is from the third to the tenth week following defoliation to 2.5 cm above growth (Broughman, 1959). Bears and Waller (1979) found a strong linear relationship between the growth rate of irrigated pasture and the logarithm of radiation under infrequent defoliation with beef cattle.

Seed yield per hectare from cover crops under oil palm, rubber and coconut trees are usually low because of shading effect (Hare, 1985). Most tropical pasture legumes are shade intolerant and so growth and seed production are drastically reduced by low solar radiation.

2.2.1.3. **Daylength**

Photoperiodism, which varies with latitude, influences daily energy input and controls flowering in plants (Skerman, 1977; Whiteman, 1980, Humphreys, 1979). It is thus an important factor in selecting pasture legumes to fit into the various ecological niches found in the tropics and also has a strong effect on seed production. In a wide range of pasture plants, the change from vegetative growth to reproductive development is induced by changing day length. This response is perceived in the leaves of the plant, which transmits a floral stimulus to the vegetative meristem to cause a change to reproductive development (Whiteman, 1980).

For many cultivars the length of day (or more exactly the length of the night period) decides when the flowering will occur or determines the strength of the flowering response (Humphreys and Riveros, 1986). Photoperiod triggers off flowering well in advance of the occurrence of unfavourable climatic conditions and facilitates out crossing by synchronizing flowering in neighbouring plants.

Most tropical grasses and legumes are short day plants but there are few, which are day neutral or long day plants (Hare, 1985). Some species within the same genus act as both long and short day plants. Further than 10° latitude higher from the equator the short day cultivars have clearly defined phases of vegetative and reproductive development and the transition occurs at a reasonable productive time (Hare, 1985). The closer one gets to the equator the more difficult it is to separate these two phases. In such circumstances, heavy seed yields are impossible. In general, tropical seed production should not be established within 10° of the equator (Hare, 1985).

2.2.1.4. **Wind**

Hopkinson and Eagles (1980) found that strong seasonal winds cause lodging of tall grass crops and loss of mature seeds from unevenly ripening grasses such as Setaria and Panicum species. With legumes nearing maturity, heavy dew followed by drying winds can cause premature shattering of pods such as in Siratro (Hopkinson and Eagles, 1980).

2.2.2 Edaphic factors

Provided mineral nutrient deficiencies are recognised and corrected, seed crop of both grasses and legumes may be grown on a wide range of soils (Hare, 1985). Poor drainage delays flowering of legumes, reduces flowering vigour, encourages diseases and delays machine harvesting of crops (Hopkinson and Eagles, 1980).

Acid, saline and waterlogged soils should be avoided. Sites susceptible to intermittent flooding should be avoided or be used for the more tolerant plants such as *Panicum maximum* (Anderson, 1970). Poorly drained sites will be disastrous for *Cenchrus ciliaris; Leucaena leucocephalia or Macrotyloma* *axillare* and cracking clay soils should be avoided for *Stylosanthes humilis* (Anderson, 1970).

2.2.3 Biotic factors

A common problem with surface sown seedling is harvesting by ants. This is common in sowing of *S. humilis and C. ciliaris.* Pelleting of seed with lime or rock phosphate reduces seed loss (Jones, 1975a). Another problem encountered in sowing of *Macroptilium species and Vigna marina* is an attack by beanfly (*Melanagromza phaseoli*). The larvae bore into the stem base and can cause almost 100% loss of plants (Jones, 1965). Disease such as damping off caused by *Phythim sp* can cause the death of the seedling, thus reducing the yields from the seed crop. Rodents such as mice and grasscutters can cut down the seedlings while wild birds can eat the seeds of grass leading to reduced or complete loss of seed production. On natural grasslands, frequent bushfires and overgrazing by livestock can lead to the area being devoid of legume seed.

2.3. **Methods of propagation of forage seed crops**

Forage seed crops can be propagated by seed, vegetative means or by both.

2.3.1. **Vegetative propagation**

Vegetative propagation is the only means by which certain plants can be established. This may be due to the fact that for such plants no viable seeds are produced or propagation through seeds may be so slow that the most convenient way is to use vegetative propagation. A typical example is *pennisetum purpureum* where no viable seeds are produced (Whiteman, 1980).

Vegetative propagation can be done in many ways. The three common methods are by using stem cutting, root-stock or by grafting (Adegbola, 1985, Le Houerou, 1980). Age of stem cuttings, length of the storage time and depth of planting are important factors affecting vegetative propagation (Addo-Kwafo, 1996).

2.3.2 **Seed propagation and factors affecting germination**

The use of seeds for crop or pasture establishment depends on seed germination and seedling establishment. The germination phase is the period from imbibition of the seed and emergence of the plumule and radicle up to the time 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). Hare (1985), Skerman (1977) and Whiteman (1980) cited the minimum germination values of the following forage crops as are the standard defines in Queensland Government seed Regulation (Table 2.1)

Table 2.1 Minimum germination values of some forage crops

Kind of Seed	**Minimum % Germinable Seed**
Stylosanthes hamata	40
Centrosema pubescens	50
Macroptilium atropurpureum	70
Macroptilium lathyroides	70
Lablab purpureus	75
Cenchrus ciliaris	20
Panicum Maximum	25
Paspalum notatum	60
Sorghum almum	65
Brachiaria mutica	15

Standard defined in Queensland Govt. Seed Regulation (Hare, 1985, Skerman, 1977 and Whiteman, 1980)

The various internal and external factors known to affect seed germination are viability and life span of seeds; moisture, temperature, light, gases especially oxygen and seed dormancy (Tackie, 1991).

2.3.3 **Viability and life span of seeds**

Various storage conditions are required to maintain viability for different seeds. Viability is the length of time a seed can retain its ability to germinate (Ellis, Hong and Robert, 1985). The length of time for which a seed remains 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 at the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT, 1980) showed that the age of the seed and storage conditions may influence seed vigour. Generally seeds remain viable for longer periods if they are dry because under such conditions 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). 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).

Several factors influence the germination of forage crops such as Siratro, Buffel grass and Centro. These factors include amount of moisture in the soil, temperature and presence of oxygen for respiration (Whiteman, 1980 and Jones 1975b).

2.3.3.1. **Moisture**

The most important factor that influences germination is the presence of water provided temperature is stable. 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 by imbibition (Mayer and Poljkoff-Mayber, 1982; Loveless, 1986).

Successful germination requires that the rate of water movement from soil to seed meet requirements for imbibition and that the rate of water loss from the seed is not excessive (Whiteman, 1980). Rate of transfer of water to the seed is very much a function of soil-seed contact. As soil-seed contact becomes poorer, the rate of water absorption and rate of germination becomes slower. Thus, rate and evenness of germination is improved when seed is sown into fine seedbeds and covered, which also reduces the rate of water loss from the soil (Campbell and Swain, 1973).

2.3.3.2. **Temperature**

Different seeds vary in their temperature requirement for germination. At relatively lower or high temperature, the germination of the seed is adversely affected. Temperature is unlikely to limit germination in the tropics. In the sub-tropics, however, low soil temperature in winter caused delayed and uneven germination in *Cajanus cajan* and rotting of imbibed seed of *Sorghum bicolor*. F.A.O. (1990b) reported 17° C as acceptable (suitable) soil temperature for germination and establishment of grain sorghum (*Sorghum bicolor*).

Among the cultivated plants, there is very little evidence of light as a factor influencing germination. On the contrary, among wild plants, such variability in the behaviour towards light is observed. Consequently seeds may be divided into the following (Ellis *et al*, 1985);-

(a) Those which germinate only in continuous light.

(b) Those which germinate after a brief illumination.

(c) Those which germinate only in the dark.

(d) Those, which are indifferent to light during germination.

2.3.4. **Dormancy in forage seeds**

Dormancy has an important survival value particularly in regions with marked seasonal change in environmental factors such as rainfall and temperature (Tybirk, 1991).

The temporary dormant period experienced by many cereal grains allows for their harvest, drying, storage and ultimate use as food otherwise these grains would germinate and become useless to man. However, the ability of certain weed seeds to lie dormant for many years in the soil has proven to be a great inconvenience to man (Delvin and Witham, 1983). During ploughing the dormancy of many of these seeds will be broken, thereby allowing them to compete with any economic crop sown in the areas, thus reducing the economic values of the crop. Different types of dormancy are encountered in nature.

One type is due to the hard seed coat impermeable to water or oxygen. This type of dormancy results from the impregnation of the seed coat with waxes or other water proofing substances. Many legumes such as alfalfa, clovers and locust beans have this type of dormancy (Ellis *et. al.*, 1985; Tybirk, 1991).

Another type of dormancy is innate dormancy, which is associated with rudimentary embryo or physiological immature embryos. A number of plant species have seeds that contain only partially developed embryos at the time of seed dispersal Such seeds therefore need some time to ripen.

A further type of dormancy is the enforced dormancy, a condition where viable seeds do not germinate because of some limitations in the environment such as the absence of light, water and reduced temperature (Tybirk, 1991, Ellis *et. al.*, 1985).

2.3.5. **Methods of breaking seed dormancy**

For dormant seed to germinate, there is the need to break the dormancy. Various methods have been used to break dormancy either in the laboratory or nursery in order to obtain fast and homogenous germination. These include "after ripening" in dry storage; mechanical and chemical scarification as well as heat treatment.

2.3.5.1 **"After ripening"**

"After ripening" is the loss of dormancy that gradually occurs when seeds are stored in an air dry state (Grant, 1979 and Ellis *et. al.* 1985). In nature "after ripening" occurs during the period between the fall of the seed to the ground and its germination, with examples being the seeds of *Centro, Panicum* and *Siratro.*

2.3.5.2 **Mechanical scarification**

Mechanical scarification involves the nicking, drilling, filing or shaking the seed in a container lined with emery (sand) paper or containing gravel (Tybirk, 1991). Tybirk (1991) has indicated that these treatments may be detrimental to the seeds as they crack the seed. However, when properly done it is efficient in increasing germination rate in species such as *Cajnus cajan, Centrosema pubescens* and *M. atropurpureum* (Larbi, 1979).

2.3.5.3 **Concentrated Sulphuric acid or Sodium hydroxide**

Concentrated Sulphuric acid (H_2SO_4) or Sodium hydroxide (NaOH) may be used to soak seed for sometime before sowing (Greulach, 1973. Ellis *et. al.*, 1985). Soaking time varies according to the plant species. Seed must be thoroughly washed after treatment in running water (Gray, 1968). This method is difficult to apply to large quantities of seed but Grof (1968) described the method successfully applied to large quantities of *Brachiaria decumbens.* Often good results are obtained with 50-90% germination within one to fourteen days when the seeds are thoroughly watered (Tybirk, 1991). Other chemical compounds that have also been used to remove seed dormancy include hydrogen peroxide, ethyl alcohol, sodium hypocholorite, thiourea, nitrates, nitrites, cyanides, gibbrelins and cytokinen (for example, kinetin). (Ellis *et. al.*, 1985).

2.3.5.4 **Immersion of seed in hot water**

Immersion of seed in hot water at 80°C for 10 minutes is effective for a wide range of species including *Leucaena leucocephala* (Grof, 1968).

2.3.5.5 **Heating the seed in an oven**

Heating the seed in an oven with temperature ranging between 80-250°C from a few seconds to several minutes helps to break seed dormancy in some species. Jones (1969) found that heating *M. atropurpureum* at 80°C for 12 hours increased germination by 80%. Heat treatment was also effective for *Panicum coloratum*.

2.3.5.6 **Alternating temperature**

In many seeds, alternating temperature can be extremely effective in breaking seed dormancy. The alternating temperature changes may be either diurnal or seasonal. The success of using alternating temperatures is influenced by the length, range of temperature and cumulative effect of cycles (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).

2.4. **Establishment of forage seed crop**

Careful attention to seed bed preparation, sowing procedures and quality of seed sown is necessary to ensure high yield of seeds which is uncontaminated by weeds or off-types (Humphreys and Riveros, 1986).

2.4. Seed bed preparation

A weed-free seedbed, firm and consolidated to plough depth is needed (Webster and Wilson, 1980). Land preparation with ploughing and shallow cultivation is necessary to produce an even seedbed. Sites, which have relatively few weeds, should be chosen for cultivation (Hare, 1985). The seedbed should be ploughed and harrowed to a fine tilth because of the fine and small seeds of the legumes and grasses that are to be sown.

2.4.2 Seed treatment

Seed treatment involves scarification, *rhizobium* inoculation and chemical treatment of seeds before sowing. The hard or waxy coat on the seed of many legumes inhibits the absorption of water and oxygen, thus preventing uniform germination. Thus the hard or waxy seed coat must be broken or scarified before germination can occur uniformly. Without scarification, the germination percentage may be less than 10% (Shelton, 1994). Bryant (1961) showed that removing buffel grass bristles increased germination in petri dishes. Inoculation of legumes prior to sowing is recommended when introducing new species to the area. Legume plants which are not effectively nodulated will be pale in colour and will not grow vigorously due to inadequate nitrogen fixation leading to nitrogen deficiency (Shelton, 1994).

Various fungicides may be applied to seeds to prevent seed and seedling rots such as damping off caused by *Pithium spp.* Fungicides should not be used in combination with inoculants (Whiteman, 1980) because they can kill the inoculants. Insecticides can also be used to protect the seed from insect attack.

2.4.3 Sowing

The main factors connected with sowing of seeds are sowing rate, sowing depth and row spacing.

In seed crop production, the sowing rates should be about twice those recommended for normal pasture sowing (Kategile, 1984). High plant densities may depress yields especially in legume crops. In general, annual species give optimum seed yields at higher rate densities than perennial species (Hare, 1985).

Numerous studies have shown that with small seeded pasture species, depth of sowing is critical to emergence and recommendations for optimum depth of sowing range from 5 to 15 mm (Grant, 1975; Larbi, 1979). The reduction in emergence from deeper sowing may differ with soil type (Grant, 1975). In a field trial with tall fescue (*Festuca elatior*) varieties, Brock (1973) showed that emergence was greater for sowings 15 mm deep than from 5 or 25 mm sowings. For large scale field sowings accurate control of depth of sowing depends on using a precision drill or on the creation of furrows of a suitable depth in which the seed can be placed. This is one of the effects of pre-rolling with a Cambridge roller (Grant, 1975).

The row method of forage seed production is increasing because larger yields are obtained, lower seeding rate is used over a larger area, the production life of the seed is extended and weed control is made easier. Furthermore harvesting seeds of true colour may be obtained, pests and diseases can be readily controlled, harvesting is usually made a lot easier, a more even supply of moisture and nutrient is ensured, appropriate row spacing may provide a better light environment for the flowering shoot (Kategile, 1984; Humphreys, 1979; Hare 1985).

Row planting is of greater value with the tree legume leucaena, with vigorous sprawling legumes like stylo and with tussock grasses like Panicum and Setaria species, where the higher seed yields have been obtained from particular row spacing (Boonman, 1972). In countries with seed certification schemes, 30 cm row spacing is obligatory for many of the tropical pasture species (Boonman, 1979).

2.4.2. **Management of forage seed crop**

On arable land, the aim is the complete elimination of the existing vegetation by several cultivation practices and possibly by herbicide application before the forage is sown (Kategile, 1984). Post sowing treatments that reduce the effect of the weeds include weeding or cultivation, use of herbicides, grazing and underseeding (Kategile, 1984).

Correct fertilizer usage is a powerful tool seed producers can use for maximum returns. The application of high levels of fertilizer is profitable for forage seed crops and treatment giving maximal seed yield is usually economic (Humphreys and Riveros, 1986). Nitrogen is the main nutritional determinant of grass yield and optimum level in the range of 100-200 kg N/ha. Inflorescence density is the main yield component, which responds to nitrogen.

Application of phosphorous fertilizer is particularly important for legume establishment. Plants with a balanced supply of nutrients may be better able to withstand stress (Hare, 1985). Souto and Debereiner (1970) showed that seedlings of *Neonotonia wightei* with adequate phosphate were more heat tolerant. Phosphorus is important for nitrogen fixation in legumes because phosphorus availability affects the nodulation process of legumes and hence amount of nitrogen in plants (Skerman, 1977; Whiteman, 1980). Potassium has also been reported as limiting seed yields particularly in second year perennial legumes. This is more so if the removal of plant residues from the field is practised (Humphreys and Riveros, 1986).

