Natural and Artificial Regeneration of *Adansonia digitata* L. at Elkhouyi, North Kordofan State, Sudan.

By

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Dedication

To my Lovely Mother and my Father

To my wife and brothers and sisters

To my relatives

To my friends

With best love

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Praise and thanks to almighty Alla, God of the world for accomplishing this work. I would like to express my profound gratitude and thanks to my supervisor Dr. Essam Warrag, University of Khartoum for his keen interest, close supervision, continuous participation and patient invaluable guidance throughout the period of the study.

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ABSTRACT

Adansonia digitata (Tabeldi, Boabab) is an economically important tree species for rural people and at the national level for its uses and nutritional and medicinal values. The species is considered endangered with poor natural regeneration in Sudan. This study surveyed the status of soil seed bank and natural regeneration at Elkhouyi Site in North Kordofan State. Also, it investigated the effect of fruit collection date, seed planting date and seed pre-germination treatment on seed germination and seedling growth at the nursery. Effect of protection from grazing for seedling and seed on germination and seedling survival was studied at the site. Soil seed bank was surveyed according to soil depth, distance and direction from existing trees. Natural regeneration was assessed by counting young seedlings (1 m in length) according to direction and distance from the nearest tree. Seed pre-germination treatments (sulfuric acid (96%), electric burner, dry heat and control) were applied for seed collected in October, November, December and January of the following year and weighed. Treated seeds were tried in January, April and July 2006. Seed germination was recorded and seedling growth was measured weekly from week 5 to week 13 and leaves number per seedling was recorded at week 13.

The results showed that there is low soil seed bank and scarce natural regeneration. Seed number per unit volume of soil is significantly higher at soil depth 5 cm than other deeper depths. Also, the seeds and seedlings were concentrated near trees. The direction from trees showed no significant effect on seed or seedling number.

Seeds collection date, planting date and scarification treatment showed significant effect on seed germination and to some extent on seedling height and leaves number. Seeds collected in January (2006), had significantly higher germination percent than those collected in October 2005, indicating importance of seed maturity and suitable fruit collection date. Seeds planted in July showed higher germination percentages and longer seedlings and more leaves than earlier planting (January and April). This also, showed the importance of seed maturity. The effect of seed treatments was significant on seeds planted in January and April. Seed coat scarification using electric burner or concentrated sulphuric acid gave higher germination percentage, especially for seeds planted in January and April.

The field study showed significantly higher survival percentage for transplanted and germinating seedlings in protected site compared to unprotected one. This indicates the importance of protection from grazing animals. Accordingly, the study recommends protection of *A. digitata* sites and enriching the soil seed bank of *A. digitata* to ensure germination.

التجديد الطبيعي والصناعي لشجرة التبلدي في منطقة الخوي بولاية شمال كردفان

الخلاصة

شجرة التبلدي من الأشجار المهمة بما تتمتع به من أهمية اقتصادية للسكان و على النطاق القومي و بما لها من استخدامات غذائية وطبية. وتعتبر من الانواع المعرضة للانقراض بالسودان، وتهدف هذه الدراسة للتعرف على المحتوى البذري في التربة والتجديد الطبيعي بمنطقة الخوي بولاية شمال كردفان. اعتنت بدراسة الاثر لفترات جمع البذور، فترات الزراعة ومعاملات البذور بالتعرف على انبات البذور، قياس الاطوال وعدد الاوراق بالمشتل. كذلك دراسة اثر حماية الشتول للرعي وانبات البذور بالحقل ودراسة البقاء للشتول.

اعتمد المسح الحقلي للمحتوى البذري في التربة والتجديد الطبيعي على عمق التربة، الاتجاهـ والبعد من الشجرة وعومات البذور المجموعة في شهر اكتوبر، نوفمبر، ديسمبر و يناير على التوالي من السنة ووزنت، وزرعت البذور المعاملة في ثلاثة فترات يناير، ابريل و يوليو 2006م بحامض الكبريتيك المركز(96%)، الابرة الكهربائية، التسخين الجاف بالاضافة للشاهد.

تم تسجيل انبات البذور وقياس الاطوال اسبوعيا من الاسبوع الخامس الى الاسبوع الثالث عشر.