Irrigation in the dry tropics with high radiation levels can increase seed yield of most seed crops. With grass seed crops, two or three harvests can be taken in a season with irrigation (Hare, 1985). Irrigation makes possible production in those environments, which are most favourable for high seed yields, and this is its principal benefit to the seed industry (Humphreys and Riveros, 1986).

Normal irrigation practice is to water a seed crop during the vegetative period and terminate it at floral initiation or flower appearance (Hare, 1985). Moisture supply to the seed crop can be manipulated to generate the maximum number of inflorescence sites, to stimulate flowering of some crops and to ensure adequate moisture for crop maturation (Humphreys and Riveros, 1986).

In quantitative short day and day neutral plants, a period of moisture stress is beneficial for flowering and seed setting (Hare, 1985). By manipulating the water supply and subjecting siratro crops to wet and dry conditions, high seed yields can be obtained (Hopkinson, 1977).

Diseases can cause problems in establishment and reduce the seed yield. Some cultivars of particular species are more resistant to disease. For example *Centrosema pubescens, cv. Belalto* is more resistant to Cerospora leaf spot than Centro. In humid weather *Botrytis cinerea* can destroy *S. quianensis* seed crops (Hare, 1985). More seeds can be obtained from centro and sirato seed crops if they are provided with stakes or trellises respectively (Skerman, 1977; Humphreys and Riveros, 1986; Hare, 1985).

2.4.3. **Harvesting of forage seed**

Proper choice of harvesting time is important particularly where a single destructive harvest is to be taken from the standing crop. The period over which high yields of good quality seed can be harvested varies considerably and depends both on the cultivar and on weather conditions, especially wind and rain (Kategile, 1984). Due to uneven ripening of seed crop, the selection of a suitable harvesting time is difficult (Hopkinson and Eagles, 1980).

With grasses, the first inflorescences usually produce more and better quality larger seeds than later (Hare, 1985). Various indicators can be used to determine when to harvest. In legumes, these include degree of pod shattering, proportion of mature and immature flowers and pods, the quantity of ripe seeds that can be shaken from plants (e.g. stylo) and the pods change in colour from green to brown at seed maturity such as in Siratro and Leucaena (Hare, 1985). With grasses, the main indicators are seed hardness especially where the seed is rubbed in the hand and if a gritty sandy noise is heard; if the seed can be pinched out of the spikelets, the amount of seed shed; ease of seed removal and changes of the overall field colour. For instance, C. ciliaris seed pluck easily when mature and *Paspalum plicatulum* seeds change from green to brown at maturity (Hare, 1985), Hopkinson and Eagles, 1980). Problems of harvesting tropical forage grasses include poor synchronisation of seed maturity, thus, flowering proceeds over a very long period with inflorescence being continuously produced. Also there is a constant turnover of spikelets and mature seeds shed very easily. In addition many of the seeds have awns, bristles and hooks, which can interfere with harvesting and cleaning.

Concerning legumes, most shatter seeds when ripe, throwing the seeds over a wide area. Furthermore, with pods forming over a long period at any particular time, there is a larger percentage of the seed on the ground unless daily harvesting is carried out. Legumes with twinning stems can intermingle making seed harvesting and cleaning very difficult (Hare, 1985).

The method of harvesting depends on the nature of the crop, the availability of labour and machinery, the size of the crop, the quantity and purity of seed required and weather (Hopkinson and Eagles, 1984). The two main methods of harvesting are the machine and hand harvesting.

Mechanical harvesting uses a great range of machinery. Humphreys (1979) grouped techniques of machine harvesting as follows: it cuts, threshes and dries. Also it cuts, dries and threshes. In addition, the machine beats or rubs and finally it sucks or sweeps. Combine harvesters are rapid and are commonly used. These machines cut the stems, thresh, separate and partially clean the seeds in a single operation (Hare, 1985). Larger areas can be harvested quickly with less labour.

Hand-harvesting tropical grass seed is usually of a higher quality than machine harvested. Depending on grass species, several methods of hand harvesting can be employed. According to Hare (1985) these include sweating, stooking, plucking and shaking.

The main aim of sweating is to detach the seeds from the heads and to allow marginally mature seed to mature fully. Panicum species will produce high yields of high quality seeds if the freshly cut seed heads are placed in a stack and then sweated for two to three days before threshing and drying.

Steps of sweating are as follows:-

(i) Ripe seed heads are cut in the field, tied into loose bundles and then sent to the shed. Long stems and leaves should be removed as their high moisture content can spoil the seed during sweating.

(ii) The bundles should be stacked not more than one metre high with the heads turned inwards. The inside temperature of the stack may rise to over

50° C, CO_2 level may reach 20%, oxygen may become virtually exhausted and moulds will not develop. The high moisture content inside the stack prevents the seed from loosing water and the immature harvested seed completes its maturation process.

(iii) When the stack is opened after two or three days, most of the mature seeds have undergone abscission. A light threshing on the floor will loosen more mature seed.

(iv) Sweated seed should be dried slowly over several days to the required moisture content of 8-10%.

Brachiaria decumbens, Chloris gayana and *Paspalum plicatulum* seed heads can be tied into bundles and stooked, heads upright in a shed. The seeds must be allowed to dry out slowly over seven to ten days before threshing. The second method is that the bundles can be placed on racks and allowed to dry and drop mature seeds on the floor from where it is collected and cleaned.

Cenchrus ciliaris and *Chloris gayana* seeds can gently be plucked by hand from the seed heads. Those seeds, which cannot be plucked, should be left until they mature further. Mature seeds of many species can be shaken out of their heads into bags in the field. Good, high quality mature seed can be harvested two or three times a week using this method. Mature seedpods of legumes such as Siratro, Centro, Leucaena, Pueraria and *Desmodium sp.* can be handpicked every two or three days (Hare, 1985). Yields are higher if some of these species are grown on trellises rather than in swards, as pods are easily hand picked.

Seeds of Stylosanthes species can be ground harvested. At the end of the season, the standing herbage is cut with matchets and rolled away, the seeds and residual debris swept into heaps and transported to a cleaning area. By using simple sieved and bamboo pans the seed can be cleaned to over 90% purity.

2.5. Seed drying, cleaning, packaging and yield

2.5.1. Seed drying

Freshly cut seed of all tropical grasses and legumes is quite moist and must be dried before storage. Grass seed may contain 60% water at harvest and it must be stored at 8-12% moisture content (Hopkinson and Eagles, 1980). Moisture promotes diseases, decay and degradation hence drying is needed to preserve seed quality (Claassen, 1995). He listed the following as factors affecting seed drying:-

(a) The maximum air temperature that should be allowed for seed drying is 43° C, beyond that damage can occur.

(b) When relative humidity is high air-drying of seed is difficult. In such conditions, a heater is required to dry the seed.

(c) Seed in the dry bin dries from the bottom up. The higher the moisture content, the faster moisture is removed.

(d) Seed dries more quickly in higher airflows. In tropical areas an airflow of about 8-10 cm^2/m^2 is required

Drying involves evaporation of water from the seed surface and the transport of water from the centre of the seed to the seed surface (Humphreys and Riveros, 1986). The saturated air around the moist seed surface must be removed. This process can be accelerated by increasing air flow past seed by heating the air or by dehumidifying the air with desiccants such as silica gel or calcium chloride (Humphreys and Riveros, 1986). The seed must not be dried too quickly or at excessively high temperature, i.e. not above 43^0 C. Seed harvested from the standing crop may be dried in shallow layers on sheets in the sun, in an airy shed or artificial hatch driers. Sun drying on tarpaulins, cement, wooden floors or even on ground is a common practice. Hopkinson and Eagles (1980) has dried seeds on an airstrip. Drying should commence as soon as possible after harvest and should continue without interruption until completed. High relative humidity (e.g. at night) need to be lowered by heating the air if drying is to continue (Kategile, 1984, Hopkinson and Eagles, 1980). Drying slowly on tarpaulins in the shade over several days is the best method. Legume seeds are usually harvested at low moisture contents of about 14% and do not require further drying after cleaning prior to storage (Hare, 1985).

2.5.2. **Seed cleaning**

Cleaning of seed aims to remove all contaminating matter. It is easier to remove inert material such as straw and dirt than weed seeds. Seed cleaning therefore should begin in the crop by careful weed control (Hopkinson and Eagles, 1980). High quality seed can be recovered using labour intensive traditional cleaning techniques (Humphreys and Riveros, 1986).

Hand harvested legume seeds from pods usually require very little cleaning but cleaning of grass seeds can be difficult because of awns, bristles and hairs (Hare, 1985). Special equipment has thus been developed to clean buffel grass seed, which is extremely chaffy and light and will not flow easily through conventional air cleaners. It is important that the cleaning equipment must itself be easily cleaned.

2.5.3. **Seed packaging and presentation**

Adequate packaging is the final necessary operation in the sequence of production and processing steps designed to place high quality seed in the hands of the user (Humphreys and Riveros, 1986). Packaging is designed to facilitate safekeeping of the seed of marked identity during storage, transport and marketing. Type of handling and distance to travel with the seed determines the type of packaging required (Humphreys and Riveros, 1986).

After cleaning, seed should be packed into new bags, either jute or polypropylene to avoid contamination. Dry sealing of seed with thick polyethylene liners for long term storage can also be carried out at this stage. Seed may also be treated with a fungicide or an insecticide. Bags should be packed to standard weight to facilitate handling (Kategile, 1984; Hopkinson and Eagles, 1980). Labelling should be clear and definitive. It should be emphasized that only seed dried to safe moisture level of 8 to 10% or preferably below 8% should be placed in impermeable containers. Durable and attractive packaging gives the consumer satisfaction on which future trading depends (Humphreys and Riveros, 1986).

2.5.4. Seed yield

Several factors may affect the seed yield of forage crops. These factors include the cultivar or the genetic potential of the forage crop, ecological zone in which the crop is found, the season in which the crop is grown, management practices adopted for the cultivation and harvesting of the crop as well as the incidence of pest and disease (Hare, 1985; Whiteman, 1980).

Diseases can cause problems in establishment and reduce the seed yield if not checked. Pest such as wild birds which feed on forage seed for their survival may cause total crop failure when they attack crops yet to be harvested. On the other hand, if forage crops are sown at the right time to coincide with rains and the correct management practices like weed control is adopted, more seeds can be obtained from the forage crops that is grown (Hare, 1985 and Skerman, 1977). Different cultivars may also give different seed yield. Hare (1985) gave the seed yield of some forage crops in South-East Asia as represented below (Table 2.2).

2.6. Seed storage

Seed storage is particularly important in tropical countries where high temperature and humidity combine to accelerate the loss of viability. Seed at 10% moisture content will store well at most ambient temperatures but can regain moisture from the air and quickly rise to the dangerous level of 14% in humid weather and begin to deteriorate rapidly. Seed longevity depends both on the state of the seed entering storage and on the conditions of the store (Kategile, 1984).

Table 2.2. **Seed yield of some forage crops in South-East Asia.**

Forage Type	**Yield (kg/ha)**
Andropogon gayanus	40-160
Panicum maximum	25-50
Urochloa mosambecensis	30
Chloris gayana	20-40
Paspalum plicatulum	80-100
Cencrus ciliaris	30
Brachiaria decumbens	20-40
Stylosanthes scabra	200-400
Stylosanthes hamata cv. Verano	900
Macroptilium atropurpurem	600-900
Centrosema pubescens	200-400

Source: Tropical pasture seed production in South-East Asia, Hare (1985)

Legume seed reaches the highest potential germination soon after harvest whereas grass seed may take up to ten months to reach its peak of germination (Harty, 1980). Storage temperature and seed moisture content are most important factors determining the rate of decline of germination of stored seed (Hopkinson and Eagles (1980), Claassen (1995).

Claassen (1995) stated that as temperature increases within the normal range, biological activities of seeds, insects and moulds increase however, moisture content is more critical than temperature. He further stated that good seed storage is achieved when the percentage relative humidity in the storage room and the storage temperature in ^{o} F add up to 100 e.g. 50^{0} Rh and 50^{0} F; one percent decrease in moisture content or ten degree decrease in temperature doubles the storage life of seed and good cold storage for seeds should not exceed 60% in relatively humidity.

Thomas and Evans (1990) suggested that seed storage will be prolonged by ensuring that the seed collected is fully mature, dried (<10% moisture) and clean, dusting with insecticide to kill insects, storing in an air-tight containers in an atmosphere of CO_2 and storing at low temperature (<4^{0}C) and low humidity.

To maintain a seed bank for a minimum period of 5 years it is necessary to have a well-insulated store room capable of maintaining a temperature of 0-5°C and a separate dehumidification system to provide a relative humidity between 30-40% (Harty, 1980). An alternative to dehumidifying the storage atmosphere is to store dried seeds in moisture proof packages. For adequate protection during long term storage, laminated materials are necessary. This consists of layers of polythene, aluminium foil and paper cellophane or polyester (Harty 1980).

Seed moisture content should be at all times strictly controlled. Drying may be carried out by exposing seeds to a suitable desiccant such as silica gel in a desiccators or drying cabinet at moderate temperature of 25-30°C (Harty, 1980).

Seeds can be stored in either room temperature of around 25° C, in a refrigerator at 4° C; in a cold room (deep freezer) of -18°C or in dry soil in a glasshouse (Gutteridge and Stur, 1990). Cobbina, Kolawole and Atta-Krah (1990) reported that the germination of leucaena seed stored at either room temperature, in a deep freezer or a dry soil in a glasshouse for 12 months was not significantly different from that at the start of the storage period. Calliandra seed retained viability when stored in a refrigerator (4°C) for 2½ years but viability was reduced by 15% when seed was stored at room temperature for one year (NAS, 1983)

CHAPTER THREE

3.0 EVALUATION OF FIELD ESTABLISHMENT AND SEED YIELD OF SOME FORAGE CROPS IN GHANA

3.1. Introduction

Seed are used to establish pastures and to extend the use of improved pastures for ruminant animals (Skerman, 1977; Whiteman, 1980, Loch, 1984). These pastures provide energy, proteins, minerals and vitamins to the animals for their growth and development. Field establishment and seed yield of forage crops have not been determined in Ghana as has been done in Australia, Britain and South-East Asia (Hare, 1985). There is need to conduct studies into field establishment and seed yields of forage crops in the country so as to ascertain their potential yield. Such information will be used to determine whether seeds of these forage species could be produced locally in sufficient quantities for farmers.

The objective of this experiment was therefore to assess field establishment and seed yield of some forage crops. Also the study aimed at assessing the effect of time of harvesting on seed yield.

3.2. Materials and method

3.2.1. Location of the experiment

The experiment was carried out at the Agricultural Research Station (A.R.S) Legon of the University of Ghana, Legon. This area is situated on the Accra Plains of the Coastal Savanna Zone. The soil of the area belongs to the tropical black earth of the Akuse series. The rainfall pattern is bimodal with the major peak in June while the minor is in September-October. The total rainfall varies from 508 mm to 743 mm per annum. Minimum and maximum mean temperature range between 32.9°C and 24.3°C respectively. The vegetation is made up of a mixture of tall and short grasses with patches of shrubs and scattered trees with neem trees (*Azadirachta indica*) being prominent. The major weed problem in the area is tephrosia, (*Tephrosia purpurea)*. Grasses that are mostly found in the area are vetiveria (*Vetiveria fulvibarbis)*, gamba grass (*Andropogon gayanus)*, buffel grass (*Cenchrus ciliaris)*, guinea grass (*Panicum maximum)*, and brachiaria (*Brachiaria lata)*.

The climatic data of A.R.S., legon for the experimental period is presented in Table 3.1

3.2.2. **Forage species studied**

Two legumes and three grasses were studied. The legumes are *Macroptilium atropurpureum* (Siratro) and *Macroptilium lathyroides* (Phasey bean) and the grasses were *Panicum maximum* (Guinea grass), *Cenchrus ciliaris* (Buffel grass) and

Table 3.1 **Climatic data for Agricultural Research Station, Legon for the experimental period November 1999 to November 2000.**

Month & Year	**Rainfall (mm)**	**Temperature**	
		Min. (°C)	**Max. (°C)**
Nov. 1999	4.1	20.2	35.5
Dec. 1999	5.5	22.2	35.2
Jan. 2000	3.6	21.5	35.3
Feb. 2000	0.0	19.0	36.6
Mar. 2000	41.5	21.5	36.5
Apr. 2000	11.5	23.0	35.5
May. 2000	40.5	22.5	35.5
Jun. 2000	146.4	22.5	34.0
Jul. 2000	2.1	21.0	30.0
Aug. 2000	0.4	20.5	32.5
Sep. 2000	1.2	22.0	35.5
Oct. 2000	5.8	21.0	35.0
Nov. 2000	29.5	23.5	34.0

Source: Meteorological Station, A.R.S. Legon

Andropogon gayanus (Gamba grass). These forage crops were selected for the experiment as they are commonly found at the Station.

3.2.3 Land preparation, field layout, planting and maintenance

The field was slashed, ploughed and harrowed in November 1999. Lining and pegging were done a week after harrowing. The legume seeds were mechanically scarified with sand paper before sowing. A split plot design was used with the forage seed crops as the main plots and three harvesting periods as the sub-plots. Each main plot measured 3.6 m x 3.6 m. There were three replications of each main plot. There were 12 rows per plot with 30 cm between rows and 30 cm between plants in a row. The legume seeds were sown 1.5 cm deep at the rate of 2.5kg/ha. For the grasses, (*P. maximum, C. ciliaris and A. gayanus),* vegetative propagation was used.

Sulphate of ammonia and single superphosphate were applied to the grasses and legumes at the rate of 123 kg and 74.3 kg per hectare respectively. The field was irrigated from a near by dam using watering can every other day when soil was dry by visual appraisal. Rogueing of weeds was done with a hoe. Siratro seedlings were provided with rellises. Seeds were harvested at 3, 4 and 5 weeks after flowering of legumes or the appearance of the inflorescence of the grasses. These harvest intervals were chosen because, before three weeks there were no dry seeds found on them and shattering was very high beyond five weeks. The seeds were air dried to moisture content of about 10%. Seeds were harvested from ten stands per row. Two non-border rows were harvested for each harvest.

3.2.4 **Data collection**

The following data were collected;-

(i) Number of days taken for the seedling emergence of the legumes or the sprouting of the grasses.

(ii) The germination percentage of the legume seeds or the sprouting of the grasses at 28 days after sowing of the seed or planting of the grasses.

(iii) Number of days taken for the legumes to flower and the grasses to bear inflorescence after sowing the legume seeds or planting the grasses.

(iv) Seed yield per hectare of each forage based on yield per harvest.

3.3 **Statistical analysis**

Percentage seedling emergence of legumes or sprouting of grasses were transformed by the arcsin before analyses of variance was carried out. Data for the other characters were also analysed using analysis of variance. The Least

Significant Difference (LSD) was used to separate the means when significant differences existed, according to Steel and Torrie (1980). Also the standard error of difference (SED) was used for tables 3.2, 3.3, 3.6 and 3.7 as a single observation was made.

3.4 Results

Table 3.2 shows the number of days taken for the seedling emergence of the legume seeds. Both *M. lathyroides* and *M. atropupureum* seed took the same number of days to emerge.

Table 3.2. **Number of days taken for the legume seeds to emerge.**

Forage species	**Days to emergence**
M. lathyroides	4
M. atropurpureum	4
SED	0

Table 3.3 shows the number of days taken for the grasses to sprout after planting. *Cenchrus ciliaris took less days to spout than A. gayanus* and *P. maximum.*

Table 3.3. **Number of days taken for the grasses to sprout after planting**

Grasses	**Days to sprout**
P. maximum	6
C. ciliaris	5
A. gayanus	6
SED	0.33

Table 3.4 shows the percentage seedling emergence of the legume seeds 28 days after sowing. Twenty-eight days was fixed to give maximum opportunity for every seed to germinate. There were no significant differences between the percentage seedling emergence of *M. lathyroides* and *M. atropurpureum.*

Table 3.4 **Percentage seedling emergence of the legumes at 28 days after sowing.**

Legumes	**Percentage seedling emergence**	
	m	**s. e.**
M. lathyroides	97 5 (1.47)	± 2.5
M. Atropurpureum	88.2 (1.25)	± 7.1
LSD (P=0,05)	35.5 (0.94)	

Numbers in parentheses show the arcsin transformed data

Table 3.5 show the percentage sprouting of the grasses at 28 days after planting. There were no significant differences in the percentage sprouting of the grasses. Percentage sprouting was above 80% for all the grasses.

Table 3.5 **Percentage sprouting of the grasses after 28 days planting.**

Grasses	Percentage sprouting	
	m	**s.e.**
P. maximum	83.8 (1.10)	± 7.8
A. gayanus	85.6 (1.03)	± 1.2
C. ciliaris	85.2 (1.02)	± 2.2
LSD (P=0.05)	17.6 (0.41)	

Numbers in parentheses show the arcsin transformed data

Table 3.6 shows the number of days taken for the legumes to have first flower. *Macroptilium lathyroides* took shorter time to have first flower than *M. atropurpureum*.

Table 3.6 **Number of days taken for the legumes to have first flower**

Legumes	**Days to first flower**
M. lathyroides	40
M. atropurpureum	55
SED	7.5

Table 3.7 shows the number of days taken for the grasses to have first inflorescence. *C. ciliaris* took the shortest time to have inflorescence while *A. guyanus* took longest time.

Table 3.7 **Number of days taken for the grasses to have first inflorescence**

Grasses	**Days to first inflorescence**
P. maximum	40
C. Ciliaris	36
A. gayanus	67
SED	9.7

Table 3.8 shows the seed yield (kg/ha) of legume seeds harvested at 3 and 4 weeks after flowering in the Accra plains. Yield from the two legumes showed no significant values. However there was significant difference between the age of harvesting. There was no significant difference between species x age interaction.

Table 3.9 shows the seed yield (kg/ha) of grasses harvested at 3, 4 and 5 weeks after inflorescence in the Accra plains. *Panicum maximum* and *C. ciliaris* showed significant yield differences from that of *A. gayanus* whereas there was no significant yield differences between *P. maximum* and *C. ciliaris*. Seeds produced in the 5th week showed significant

Table 3.8 **Seed yield (kg/ha) of legumes harvested at 3 and 4 weeks after flowering in the Accra plains.**

Forage species	**Age of harvested seed**		**Mean**
	3 WAF	4 WAF	
M. lathyroides	22.63	8.13	15.38
M. atropurpureum	22.40	11.77	17.08
Mean	22.52	9.95	

LSD (P=0.05); Species =6.5
Age = 3.7
Species x Age = N/S

difference from seeds produced in the 3rd and 4th week whereas seeds produced in the 3rd and 4th week showed no significant differences. Species x age showed no significant differences.

Table 3.9 **Seed yield (kg/ha) of grasses harvested at 3, 4 and 5 weeks after inflorescence in the Accra plains.**

Grasses	**Age of harvested seed**			**Mean**
	3 WAF	4 WAF	5WAF	
P. maximum	22.17	15.97	14.13	17.41
C. Ciliaris	13.33	11.43	10.17	11.64
A. gayanus	3.07	2.83	2.20	2.76
Mean	12.86	11.67	8.83	

WAF: Weeks after flowering
LSD (P=0.05): Species = 9.5
Age = 2.5
Species x weeks = N/S

3.5 Discussion

The early germination and high seedling emergence of the legumes could be explained by the scarification that was done before the seeds were sown. This might have enhanced the imbibition of water by the seed as a result of increase water and gaseous intake, tear in the seed coat, softening of the seed coat and breaking of dormancy.

Immediately after planting there was a downpour of rain and this also led to high germination and sprouting of the seeds and vegetative parts respectively. Soil moisture was thus adequate and the temperature range between 24.3 to 32.9°C at that time was favourable for seedling growth.

Maximum vegetative productivity is attained around the time of first flowering or inflorescence after which most photosynthetates get directed into reproduction (Odoi, Asante and Annan 1999). Early flowering is therefore usually not desirable if maximum forage production is the goal.

Andropogon gayanus had prolonged growing period before the first inflorescence and therefore holds greater promise for forage production. As it takes shorter time for *C. ciliaris* to have inflorescence, it should be grazed at a shorter intervals after planting before the seadhead forms, as this intervals after planting before the seadhead forms, as this will reduce the quality of the forage. However, if the sole aim is for seed production, then *C.ciliaris, M. lathyroides* and *P. maximum* are more desirable as they take shorter days to produce seeds. The number of days taken for *M. atropurpureum* to flower (55 days) is in agreement with Perbery (1967). He reported that it took 57 days for *M. atropurpureum* to flower in the tropics.

The large reduction in the yields of *M.lathyroides* and *M. atropurpureum* from the third and fourth weeks was due to the shattering of the pods. Shattering of the pods was high after the third week of harvest. This also explains why there was no seed yield at five weeks after flowering opening. This is in conformity with the report of Hare (1985) that seed pods of legumes shatter readily when ripe, throwing the seed over a wide area.

With *P. maximum,* shedding of the seeds was noticed about three weeks after anthesis. Hare (1985) had observed that seed maturity in this grass is reached about 22 days after anthesis yet shedding can occur at a very early age and that seed at only 10 days after anthesis showed 23% seed shattering. There was shedding of the seeds during the four and five weeks sometimes eating the ripe seeds thus reducing the seed yield of *P. maximum*. Shedding of the seeds was not pronounced in *C. ciliaris* and *A. gayanus*. Thus the differences in the yields at the various weeks of *A. gayanus* were not as high as that of *P. maximum* and *C. ciliaris*.

Comparing the seed yield with what Hare (1985) found in South East Asia, large differences were found between the Accra plains and South East Asia. For instance while between 600-900 kg/ha was obtained from *M. atropurpureum*, and 40-160 kg/ha, from *A. gayanus* in South East Asia, an estimated 17.8 kg/ha of *M. atropurpureum* and 2.76kg/ha of *A. gayanus* were obtained in the present study. This difference may be due to differences in cultivar, climatic conditions, soils and cultural practices adopted between the two environments.

In conclusion, scarification of legume seed should be adopted to enhance high germination of the seeds. Also since it was noticed that seed shattering occurred greatly after the 3rd week, effort should be made to harvest these legume and grass seeds early to avoid loss of seeds during harvesting.

CHAPTER FOUR

4.0 THE EFFECT OF STORAGE CONDITIONS ON VIABILITY OF FORAGE SEEDS

4.1. Introduction

Lack of proper seed storage facilities after drying and packaging has been a primary cause of the failure of germination of quite highly priced grass seeds (Humphreys and Riveros, 1986). Seed storage is particularly important in tropical countries where higher temperature and humidity combine to accelerate the loss of viability of the seeds. Seed longevity depends both on the age of the seed entering storage and the conditions of the storage (Kategile, 1984). Most seeds survive when water content and storage temperature are low.

The objective of this experiment was to compare the viability of seeds harvested at different maturity stages and stored under different environmental conditions for various lengths of time.

4.2. Materials and method

The experiment was carried out at the Agricultural Research Station (ARS), Legon of the University of Ghana, Legon. Seeds obtained from Experiment 1 were used. Seeds from the individual sub-plots harvested at 3, 4, and 5 weeks were bulked together. One third of each seedlot was stored at room temperature of (25°C); a third in a refrigerator (8°C) and the other one third stored in a cold room (-3°C) for four months. During the storage period, samples from each group were taken at monthly intervals for germination test.

The legume seeds were subjected to sandpaper scarification before the germination test. Fifty seeds of each forage species harvested at 3, 4 or 5 weeks after flowering was placed in a petri dish lined with cotton wool which was kept moist. The experimental design was the split plot. The main plot was the environment, while the combination of forage species and seed age were the sub plots. There were there replications. Seeds were observed daily to find out the percentage germination up to 28 days. The appearance of the radicle was used to indicate germination.

The rate of germination was calculated using the method of Maquire (1962). This was done by multiplying the number of seeds germinated in each day by 2 to get the rate of germination to be obtained in percentage at each counting in the standard germination test by the number of days seeds have been in the germinator. The value summed up at each count were then summed up at the end of the germination test to obtain the germination rate. This is expressed as follows:

GR = No of normal seedlings at 1st count + No of normal seedlings at 2nd count +...+ No of seedlings at final count / Days to 1st count + Days to 2nd count +...+ Days to final count

Where

GR= Germination rate

4.3 Statistical analysis

The percentage germination data were transformed by the arcsin transformation before being subjected to analyses of variance. Line graphs were drawn and regression analysis were used to show the trend in germination with time by giving regression equation.

4.4 Results

Figure 4.1 shows the percentage germination of *M. lathyroides* seeds harvested at three weeks and four weeks and stored under (a) room temperature (b) fridge and (c) cold room.

At room temperature, there was a gradual decrease in percentage germination of the seeds from the first month to the second month before it rose again in the third month. It however decreased in the fourth month. There was a significant percentage difference among the months. The regression equation for the seed is $y= - 6.68 + 97.3x$ with R^2 value being

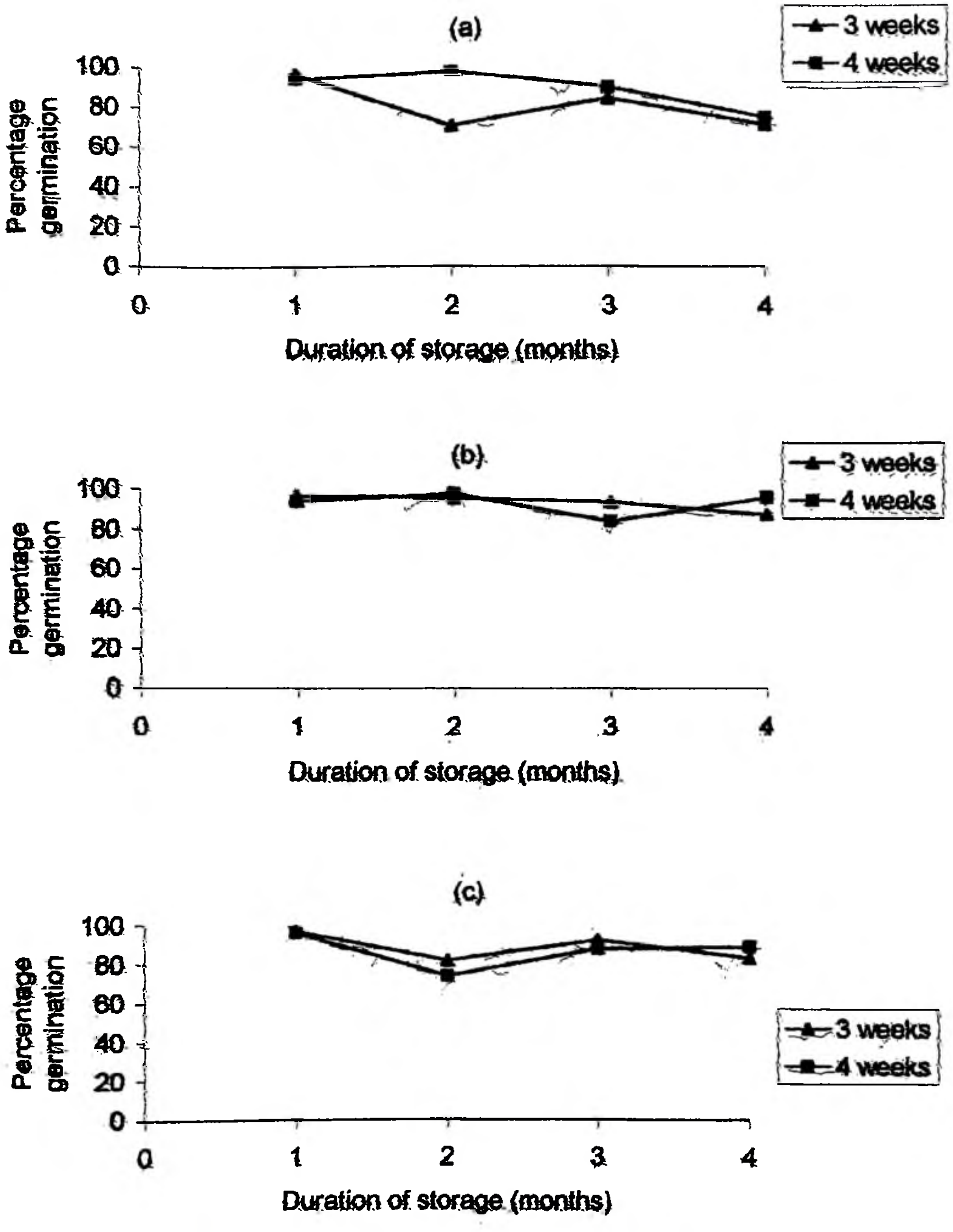


Figure 4.1: Percentage germination of *M. lathyroides* seeds harvested at three weeks and four weeks and stored under (a) room temperature (b) fridge and (c) cold room.

0.4604805. For the seeds harvested at four weeks, there was gradual decrease in percentage germination from the 2^{nd} month to the 4^{th} month after initial increase in percentage germination from the first month. There was a significant difference in percentage germination among the months. The regression equation is $y = -7.08+106.85x$ with R^2 value being 0.7524453.

With regard to fridge storage, seeds harvested at 3 weeks showed a decrease in percentage seed germination from the first to the fourth month. There was a significant difference in percentage germination among the months. Its regression equation is $y=-2.75+100.3x$, R^2 value being 0.8123422. Seeds harvested at 4 weeks showed percentage germination increase from the first to the second month, a decrease from the second to the third month before increasing again in the fourth month. There was a significant difference in percentage germination among the months, its regression equation is $y=-0.88+94.7x$ and $R^2 = 0.0209838$.

For cold room storage, seeds harvested at 3 weeks showed a gradual decrease in percentage germination from the first month of the to the fourth month. The same trend was also observed for seeds harvested at 4 weeks. There was significant differences in percentage germination among the months for the two harvested intervals. The regression

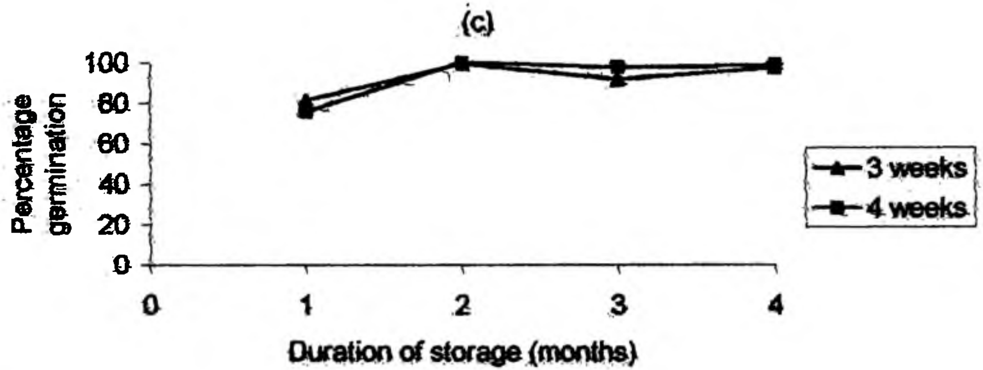
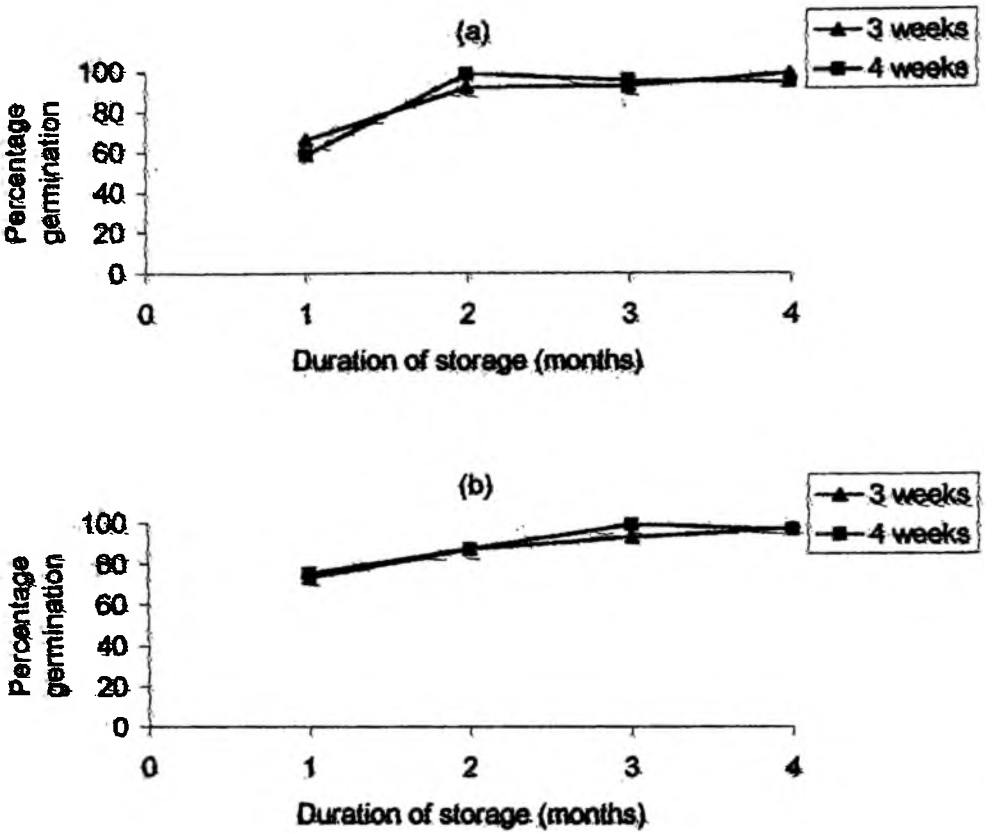


Figure 4.2: Percentage germination of *M. atropurpureum* seeds harvested at three weeks and four weeks and stored under (a) room temperature (b) fridge and (c) cold room.


(a)
3 weeks
4 weeks
Percentage germination
0
20
40
60
80
100
0
1
2
3
4
Duration of storage (months)
(b)
3 weeks
4 weeks
Percentage germination
0
20
40
60
80
100
0
1
2
3
4
Duration of storage (months)

equation for seeds harvested at 3 weeks is y=-3.17+96.5x with R^2 value = 0.3156708 while the 4^{th} week is y=-0.91+88.95x with R^2 = 0.0180207.

Figure 4.2 shows the percentage germination of *M. atropurpureum* seeds harvested at 3 and 4 weeks and stored at room temperature (b) fridge and (c) cold room. At room temperature seeds harvested at 3 weeks showed a percentage increase in germination from the first to the fourth month with significant differences among the months. Its regression equation is y=9.54+62.65x and R^2 being 0.77262046. Seeds harvested at 4 weeks showed a percentage increased in germination from the first month to the second month and then a decrease in percentage germination from the second to the fourth month. However their percentage germination showed significant differences among the months. Its regression equation is y=80.9+10.01x with R^2 value = 0.50127746.

Concerning fridge storage, both seeds harvested at 3 and 4 weeks respectively showed an increase in percentage germination from the first to the fourth month. There was significant differences in percentage germination among the months for the two harvest periods. The regression equation for the 3 week harvest is y=68.15+7.8x with R^2=9271 while for the 4 weeks is y=70.6+7.62x and R^2=0.8194936

On cold room storage seeds harvested at 3 weeks showed an increase in germination from the first month to the second month a decrease in the third month and an upward trend in the fourth month. The same pattern was exhibited by the seeds harvested at 4 weeks. Both harvested intervals showed a significant difference in their percentage germination among the months. The regression equation for the seeds harvested at 3 weeks is $y=82.45+3.91x$ while $R^2=0.3969283$. The regression equation for the 4^{th} week is $y=76.55 + 6.5x$ while R^2 being 0.53680011.

Figure 4.3 shows the percentage germination of *C. ciliaris* seeds harvested at 3, 4 and 5 weeks and stored at (a) room temperature (b) fridge and (c) cold room. At room temperature seeds harvested at 3 weeks showed an increase in germination percentage from the first month to the third month before declining in the fourth month. With seeds harvested at 4 weeks there was an increase in percentage germination from the first month to the second month, declining in the third month and increasing in the fourth month. Seeds harvested at 5 weeks showed an increase in germination percentage from first month to the third month before decreasing in the fourth month. There was significant differences in percentage germination among the months for the three harvested intervals. The regression equation for the seeds harvested at

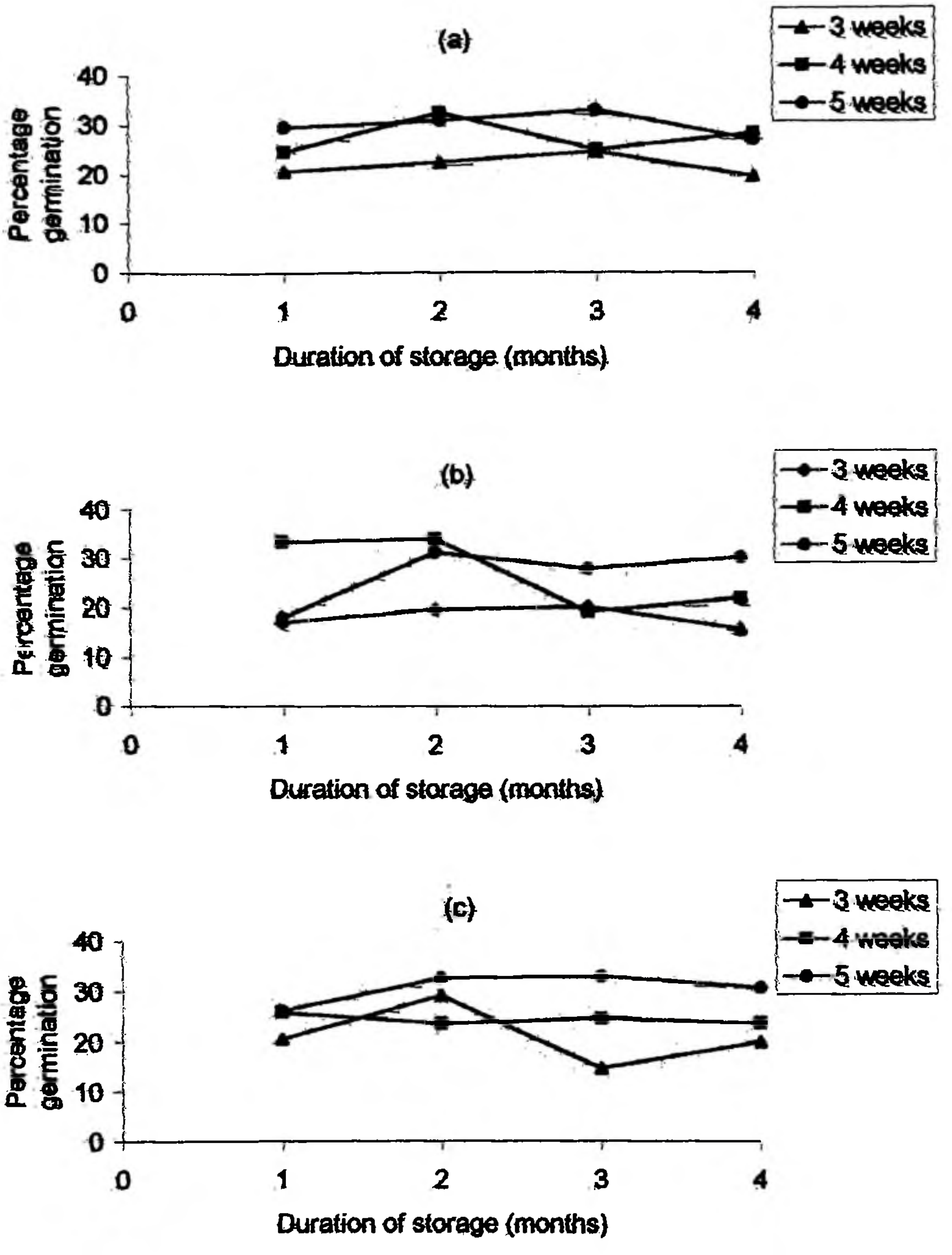


Figure 4.3: Percentage germination of *Cenchrus ciliaris* seeds harvested at three weeks, four weeks and five weeks and stored under (a) room temperature (b) fridge and (c) cold room.

3 weeks is y=22.2-022x with R^2 being 0.017448. The regression equation for the 4^{th} weeks is 26.85+0.23x while its R^2 is 0.00791. The regression equation for the 5^{th} week harvest is y=31.7-0.7x with R^2 being 0.130667.

On fridge storage, seeds harvested at 3 weeks showed an increase in percentage germination from the first month to the third month before declining at the fourth month. However, seeds harvested at 4 weeks had a gradual increase in percent germination from the first to the second month, declining in the third month and increasing again in the fourth month. For seeds harvested at 5 weeks there was an increase in percentage germination from the first to the second month declining in the third month and increasing again in the fourth month. Differences in percentage germination among the months for the 3 harvest intervals were significant. The regression equation for the seeds harvested at 3 weeks is y=19-0.33x while its R^2 is 0.037951. The regression equation for the seeds harvested at 4 weeks is y=39.3-4.86x with R^2 being 0.683082. The regression equation for the seeds harvested at 5 weeks is y=18.5+3.36x with R^2 being 0.506988.

With regard to cold room storage, seeds harvested at 3 weeks showed an increase in percentage germination from the first month to the second month, declining in the third month and increasing again in the fourth month. Seeds harvested at 4 weeks showed a downward decline in percent germination from the first to the fourth month. On the other hand, seeds harvested at 5 weeks showed an increase in percentage germination from the first to the third month before declining in the fourth month. Differences in percentage germination among the months for the various harvested intervals were significant. The regression equation for the seeds harvested at 3 weeks is $y=25.35-1.67x$ while R^2 is 0.127292. The regression equation for the seeds harvested at 4 weeks is $y=26-0.59x$ with $R^2 =0.487877$. The regression equation for the seeds harvested at 5 weeks is $y=27.3+1.35$ and $R^2 = 0.318091$.

Figure 4.4 shows the percentage *A. gayanus* seeds harvested at 3, 4 and 5 weeks and stored under (a) room temperature (b) fridge and (c) cold room.

At room temperature seeds harvested at 3 weeks showed percentage increase in germination from the first month to the third month before declining in the fourth month. Seeds harvested at 4 weeks also exhibited the same pattern of percentage germination at that of those harvested at 3 weeks. However, seeds harvested at 5 weeks showed percentage increase in germination from the first to the second month declining in the third month and raising again in the fourth month. Significant differences in percentage germination were observed over the harvested intervals. The regression

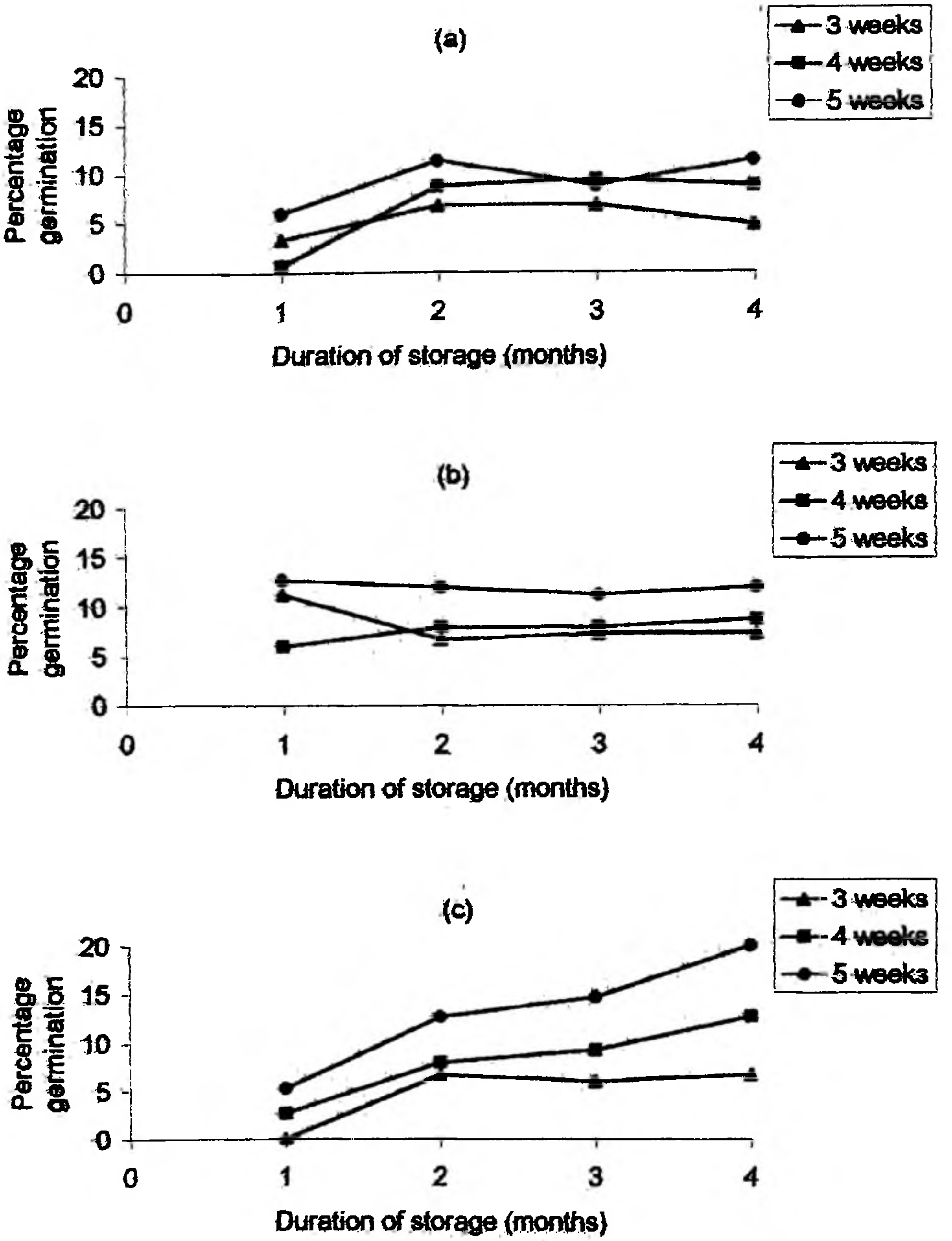


Figure 4.4: Percentage germination of *Andropogon gayanus* seeds harvested at three weeks, four weeks and five weeks and stored under (a) room temperature (b) fridge and (c) cold room.

equation for the seeds harvested at 3 weeks is y=4.3+0.42x with R^2 being 0.106651. The regression equation for the seeds harvested at 4 weeks is y=0.7+2.46 with R^2 = 0.597158. The regression equation for the seeds harvested at 5 weeks is y=6+1.33 with R^2 = 0.459514.

Concerning fridge storage, seeds harvested at 3 weeks showed a decrease in percentage germination from the first month to the second month and a constant percentage germination in third and fourth month. Seeds harvested at 4 weeks showed a decline in the percentage germination from the first to the fourth month. For the seeds harvested at 5 weeks there was a decline in the percentage germination from the last month to the third month and a rise in the fourth month. There were significant differences in percentage germination among the months for the 3 harvest intervals. The regression equations for the seeds harvested at 3 weeks is y=11-1.14x with R^2 being 0.4824053. The regression equation for the seeds harvested at 4 weeks is y=5.65+0.81x with R^2 = 0.8065151. The regression equation for the seeds harvested at 5 weeks is y=12.7-0.28x with R^2=0.4.

On cold room storage, seeds harvested at 3, 4 and 5 weeks all showed an increase in percentage germination from the first month to the fourth month. Significant differences in percentage germination were recorded among the months for the 3 harvest intervals. The regression equation for seeds harvested at 3 weeks is y= -3.553e-15+1.94x with R^2 = 0.5938151. The regression equation for the seeds harvested at 4 weeks is y=0.35+3.13x. With R^2 = 0.9466061. The regression equation for the seeds harvested at 5 weeks is y=1.65+4.61x with R^2=0.9560314.

Figure 4.5 shows the rate of germination of *M. lathyroides* seeds harvested at 3 and 4 weeks and stored at (a) room temperature (b) fridge and (c) cold room. At room temperature seeds harvested at 3 weeks showed a decrease in the rate of germination from the first to the second month raising again in the third month and declining in the fourth month. Seeds harvested at 4 weeks showed a down ward decline in the rate of germination from the first month to the fourth month. There was significant difference in the rate of germination of the seeds among the months for the 2 harvested intervals. Regression equation for *M. lathyroides*. The regression equation for seeds harvested at 3 weeks is y=28.35-3.42x with R^2=0.553492. The regression equation for seeds harvested at 4 weeks is y=33.9-3.56x with R^2 = 0.74271.

Concerning fridge storage, seeds harvested at 3 weeks showed a decline in the rate of germination from the first to the fourth month while the seeds harvested at 4 weeks had an increase in the rate of germination from the first to the second month declining in the third month and increasing in

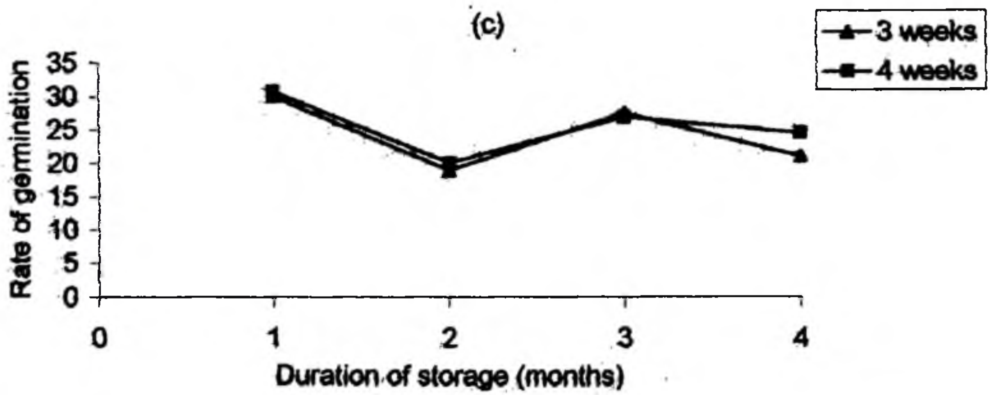
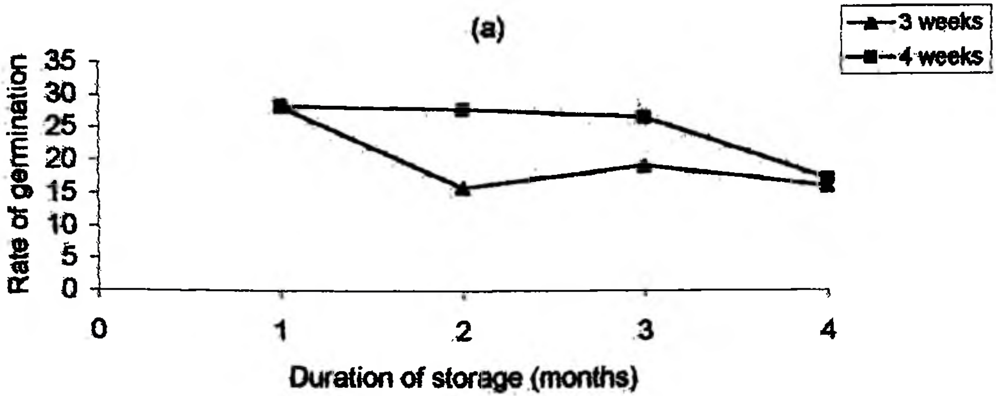
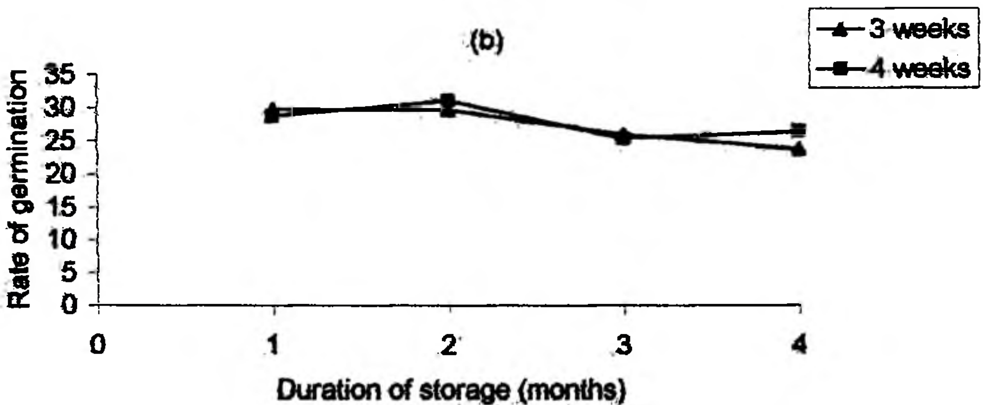


Figure 4.5: Rate of germination of *M. lathyroides* seeds harvested at three weeks and four weeks and stored under (a) room temperature (b) fridge and (c) cold room.

(a)


3 weeks
4 weeks
Rate of germination
35
30
25
20
15
10
5
0
0
1
2
3
4
Duration of storage (months)

(b)


3 weeks
4 weeks
Rate of germination
35
30
25
20
15
10
5
0
0
1
2
3
4
Duration of storage (months)

the fourth month. Significant differences were recorded for the rate of germination among the months for the 2 harvested intervals. The regression equation for the seeds harvested at 3 weeks is y=32.8-2.18x while R^2 = 0.899054. The regression equation for seeds harvested at 4 weeks is y=32.2-1.3x with R^2=0.418524.

With regard to cold room storage, there was a decrease in the rate of germination from the first month to the second month, an increase in the third month and also a decline in the fourth month for seeds harvested at 3 weeks. Seeds harvested at 4 weeks exhibited the same pattern as that of seeds harvested 3 weeks. Significant differences in the rate of germination were found among the months for the 2 harvested intervals. The regression equation for the seeds harvested at 3 weeks is y=28.95-1.87x with R^2 = 0.208378. The regression equation for seeds harvested at 4 weeks is y=28.5-1.21x with R^2 = 0.121628.

Figure 4.6 shows the rate of germination of *M. atropurpureum* seeds harvested at 3 and 4 weeks and stored at (a) room temperature (b) fridge and (c) cold room. At room temperature both seeds harvested at 3 and 4 weeks exhibited the same rate of germination. Both had increase in the rate of germination from the first to the second month, declining in the third month and raising again in the fourth month. There were

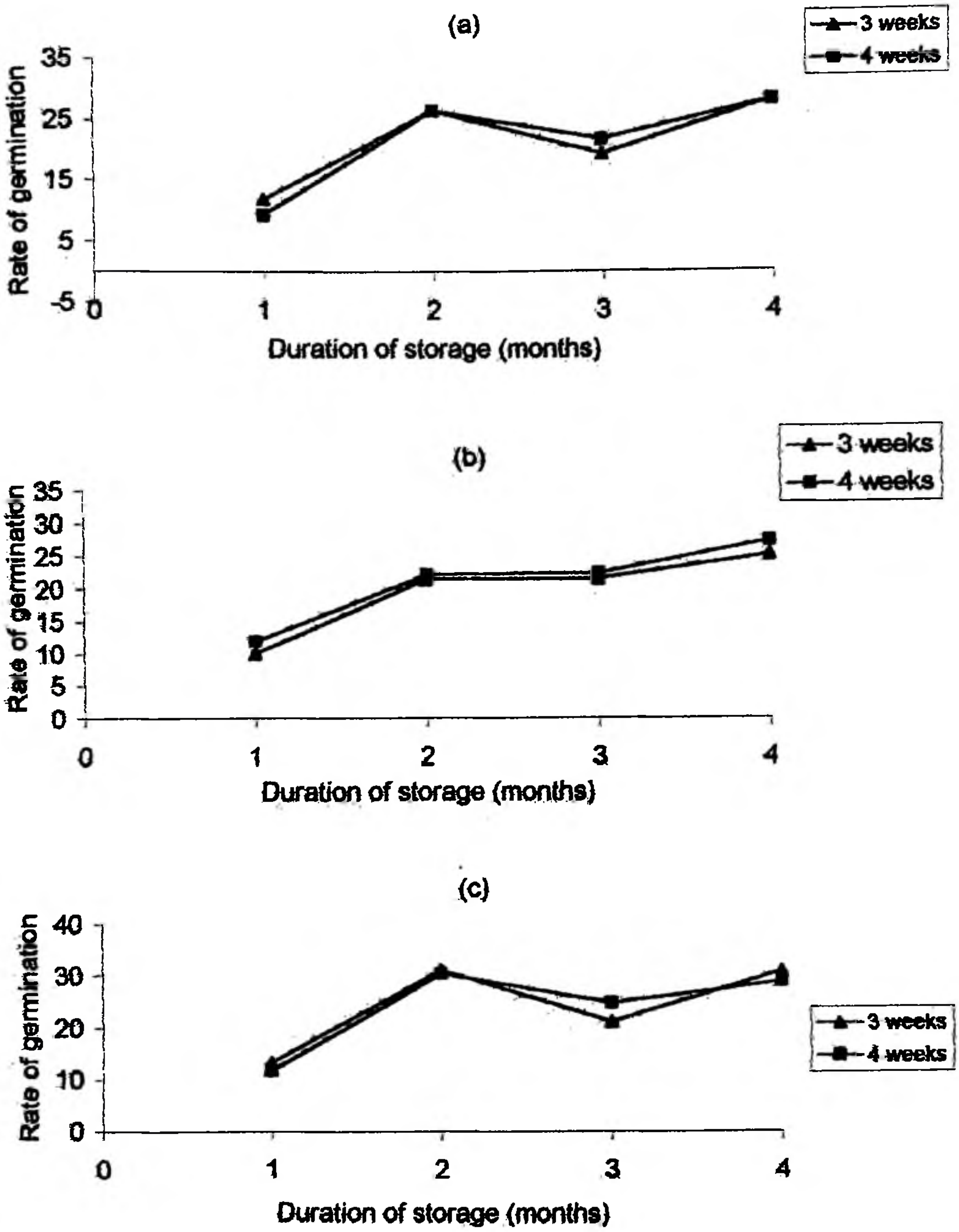


Figure 4.6: Rate of germination of *M. atropurpureum* seeds harvested at three weeks and four weeks and stored under (a) room temperature (b) fridge and (c) cold room.

significant differences in the rate of germination among the months for the two harvested intervals. The regression equation for the seeds harvested at 3 weeks is $y=4.06+11.2x$ with $R^2=0.503193$. The regression equation for the seeds harvested at 4 weeks is $y=8.6+5.08x$ with $R^2=0.601155$.

Concerning fridge storage, seeds harvested at both 3 and 4 weeks had increase in the rate of germination from the first month to the fourth month. There were significant differences in the rate of germination among the months for the two harvested intervals. The regression equation for the seeds harvested at 3 weeks is $y=8.15+4.57x$ with $R^2=0.796359$. The regression equation for the seeds harvested at 4 weeks is $y=9.3+4.65$ with $R^2=0.880443$.

In cold room storage, both seeds harvested at 3 and 4 weeks respectively had their rate of germination increasing from the first to the second month, declining in the third month and increasing again in the fourth month. There was significant difference in the rate of germination of the seeds among the months for the two harvested intervals. The regression equation for the seeds harvested at 3 weeks is $y=13.5+4.19x$ with $R^2=0.406302$. The regression equation for seeds harvested at 4 weeks is $y=12.55+12.5x$ with $R^2=0.47683$.

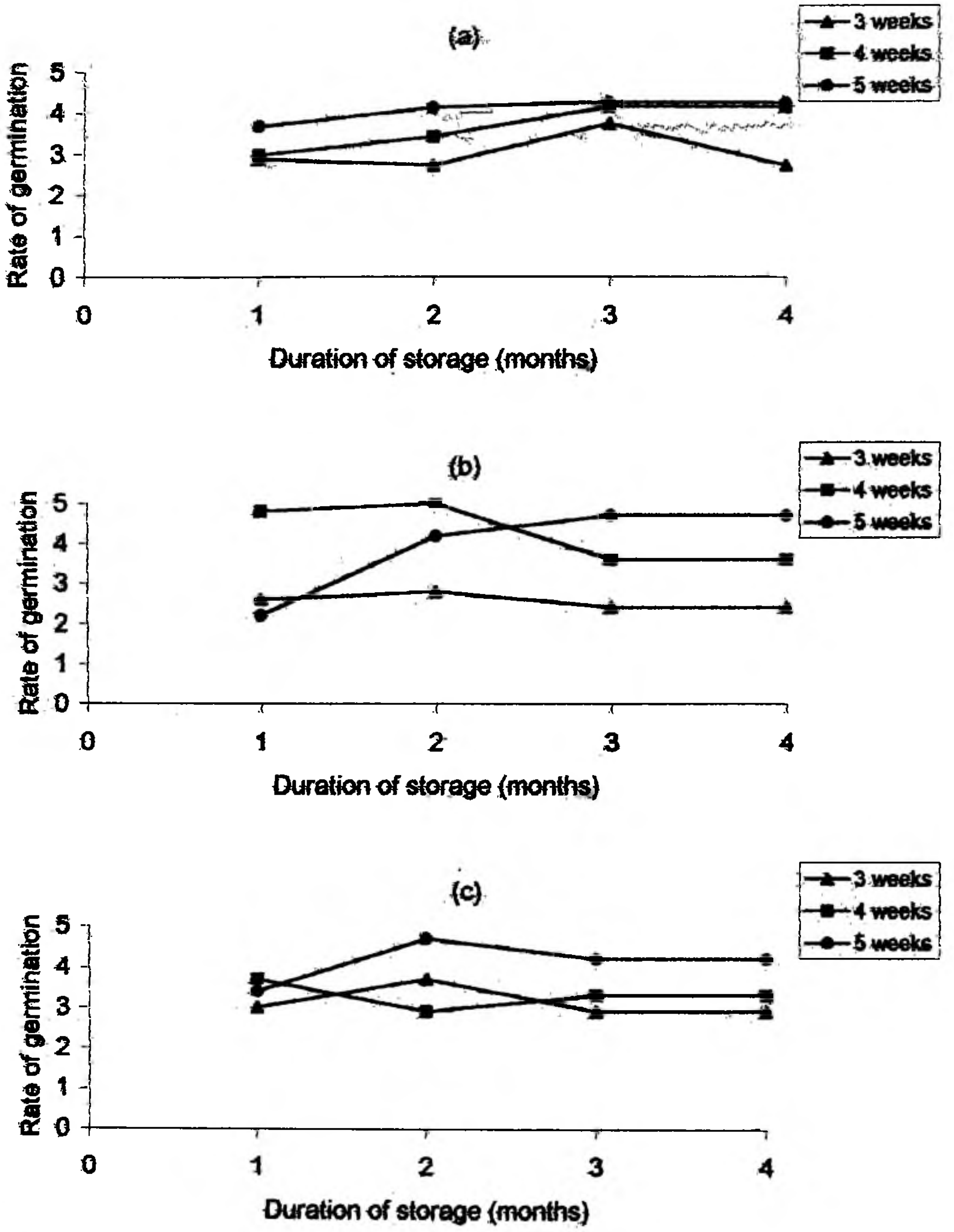


Figure 4.7: Rate of ~~germination~~ germination of *Cenchrus ciliaris* seeds harvested at three weeks, four weeks and five weeks and stored under (a) room temperature (b) fridge and (c) cold room.

Figure 4.7 shows the rate of germination of *C. ciliaris* seeds harvested at 3, 4 and 5 weeks and stored at (a) room temperature (b) fridge and (c) cold room. There was no significant differences in the rate of germination among the months for the different harvested intervals under the various storage conditions. The regression equation for the seeds harvested at 3 weeks under room temperature is y=2.9+0.04x with R^2=0.011765. The regression equation for the seeds harvested at 4 weeks under room temperature is y=2.65+0.4x with R^2=0.898876. The regression equation for the seeds harvested at 5 weeks under room temperature is y=3.65+0.16x with R^2=0.752941. The regression equation for the seeds harvested at 3 weeks under fridge storage is y=2.8-0.1x with R^2=0.454545. The regression equation for seeds harvested at 4 weeks under fridge storage is y=5.5=0.5x with R^2=0.730994. The regression equation for seeds harvested at 5 weeks under fridge storage is y=1.95+0.8x with R^2=0.752941. The regression equation for seeds harvested at 3 weeks under cold room storage is y=3.4-0.11x with R^2=0.1351955. The regression equation for seeds harvested for 4 weeks under cold room storage is y=3.5-0.08x with R^2=0.1. The regression equation for seeds harvested at 5 weeks under cold room storage is y=3.65+0.19x with R^2=0.2080692.

Figure 4.8 shows the rate of germination of *A. gayanus* seeds harvested at 3, 4 and 5 weeks and stored under (a) room

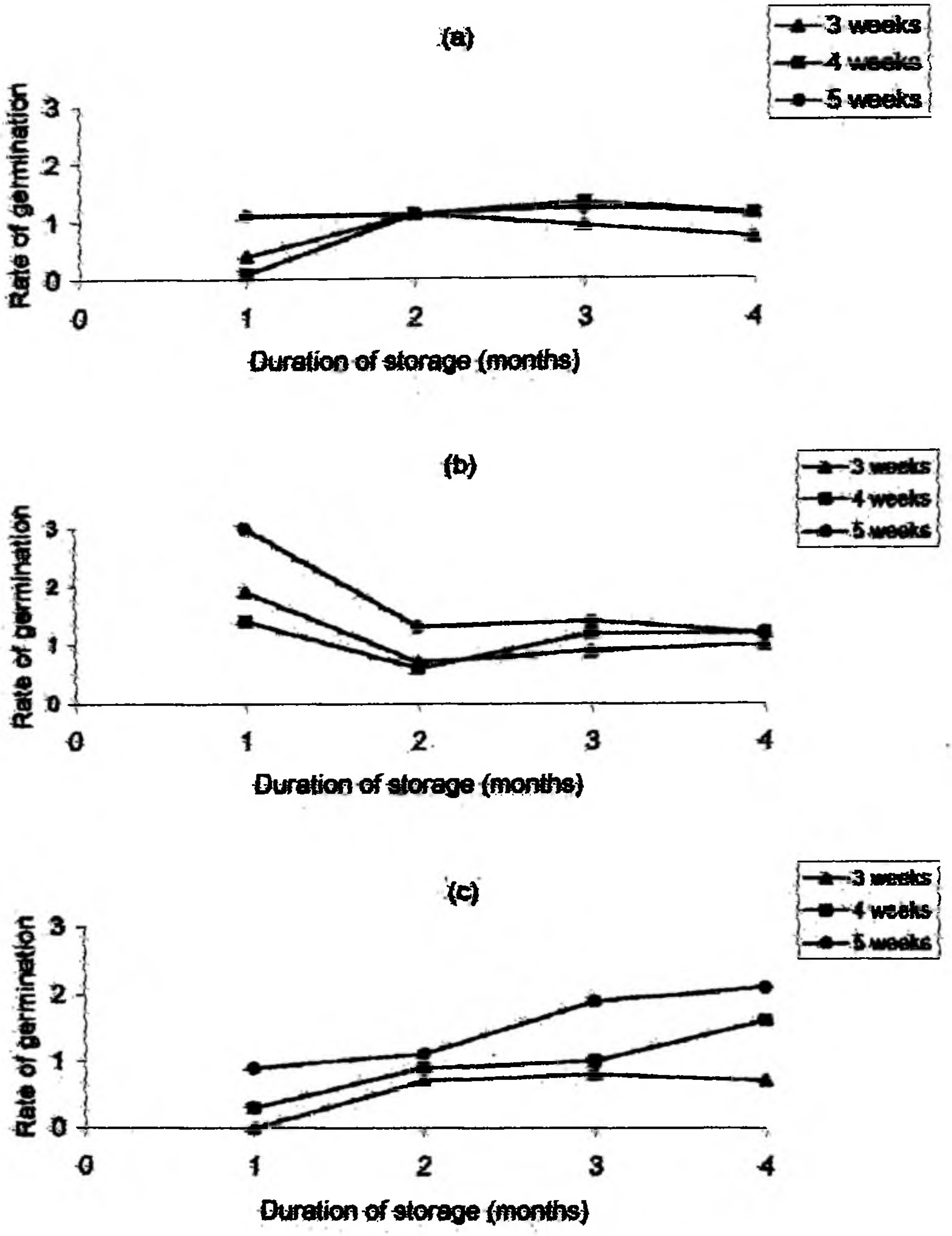


Figure 4·8 Rate of germination of *Andropogon gayanus* seeds harvested at three weeks, four weeks and five weeks and stored under (a) room temperature (b) fridge and (c) cold room.

temperature (b) fridge and (c) cold room. There was no significant differences in the rate of germination among the months for the difference harvested intervals under the various storage conditions. The regression equation for the seeds harvested at 3 weeks under room temperature is y=0.6+0.07x with R^2= 0.0915888. The regression equation for seeds harvested at 4 weeks under room temperature is y=0.1+0.32x with R^2=0.5818182. The regression equation for seeds harvested at 5 weeks under room temperature is y=1.1+0.01x with R^2=0.0668867. The regression equation for seeds harvested at 3 weeks under fridge storage is y=1.75-0.25x with R^2=0.2687316. The regression equation for seeds harvested at 4 weeks under fridge storage is y=1.1+0x with R^2=0. The regression for seeds harvested at 5 weeks under fridge storage is y=3.05-0.53x with R^2=0.6420571. The regression equation for seeds harvested at 5 weeks under cold room storage is y=0+0.22x with R^2=0.5902439. The regression equation for seeds harvested at 4 weeks under cold room storage is y=-0.05+0.4x with R^2=0.9411765. The regression equation for seeds harvested at 5 weeks under cold room storage is y=0.4+0.44x with R^2=0.9307892.

4.5 Discussion

The mean germination percentage of *M. lathyroides* harvested at both the 3 and 4 weeks after flower opening ranged between

80.6 and 93.4 over the storage period. This was considered high (Hare, 1985, Skerman, 1977, Whiteman, 1980). It was also observed that storage in the fridge gave the highest mean germination percentage of 93.4 while room temperature had mean value of 80.6 because in the fridge temperature was kept constant. In experiment one, it was observed that more seeds were obtained from the 3rd week harvest than the 4th week after flowering. Since both harvesting periods can have germination percentage of above 70, it is suggested that seeds from the crop should be harvested at the 3rd week after flowering so as to obtain more seeds for pasture.

Macroptilium atropurpureum had been germination percentage of 85.9 and 92.8 for seeds harvested at 3rd and 4th weeks after flowering over the storage period. These figures are considered very high by Skerman (1977), Whiteman (1980) and Hare (1985) for sowing these crops. In experiment one, since more seeds were obtained during the 3rd week of harvest than the 4th week and both harvesting periods can have germination percentage of above 70, it is suggested that seeds from the crop should be harvested at the 3rd week after flowering so as to obtain more seeds. Cold room storage gave the highest mean germination of 92.8% while room temperature storage had the lowest of 85.9% over the entire treatments. This conforms to the suggestions of Thomas and Evans (1990) who indicated that seed storage would be prolonged by storing at low temperature (<4° C). The temperature in the cold room were around 3° C.

Cenchrus ciliaris had mean seed germination percentage of increasing with increase in time of harvest. Thus seeds harvested at three weeks after anthesis had the lowest germination of 18.2 percent while those harvested at five weeks had the highest germination of 30.7 percent. Skerman (1977), Hare (1985) and Whiteman (1980) reported 20% as the minimum germination percentage for *C. ciliaris*. This is due to the fact that the seeds harvested at the 5^{th} week were more matured whereby drying had become prominent.

Cold room storage gave the highest mean germination percentage of 30.7 at the 5^{th} week harvest while storage in a fridge had the lowest germination percentage of 18.2 from the 3^{rd} week harvest. It is thus suggested that seeds of *C. ciliaris* in the 5^{th} week should be stored in a cold room so as to get more seeds germinating when sown.

The mean germination percentage of *A. gayanus* ranged between 5.4 and 13.2 under the various treatments for the 3^{rd}, 4^{th} and 5^{th} weeks of harvest over the entire study period. This figure is considered very low and hence it is thus suggested that vegetative parts should be used in its establishment. This low value may be due to the dormancy and the quality of the seeds. Seeds harvested at the 5^{th} week gave the highest seed germination percentage. Cold room storage also gave highest germination percentage. Thus, it is again suggested that if seeds are to be used instead of vegetative parts, which may be due to its bulkiness, seeds should be harvested at the 5^{th} week after the appearance of inflorescence so as to enhance seed germination after sowing.

Harty (1980) stated that legume seeds reaches the highest potential germination point immediately after harvest whereas grass seed may take up to ten months to reach its peak of germination. In the present experiment, the percentage germination of *C. ciliaris* and *A. gayanus* increased as the number of months of storage increase. With regard to the legume seed, germination percentage increased with increase in duration of storage, thus contradicting the statement that legume seeds reduce viability as storage time increases. This phenomenon may be due to the fact that the four month storage period may be too short for the seeds to lose viability.

The seeds of *P. maximum* did not germinate at all over the entire study period. The failure of these seeds to germinate is not quite clear but may be due to a number of factors. Hare (1985) reported that seed maturity in *P. maximum* is reached about 22 days after anthesis yet shedding can occur at a very early age with seeds at only 10 days showing 23% seed shattering. Also the harvesting period coincided with the harmattan in which most of the seeds shattered because of the dry winds. Thus it is possible that the fully matured seeds which could germinate after harvesting and storage had been shattered away leaving immature seeds not viable in the spikelets to be harvested.

Maguire (1962) reported that seed lots with total germination often vary in the rate of seedling emergence. This seems to explain the differences observed in both the percentage germination and the rate of germination. For instance M. lathyroides harvested at 3rd week had mean germination percentage of 80.6; 93.4 and 88.6 under the various storage treatments while its germination rates were 19.8, 27.4 and 23.3 respectively.

The R^2 obtained from the regression equations of the various line graphs showed that some of the seeds had both high percentage and rate of germination than other seeds. For example the R^2 value of percentage germination of *M. lathyroides* seeds harvested at three and four weeks respectively and stored at room temperature were 0.4604805 and 0.7524453 respectively, while those stored in a fridge had their R^2 values as 0.812344 for seeds harvested at three weeks and 0.0209838 for seeds harvested at four weeks. However, this cannot be used to show the trend of germination as the response used to calculate the regression equation were very small.

CHAPTER FIVE

5.0 EVALUATION OF SEED TREATMENT METHODS FOR IMPROVING GERMINATION OF FORAGE SEEDS

5.1 Introduction

The success of pasture establishment depends greatly on seed germination and seedling emergence. Sometimes when seeds are sown, they fail to germinate after providing them with conditions normally adequate for germination. This phenomenon known as seed dormancy may be due to the hard seed coat impermeable to water or oxygen and/or physiologically immature embryo (Greulach, 1973). Thus there is the need to treat seeds before sowing so as to break this dormancy and also provide better chance of pasture establishment. Hymphreys and Riveros (1986) advocated that successful pasture establishment occurs when good quality seed or cutting is given the right conditions to germinate or sprout and grow. The erratic seed germination and seedling emergence frequently associated with the culture of most forage legumes and grasses have hindered the use of these valuable crops in this country, Larbi (1979). It appears evident from the high cost of seed and the value of these crops in permanent agriculture that the need exist for critical investigation into the factors that influence their germination.

The objective of this experiment was to determine efficient methods of breaking dormancy in the seed produced from Experiment 1 in order to increase seed germination and seedling emergence.

5.2. **Materials and method**

The experiment was carried out at the Agricultural Research Station (ARS), University of Ghana, Legon. Seeds obtained from Experiment 1 which had been stored in room temperature were used. Room temperature was considered as control for environmental factors as most farmers stored their seeds at room temperature. The seeds were subjected to the following treatments:

(a) Control, where there was no treatment.

(b) Sand paper rubbing (mechanical scarification).

(c) Treating the seeds with 72% concentrated H_2SO_4 for 5 minutes and washing them thoroughly in water.

(d) Treating the seeds with 40 - 50% concentrated NaOH for 5 minutes and washing them thoroughly with water.

(e) Soaking the seeds in water at room temperature for 14 hours before sowing.

(f) Immersing the seeds in hot water at 80°C for 5 minutes before sowing.

Seeds of five forage species, namely: *M. lathyroides, M. atrotroperum, C. ciliaris, P. maximum* and *A. gayanus* were used. Cotton wool was placed in each petri dish using fifty seeds for the germination test. Water was sprinkled onto the seeds in the petri dishes for germination to occur. The appearance of the radicle was used to indicate germination. The treatments were a factorial combination of five forage species and six seed treatment. A completely randomised design with three replications was used. Daily observation and counting was made on the germination of the seeds and the number of seeds that germinated under the different treatments was recorded on the 28th day.

Parameters taken were as follows:

(a) Percentage germination of the seeds under different treatment at the 28th day.

(b) Rate of germination of the seeds under different seed treatment.

(c) Effect of seed treatment on number of days to germination.

5.3 **Statistical analysis**

The percentage germination obtained were transformed by the arcsin transformation and together with rate and effect of seed treatment on germination were subjected to analysis of variance. Data were analysed as a 5 x 6 factorial treatment combination in a completely randomised design with 3 replications.

5.4 Results

Table 5.1 shows the percentage germination of the seeds of the forage species under different methods of breaking dormancy in seeds. Seeds of P. maximum did not germinate over the study period. There was a significant ($P<0.05$) species x treatment effect on percentage germination. For instance the difference in percentage germination of *M. lathyroides* and *M. atropurpureum* without seed treatment was 57.3%, but under mechanical scarification the difference was only 6.3%. Soaking seeds of *M. lathyroides* produced 64% seed germination as opposed to 18% for *M. atropurpureum* under similar conditions.

Macroptilium lathyroides had the highest percentage of 89.3% under mechanical scarification and when treated with hot water, but concentrated H_2SO_4 depressed its germinability to 38.7%.

M. atropurperum had its highest germination under mechanical scarification, which recorded 83%. Soaking over night and concentrated NaOH slightly increased the germination percentage.

For *C. ciliaris* soaking over night increased the germination percentage slightly to 16%. Mechanical scarification, concentrated H_2SO_4, concentrated NaOH and hot water treatments depressed the percentage germination.

Table 5.1 **Percentage germination of forage seeds under different seed treatment**

FORAGE SPECIES	**SEED TREATMENT**						
	CONTROL	MECH. SCARIFICATION	CONC. H_2SO	CONC. NaOH	HOT WATER	SOAK OVER-NIGHT	LSD (5%)
M. lathyroides	57.3 (0.86)	89.3 (1.28)	3.8.7 (0.67)	66.7 (0.95)	89.3 1.30	64.7 0.93	(0.25
M. atropurpurem	10.0 (0.32)	83.0 (1.16)	24.7 (0.52)	15.3 (0.40)	34.7 (0.63)	18.00 (0.44)	(0.15
C. ciliaris	12.7 (0.36)	9.3 (0.31)	8.0 (0.32)	11.3 (0.34)	6.7 (0.21)	16.0 (0.41)	(0.21
A. gayanus	2.7 (0.13)	1.3 (0.07)	0.7 (0.05)	2.0 (0.14)	2.7 (0.13)	1.3 (0.07)	(0.18
P. maximum	-	-	-	-	-	-	-
LSD (5%)	(0.14)	(0.22)	(0.21)	(0.08)	(0.27)	(0.11)	

- Seeds did not germinate

LSD (P=0.05): Species x Treatment = 8.7 (0.17)

Parenthesis shows the arcsin transformed data.

Table 5.2 shows the rate of germination of the forage seeds under different seed treatment. There was a significant ($P<0.05$) forage species x treatment effect on the rate of germination. For instance the difference in the rate of germination of *M. lathyroides* and *M. atropurpureum* under hot water treatment was 19.4 but under concentrated H_2SO_4 the difference was only 5.8. Concentrated NaOH treatment had its rate of germination as 18.2 for *M. lathyroides* as opposed to 2.4 for *M. atropurpureum* under similar conditions.

Macroptilium lathyroides had its highest rate of germination when subjected to mechanical scarification, recording a rate of 28.2 concentrated H_2SO_4 depressed its rate of germination to 10.9 as compared to control of 15.5.

Macroptilium atropurpureum had highest rate of germination of 24.9 under mechanical scarification whereas soaking over night and conc. H_2SO_4 slightly increased its rate of germination.

For *C. ciliaris*, mechanical scarification increased its germination rate to 8.4 whereas the other treatments depressed its rate of germination as compared to control, except soaking over night where its rate of germination was 3.1.

Table 5.2 **Rate of germination of forage seeds after various seed treatment**

SPECIES	TREATMENT						
	CONTROL	MECH. SCARIFICATION	CONC. H_2SO_4	CONC. NaOH	HOT WATER	SOAKING OVER-NIGHT	LSD (5%)
M. lathyriodes	15.5	28.2	10.9	18.2	26.3	17.5	4.1
M.atropurpureum	1.3	24.9	5.1	2.4	6.9	4.0	3.5
C. ciliaris	2.0	8.4	1.3	1.2	0.7	3.1	1.1
A. gayanus	0.5	0.2	0.1	0.2	0.4	0.2	N/S
P. maximum	-	-	-	-	-	-	-
LSD (5%)	2.9	4.8	2.3	1.7	1.1	1.5	

LSD (P=0.05); Species x Treatment =2.3
- Seed did not germinate
N/S- Not significant

Table 5.3 shows the effect of seed treatment on number of days to germination. There was significant ($P<0.05$) forage species x treatment effect on the number of days to germination. For example, the difference in the effect of seed treatment of *C. ciliaris* and *A. gayanus* under concentrated NaOH was 6.0 but under hot water treatment the difference was only 1.0. Also the effect of seed treatment on *C. ciliaris* under mechanical scarification was 5.0 but only 1.0 for *A. gayanus* under similar conditions.

Table 5.3. **Effect of seed treatment on number of days to germination.**

SPECIES	TREATMENT						
	CONTROL	MECH SCARIFI-CATION	CONC. H_2SO_4	CONC. NaOH	HOT WATER	SOAKING OVER-NIGHT	LSD (5%)
M. lathyroides	3	3	3	3	3	3	NS
M. atropurpureum	4	3	3	4	3	3	2
C. ciliaris	4	5	3	6	4	4	4
A. gayanus	3	1	1	12	3	4	5
P. maximum	-	-	-	-	-	-	-
LSD (5%)	3	2	3	4	4	2	

LSD (P=0.05); Species x Treatment= 3
- Did not germinate

5.5 **Discussion**

The difference in the germination of the forage species were influenced by the different treatments adopted. These results are similar to those of other workers. Grant and Clatworthy (1984) Whiteman (1980) have reported that acid scarification is somewhat unreliable giving different results when used to treat seeds. Although seed treatment generally promotes germination, the actual method used would depend on the forage species and the feasibility of the seed treatment method. The high rate of germination agrees with the findings of Addo-Kwafo (1996) and Larbi (1979) who worked with mechanical scarification and other methods. They found that mechanical scarification gave highest percentage germination when compared to other methods. Scarification is known to improve germination by enhancing permeability to moisture and gases (Multhorpe and Mourby, 1986; Tybirk, 1991). It may also increase the seeds sensitivity to temperature and light as well as result in the removal or destruction of some of the inhibitory substances, thus improving germination (Ellis *et. al.*, 1985).

The low germination given by the scarified seeds of *C. ciliaris* and *A. gayanus* might be attributed to the fact that mechanical scarification led to the peeling off of a greater part of the embryo, thus leading to low germination. Dell (1980) reported that different treatments gave different water uptake curves for *Albizza lophanta*. This gives an indication that the various treatments adopted in the trial might have affected the imbibition of water by the seeds differently leading to some of the species recording higher germination than other. For example, soaking overnight gave a germination percentage of 64.67, 18 and 16 for *M. lathyroides*, *M. atropurpureum* and *C. ciliaris* of 57.3, 10 and 12.7% respectively.

Untreated seeds have been found to germinate in spurts if kept moist over long periods of time (Halery, 1974, Coe and Coe, 1987). This explains the reason for the germination of untreated seeds of A. gayanus having 2.7% which was more than some treated ones.

Immersion of seed in hot water at 80°C for ten minutes is effective for a wide range of species including *Leucaena leucocephala* (Gray, 1968). This explained the high germination percentage values of 89.3 and 34.7 obtained from M. lathyroides and M. atropurpureum as compared to the control. However, Ellis *et. al.* (1985) had observed imbibition injury and subsequent destruction of the embryo of forage sorghum (*Sorghum vulgare*) when immersed in warm water. In the same way Rudrapel and Basu (1980) also observed soaking injury resulting from rapid imbibition when soybean was immersed in warm water. These findings might explain why *C. ciliaris* and *A. gayanus* seeds for hot water treatment had low percentage germination.

Acid scarification is somewhat unreliable (Whiteman, 1980, Grant and Clatworthy, 1984) as there is the tendency for it to kill some seeds (Ellis *et. al.*, 1985). This perhaps explains the very low germination of *M. lathyroides, C. ciliaris* and *A. gayanus* as compared to the control apart from *M. atropurpereum*, probably due to the resistance of latter to damage by concentrated H_2SO_4. However, good results are obtained with 50-90% germination within fourteen days when concentrated H_2SO_4 or concentrated NaOH are used and the seeds thoroughly watered (Tybirk, 1991). This explains the high percentage germination with concentrated NaOH treatment in *M. lathyroides* and M. *atropurpureum* compared to the Control.

Maquire (1962) reported that seedlots with similar total germination often vary in the rate of seedling emergence and rate of growth. This finding explains the differences observed in both percentage germination and the rate of germination. Thus though *M. lathyroides* and *M. atropurpureum* had similar germination percentage (89.3 and 83.3) respectively for mechanical scarification where their rates of germination were 28.2 and 24.9 respectively.

The reason why *P. maximum* did not germinate is not quite clear but it is possible that the fully matured seeds which could germinate after harvesting and storage had been scattered away leaving the immature seeds in the spikelets to be harvested as the crop at any particular time will contain a very high proportion of immature seeds (Hare, 1985).

From the above results and discussion, it can be concluded that mechanical and acid scarification as well as hot water treatment and soaking over night can be used to break seed dormancy of *M. lathyroides*, *M. atropurpureum* and *C. ciliaris* in order to enhance the germination of these seeds.

CHAPTER SIX

6.0 SUMMARY

Ruminant livestock depend on natural grassland, cut herbage, crop residues and agro-industrial products for their nutritional needs. However, there is reduction in area under natural grassland for grazing as a result of growing human population with consequent demand for cropping, settlement, industrial and infrastructural development. Thus, there is the need for farmers to establish high yielding sown pastures on limited land area to feed their animals and this calls for cheap propagules that the farmers would used. Five forage crops were studied to find out their seed yield potential at various harvest intervals and how their germination can be enhanced.

The first experiment investigated the field establishment and seed yield of *M. lathyroides*, *M. atropurpereum*, *P. maximum*, *C. ciliaris* and *A. gayanus* at different harvest intervals. This would help to ascertain how to get enough seeds to establish pastures for our ruminant livestock. The study showed that it took four days for *M. lathyroides* and *M. atropurpereum* to emerge from the soil after sowing while *P. maximum*, *C. ciliaris* and *A. gayanus* took, 5 and 6 days respectively to sprout or emerge from the soil after planting vegetatively.

Also it took *M. lathyroides* 40 days to flower; 55 days for *M. atropurpereum* to flower; 40 days for *P. maximum* to bear inflorescence; 36 days for *C. ciliaris* and 67 days for *A. gayanus*. Highest seed yield was obtained from *M. lathyroides* and *M. atropurpereum* harvested at three weeks after first flowering. Seed obtained from *M. lathyroides* and *M. atropurpereum* in the first harvest period were higher than those harvested later in the season due to the high shattering of the legume seeds especially at five weeks after first flowering.

Seed yield of *P. maximum* and *C. ciliaris* were higher than that of *A. gayanus*. With *P. maximum,* shedding of the seeds were noticed around 24 days after anthesis, thus affecting the yield. Shedding of seeds was not prominent in *C. ciliaris* and *A. gayanus*.

The second experiment was conducted to compare the viability of the seeds harvested from Experiment 1 and stored under different conditions for different periods of time. The study showed that the mean germination percentage of the seeds of *M. lathyroides* and *M. atropurpureum* harvested at both three and four weeks after flowering ranged between 80.6% and 93.4% over the 4 month period under room temperature, fridge and cold room storage. Percentage seed germination of *C. ciliaris* ranged between 18.2% and 30.7% for the three harvest periods over the four months storage under the storage environment. *Andropogon gayanus* had mean seed germination percentage of between 5.4% and 13.2% over the study period which was rather very low. Seeds of P. maximum did not germinate at all over the study period which could be attributed to early shedding of the mature seeds. Coldroom storage gave highest percentage seed and rate of germination for *M. atropurpureum; A. gayanus* and *C. cilaris,* while storage in a fridge gave highest germination percentage for *M. lathyroides*. Seeds of *C. ciliaris* and *A. gayanus* harvested at five weeks after inflorescence gave highest germination percentage than those harvested at three and five weeks after flowering. With regard to *M. lathyroides* and *M. atropurpureum* seeds harvested at three and four weeks after flower opening gave germination percentage of 80% under all storage conditions.

Experiment three was conducted to determine efficient methods of breaking seed dormancy from seeds obtained from Experiment one. Highest seed germination occurred in the mechanically scarified seeds of *M. lathyroides* and *M. atropurpureum* which were 89.3% and 83.3% respectively. *Cenchrus ciliaris* and *A. gayanus* had very low values of 1.3% and 9.3% respectively. Soaking seeds overnight gave a higher germination percentage of 64.7; 18 and 16 respectively for *M. lathyroides, M.*

atropurpureum and *C. ciliaris* than the control. Hot water treatment increased the germination percentage of *M. lathyroides* from 57.3% to 89.3%. Acid scarification using concentrated H_2SO_4 decreased the percentage germination of *M. lathyroides* but increased the percentage germination of *M. atropurpureum*. *Panicum maximum* seeds did not germinate at all over the study period, not even with any of the seed treatments.

CHAPTER SEVEN

7.0 CONCLUSIONS AND RECOMMENDATIONS

Seed yield obtained from *M. lathyroides* and *M. atropurpureum* harvested at three weeks after flower opening was higher than when harvesting was done a week or two later. This was due to the shattering of the seeds. Seed yield obtained from *P. maximum* and *C. ciliaris* were higher than that of *A. gayanus* harvested at the three harvest intervals. With regard to *M. lathyroides* and *M. atropurpureum,* since the seeds harvested at both three and four weeks after flower opening had a germination percentage of above 80% under various storage conditions but fewer seeds were collected during the fourth week harvest, it is recommended that the seeds of *M. lathyroides* and *M. atropurpureum* should be harvested three weeks after flower opening.

Since there was not much yield differences between *C. ciliaris* and *P. maximum* but higher germination percentage were obtained from those harvested at five weeks after the appearance of inflorescence, it is recommended that those seeds should be harvested at fifth week after the appearance of inflorescence.

On storage conditions, since the percentage germination and the rate of germination obtained from cold room storage was higher for *M. atropurpureum*, *C. ciliaris* and *A. gayanus* than *M. lathyroides*, it is recommended that if cold room is available these seeds should be stored there, while *M. lathyroides* should be stored in a fridge. If cold room is not available, these seeds can be stored in a fridge or well ventilated room. However for long-term storage they should be kept in a cold room with a temperature below 2°C. Storage helps "after ripening" to occur thereby encouraging seeds to germinate readily after sowing.

Scarified seeds of *M. lathyroides* and *M. atropurpureum* gave high germination percentage of between 83.3% and 89.3%. Seed of this forage species should be mechanically scarified before sowing. Hot water treatment can also be applied to *M. lathyroides* to enhance germination as it gave a percentage germination of 89.3%. Soaking overnight can be used to improve the germination of *C. ciliaris*.

It is also recommended that vegetative propagation could be used to establish pastures from *A. gayanus* as it recorded low germination form the germination tests conducted.

Further studies should also be carried out on *P. maximum* to find effective ways of improving its germinability since the work done showed that none of the seeds germinated using

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APPENDICES

APPENDIX 1: Analysis of variance (ANOVA) for percentage emergence of the legumes.

Source of variation	d.f.	s.s.	m.s.	v.r	F pr.
Reps	2	139.8	69.9	0.69	
Forage species	1	128.8	128.8	1.27	0.378
Residual	2	203.6	101.8		
Total	5	472.3			

APPENDIX 2: ANOVA for percentage sprouting of the grasses.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps	2	162.06	81.03	1.39	
Forage species	2	5.36	2.68	0.04	0.957
Residual	4	241.28	60.32		
Total	8	408.70			

APPENDIX 3: ANOVA for yield of dried legume seeds (kg/ha)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps	2	234.032	117.016	16.67	
Species	1	8.670	8.670	1.25	0.380
Residual	2	13.875	6.938	1.29	
Age	1	473.763	473.763	88.09	<0.001
Species x Age	1	11.213	11.213	2.08	0.222
Residual	4	21.513	5.378		
Total	11	763.067			

APPENDIX 4 ANOVA for yield of dried grass seeds (kg/ha)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps	2	51.354	25.677	0.49	
Species	2	989.023	494.511	9.39	0.031
Residual	4	210.750	52.688	8.58	
Age	2	76.432	38.216	6.22	0.014
Species x Age	4	46.646	11.661	1.90	0.176
Residual	12	73.729	6.144		
Total	16	1447.934			

APPENDIX 5 ANOVA for percentage germination of forage seed under different seed treatment at 28th day.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Forage species	4	57376.44	14344.11	521.39	<0.001
Treatment	5	5052.62	1010.52	36.73	<0.00
Forage spp x Treatment	20	11763.82	588.19	21.38	<0.001
Residual	60	1650.67	27.51		
Total	89	75843.56			

APPENDIX 6 ANOVA for rate of germination of forage seed under different seed treatment at 28th day.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Forage species	4	4860.01	1215.00	622.41	<0.001
Treatment	5	589.90	117.98	60.44	<0.001
Forage spp x Treatment	20	1229.89	61.49	31.50	<0.001
Residual	60	117.13	1.95		
Total	89	6796.92			

APPENDIX 7 ANOVA for effect of seed treatment on germination time of forage crops (days).

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Forage species	4	202.33	50.58	18.51	<0.001
Treatment	5	98.09	19.62	7.18	<0.001
Forage spp x Treatment	20	200.4	10.02	3.67	<0.001
Residual	60	164.00	2.73		
Total	89	664.89			

APPENDIX 8 ANOVA for percentage germination at 3rd and 4th week harvests under three different storage conditions for *M. lathyroides*.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps	2	114.19	57.10	15.06	
Weeks	1	78.13	78.13	20.60	0.045
Residual (a)	2	7.58	3.79	0.08	
Months	3	1547.71	515.90	10.95	<0.001
Treatment	2	865.44	432.72	9.19	<0.001
Weeks x months	3	366.26	122.09	2.59	0.065
Weeks x Treatment	2	387.00	193.50	4.11	0.023
Months x Treatment	6	1460.67	243.44	5.17	<0.001
Weeks x months x Treat.	6	806.44	134.41	2.85	0.020
Residual (b)	44	2072.22	47.10		
Total	71	7705.65			

APPENDIX 9 ANOVA for percentage germination at 3rd and 4th week harvests under three different storage conditions for *M. atropurpureum*.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps	2	17.36	8.68	0.04	
Weeks	1	8.00	8.00	0.04	0.865
Residual (a)	2	432.75	216.38	4.32	
Months	3	7369.50	2456.50	49.01	<0.001
Treatment	2	489.36	244.68	4.88	0.012
Weeks x months	3	201.11	67.04	1.34	0.274
Weeks x Treatment	2	20.08	10.04	0.20	0.819
Months x Treatment	6	879.75	146.62	2.93	0.017
Weeks x months x Treat.	6	129.47	21.58	0.43	0.855
Residual (b)	44	2205.22	50.12		
Total	71	11752.61			

APPENDIX 10 ANOVA for rate of germination at 3rd and 4th week harvest under three different conditions for *M. lathyroides*.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps	2	6.21	3.10	1.01	
Weeks	1	98.80	98.80	32.08	0.030
Residual (a)	2	6.14	3.07	0.48	
Months	3	596.80	198.93	30.94	<0.001
Treatment	2	330.14	165.07	25.67	<0.001
Weeks x months	3	57.37	19.12	2.97	0.042
Weeks x Treatment	2	75.12	37.56	5.84	0.006
Months x Treatment	6	382.33	63.72	9.91	<0.001
Weeks x months x Treat.	6	110.41	18.40	2.86	0.019
Residual (b)	44	282.90	6.43		
Total	71	1946.20			

APPENDIX 11 ANOVA for rate of germination at 3rd and 4th week harvest under three different storage conditions for *M. atropurpureum*.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps	2	3.61	1.81	0.12	
Weeks	1	2.23	2.23	0.14	0.74
Residual (a)	2	31.39	15.70	3.44	
Months	3	3007.37	1002.46	219.71	<0.001
Treatment	2	169.02	84.51	18.52	<0.001
Weeks x months	3	24.19	8.06	1.77	0.167
Weeks x Treatment	2	8.16	4.08	0.09	0.416
Months x Treatment	6	129.42	21.57	4.73	<0.001
Weeks x months x Treat.	6	27.70	4.62	1.01	0.430
Residual (b)	44	200.75	4.56		
Total	71	3603.83			

APPENDIX 12 ANOVA for percentage germination at 3rd 4th and 5th week harvest under three different storage conditions for *C. ciliaris*.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps	2	15.91	7.95	0.74	
Weeks	2	1466.80	733.40	68.25	<0.001
Residual (a)	4	42.98	10.75	0.50	
Months	3	365.21	121.74	5.63	0.002
Treatment	2	92.46	46.23	2.14	0.126
Weeks x months	6	340.31	56.72	2.62	0.024
Weeks x Treatment	4	150.76	37.69	1.74	0.151
Months x Treatment	6	58.30	9.70	0.45	0.843
Weeks x months x Treat.	12	778.35	64.86	3.00	0.002
Residual (b)	66	1427.11	21.62		
Total	107	4738.10			

APPENDIX 13 ANOVA for percentage germination at 3rd 4th and 5th week harvest under three different storage conditions for *A. gayanus.*

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps	2	131.56	65.78	11.84	
Weeks	2	560.22	280.11	50.42	<0.001
Residual (a)	4	22.22	5.56	0.75	
Months	3	363.07	121.03	16.25	<0.001
Treatment	2	36.22	43.11	5.79	0.005
Weeks x months	6	98.15	16.36	2.20	0.054
Weeks x Treatment	4	94.90	23.72	3.19	0.019
Months x Treatment	6	342.82	57.14	7.67	<0.001
Weeks x months x Treat.	12	68.96	5.75	0.77	0.677
Residual (b)	66	491.56	7.45		
Total	107	2259.67			

APPENDIX 14 ANOVA for rate of germination at 3rd 4th and 5th week harvest under three different storage conditions for *C. ciliaris.*

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps	2	0.0803	0.0401	0.46	
Weeks	2	29.1034	14.5517	167.59	<0.001
Residual (a)	4	0.3473	0.6868	0.13	
Months	3	3.6640	1.2213	1.89	0.153
Treatment	2	0.2410	0.1205	0.18	0.837
Weeks x months	6	11.2954	1.8826	2.80	0.017
Weeks x Treatment	4	5.7103	1.4276	2.12	0.088
Months x Treatment	6	6.1987	1.0331	1.53	0.181
Weeks x months x Treat.	12	13.8532	1.1544	1.71	0.084
Residual (b)	66	44.4440	0.6734		
Total	107	114.9376			

APPENDIX 15 ANOVA for rate of germination at 3rd 4th and 5th week harvest under three different storage conditions for *A. gayanus*.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps	2	0.6500	0.3250	2.17	
Weeks	2	7.7197	3.8598	25.83	0.005
Residual (a)	4	0.5977	0.1494	0.72	
Months	3	0.9962	0.3321	1.60	0.198
Treatment	2	3.0442	1.5221	7.32	<0.001
Weeks x months	6	2.6946	0.4491	2.16	0.058
Weeks x Treatment	4	1.5612	0.3903	1.88	0.125
Months x Treatment	6	14.6203	2.4367	11.72	<0.001
Weeks x months x Treat.	12	1.9316	0.1610	0.77	0.674
Residual (b)	66	13.7198	0.2079		
Total	107	47.5353			

APPENDIX 16: Mean percentage germination of *M. lathyroides* harvested at three weeks and four weeks and stored under three different conditions.

DURATION OF STORAGE	AGE AT HARVESTING					
	3 WEEKS AFTER HARVESTING			4 WEEKS AFTER HARVESTING		
	ROOM TEMP.	FRIDGE	COLD ROOM	ROOM TEMP.	FRIDGE	COLD ROOM
One Month	97.3 (1.35)	96.3 (1.37)	97.0 (1.30)	95.0 (1.26)	93.7 (1.29)	96.3 (1.43)
Two Months	70.7 (0.80)	95.7 (1.28)	82.0 (0.90)	98.0 (1.41)	98.0 (1.41)	74.0 (0.84)
Three months	83.7 (1.04)	94.0 (1.37)	92.3 (1.10)	89.3 (1.16)	84.3 (1.02)	37.7 (1.07)
Four Months	70.7 (0.79)	87.7 (1.07)	83.0 (0.90)	74.3 (0.84)	96.0 (1.34)	88.7 (1.11)

Parentheses show the transformed the arcsin transformation

APPENDIX 17: Mean percentage germination of *M. atropurpureum* harvested at three weeks and four weeks and stored under three different conditions.

DURATION OF STORAGE	AGE AT HARVESTING					
	3 WEEKS AFTER HARVESTING			4 WEEKS AFTER HARVESTING		
	ROOM TEMP.	FRIDGE	COLD ROOM	ROOM TEMP.	FRIDGE	COLD ROOM
One Month	66.0 (0.74)	73.3 (0.84)	81.3 (0.95)	58.7 (0.63)	75.3 (0.88)	75.7 (0.86)
Two Months	91.0 (1.15)	87.0 (1.08)	99.3 (1.48)	97.7 (1.45)	87.3 (1.09)	100.0 (1.57)
Three months	91.3 (1.17)	93.0 (1.20)	91.3 (1.17)	94.0 (1.30)	99.3 (1.48)	93.3 (1.38)
Four Months	97.7 (1.36)	97.3 (1.44)	97.0 (1.34)	93.3 (1.21)	96.7 (1.32)	98.3 (1.47)

Parentheses show the transformed the arcsin transformation

APPENDIX 18: Mean rate of germination of *M. lathyroides* harvested at three weeks and four weeks and stored under three different conditions.

DURATION OF STORAGE	AGE AT HARVESTING					
	3 WEEKS AFTER HARVESTING			4 WEEKS AFTER HARVESTING		
	ROOM TEMP.	FRIDGE	COLD ROOM	ROOM TEMP.	FRIDGE	COLD ROOM
One Month	28.4	29.8	30.0	28.5	28.8	30.7
Two Months	15.5	29.8	18.8	27.9	31.2	20.0
Three months	19.1	26.0	27.4	26.5	25.4	26.8
Four Months	15.9	23.8	20.9	17.5	26.4	24.4

APPENDIX 19: Mean rate of germination of *M. athropurpureum* harvested at three weeks and four weeks and stored under three different conditions.

DURATION OF STORAGE	AGE AT HARVESTING					
	3 WEEKS AFTER HARVESTING			4 WEEKS AFTER HARVESTING		
	ROOM TEMP.	FRIDGE	COLD ROOM	ROOM TEMP.	FRIDGE	COLD ROOM
One Month	11.9	10.0	13.3	9.3	11.9	11.7
Two Months	26.5	21.7	31.0	26.5	22.1	30.3
Three months	19.1	21.6	21.0	21.5	22.4	24.6
Four Months	27.9	25.2	30.6	27.9	27.3	28.6

APPENDIX 20: Mean percentage germination of *C. ciliaris* harvested at three weeks, four weeks and five weeks and stored under three different conditions.

Duration of Storage	AGE AT HARVESTING								
	3 WEEKS AFTER HARV.			4 WEEKS AFTER HARV.			5 WEEKS AFTER HARV.		
	ROOM TEMP.	FRIDGE	COLD ROOM	ROOM TEMP.	FRIDGE	COLD ROOM	ROOM TEMP.	FRIDGE	COLD ROOM
One Month	20.7 (0.21)	17.0 (0.17)	20.7 (0.21)	24.7 (0.25)	33.3 (0.34)	26.0 (0.26)	29.7 (0.30)	18.0 (0.18)	26.3 (0.27)
Two Months	22.3 (0.23)	19.7 (0.20)	29.3 (0.30)	32.3 (0.33)	34.0 (0.35)	23.7 (0.24)	30.6 (0.31)	31.3 (0.31)	32.7 (0.33)
Three Months	24.3 (0.25)	20.3 (0.21)	14.7 (0.15)	24.7 (0.25)	19.3 (0.19)	24.7 (0.25)	32.7 (0.33)	28.0 (0.28)	33.0 (0.34)
Four Months	19.3 (0.19)	15.7 (0.16)	20.0 (0.20)	28.0 (0.28)	22.0 (0.22)	23.7 (0.24)	26.7 (0.27)	30.3 (0.31)	30.7 (0.31)

Parentheses show the transformed data using the arcsin transformation

APPENDIX 21: Mean percentage germination of *A. gayanus* harvested

at three weeks, four weeks and five weeks and stored under three different conditions.

Duration of Storage	AGE AT HARVESTING								
	3 WEEKS AFTER HARV.			4 WEEKS AFTER HARV.			5 WEEKS AFTER HARV.		
	ROOM TEMP.	FRIDGE	COLD ROOM	ROOM TEMP.	FRIDGE	COLD ROOM	ROOM TEMP.	FRIDGE	COLD ROOM
One Month	3.3 (0.03)	11.3 (0.11)	0.0 (0.00)	0.7 (0.01)	6.0 (0.06)	2.6 (0.03)	6.0 (0.06)	12.7 (0.13)	5.3 (0.05)
Two Months	6.7 (0.07)	6.7 (0.07)	6.7 (0.07)	8.7 (0.09)	8.0 (0.08)	8.0 (0.08)	11.3 (0.11)	12.0 (0.12)	12.7 (0.13)
Three Months	6.7 (0.07)	7.3 (0.07)	6.0 (0.06)	9.3 (0.09)	8.0 (0.08)	9.3 (0.09)	8.7 (0.09)	11.3 90.11)	14.7 (0.15)
Four Months	4.7 (0.05)	7.3 (0.07)	6.7 (0.07)	8.7 (0.09)	8.7 (0.09)	12.7 (0.13)	11.3 (0.11)	12.0 (0.12)	20.0 (0.20)

Parentheses show the transformed data using the arcsin tranformation

APPENDIX 22: Mean rate of germination of *C. ciliaris* harvested at three weeks, four weeks and five weeks and stored under three different conditions.

Duration of Storage	AGE AT HARVESTING								
	3 WEEKS AFTER HARV.			4 WEEKS AFTER HARV.			5 WEEKS AFTER HARV.		
	ROOM TEMP.	FRIDGE	COLD ROOM	ROOM TEMP.	FRIDGE	COLD ROOM	ROOM TEMP.	FRIDGE	COLD ROOM
One Month	2.9	2.6	3.0	3.0	4.8	3.7	3.7	2.2	3.4
Two Months	2.7	2.8	3.7	3.4	5.0	2.9	4.1	4.2	4.7
Three Months	3.7	2.4	2.9	4.1	3.6	3.3	4.2	4.7	4.2
Four Months	2.7	2.4	2.9	4.1	3.6	3.3	4.2	4.7	4.2

APPENDIX 23: Mean rate of germination of *A. gayanus* harvested at three weeks, four weeks and five weeks and stored under three different conditions.

Duration of Storage	AGE AT HARVESTING								
	3 WEEKS AFTER HARV.			4 WEEKS AFTER HARV.			5 WEEKS AFTER HARV.		
	ROOM TEMP.	FRIDGE	COLD ROOM	ROOM TEMP.	FRIDGE	COLD ROOM	ROOM TEMP.	FRIDGE	COLD ROOM
One Month	0.1	1.9	0.0	0.1	1.4	0.3	1.1	3.0	0.9
Two Months	1.1	0.7	0.7	1.1	0.6	0.9	1.1	1.3	1.1
Three Months	0.9	0.9	0.8	1.3	1.2	1.0	1.2	1.4	1.9
Four Months	0.7	1.0	0.7	1.1	1.2	1.6	1.1	1.2	2.1