واوضحت النتائج بأن هنالك تدني في المحتوى البذري في التربة وندرة في التجديد الطبيعي للشتول، حيث كانت هنالك فروقات معنوية لعدد البذور في وحدة الحجم وكانت اكبر فروقات معنوية في عمق 5 سم للتربة مقارنة بالاعماق الاخرى. وبالنسبة للبعد فان البذور والشتول متمركزة حول الاشجار في البعد 10 متر مقارنة بالابعاد 20 متر و30 متر، كما لا توجد فروقات معنوية في الاتجاهات.

اظهرت فترات جمع البذور و فترات زراعة البذور ومعاملة البذور فروقات معنوية في كل من الانبات للبذور، اطوال الشتول و عدد الاوراق للشتول. أظهرت البذورالمجموعة في يناير اعلى فروقات معنوية عن البذور المجموعة في

اكتوبر2005م، ويشير ذلك الى اهمية نضوج البذور وكذلك هنالك قطع مبكر للثمار قبل نضوج البذور بها. و أظهرت فترة زراعة البذور في يوليو2006 اعلى نسبة انبات، طول الشتول وعدد الاوراق مقارنة بالمزروعة مبكرا في شهري (يناير وابريل) وايضا تظهر اهمية نضوج البذور.

اما النتائج في الحقل فقد اوضحت بأن هنالك فروقات معنوية و أظهرت اعلى نسبة لبقاء الشتول بالمنطقة المحمية مقارنة بالمنطقة غيرالمحمية وتوصي الدراسة باهمية الحماية للشتول من رعي الحيوانات.

CHAPTER ONE

INTRODOUCTION

1.1 General

Arid and semi-arid regions are blessed with many forest tree species like acacias, palm and shrubs which provide shade, an aesthetic sight, or other fruits, tannins, resins, oils, extracts and pharmaceutical products (Sleppler and Nair 1987, Glew et al. 1997, Nowak and Schulz 1998, Muok et al. 2000). Of these species *Adansonia digitata* is an important species to people in arid zones (Becher 1983).

A. digitata, commonly named baobab tree is found in the arid and semi arid region of Sudan. It is also commonly called monkey bread as monkeys eat the fruits (Rashford 1994). Vernacular names for the baobab tree in the Sudan are: ‘Humar’, ‘Homeira’, or ‘Tebeldi’. It is a very large tree; one of the longest lived in Africa.Trunk comparatively short and stout 12-18 high, of big-sized girth. Baobab seeds have very hard seed coats with low percentage germination (20%) (Danthu et al.1995).

Sidibe and Williams (2002) described the phenology of baobab. Trees shed their leaves during the dry season, which can last most of the year depending on the climate in the arid zone where the trees are growing. Leaves are digitate, normally having 5 leaflets when mature. The leaflets have entire margins and are elliptic to obviate-elliptic. Mature leaf size may reach a diameter of 20 cm. The flowers bloom during the wet season and the dry season as well. They are very large and suspended on long peduncles. The fruit is bottle or cucumber shaped and develops 5-6 months after flowering. It has a woody outer shell, 7.5-54 cm long x 7.5-20 cm wide, covered by velvety yellowish, sometimes greenish hairs. The internal fruit pulp is split into mealy agglomerates that enclose several reniform seeds (approximately 10 mm long).

1.2 Importance

A. digitata is an important species to the livelihood of the people in arid zones (Becher 1983). Due to the great size and bizarre shapes, baobabs are often the most prominent tree species (Fenner 1980). The woods little used other than for floats for fishing nets as sub statute for cork in western Sudan. The tree is also a good fodder, especially for game animals. Cattle eat the leaves and flowers that would fall to the ground. Roots can be tapped where water is a problem. On the other hand, where domestic plants are cultivated and/or domestic animals are raised, the natural reproduction cycle of the baobab is often threatened (Nordiede et al 1996). Tubers, twigs, fruits, seeds, leaves and flowers of this plant are identified as common ingredients in traditional dishes in rural and urban areas (Nordiede et al. 1996). Many of the products sold in markets are an important source of income for the people (Bonkoungou et al. 1999). The baobab tree has played an important role in the economy and culture of Africa (Vogt 1995, Sidibe and Williams 2002). The fruits are considered as a major non timber forest product for its economical value. Dry fruits pulp is either fresh or added to gruels on cooling after cooking – a good way of preserving the vitamin contents. Also, it can be grinded to make a refreshing drink with a pleasing wine-gum flavor. The pulp is removed from the fibers and seed by kneading in cold water and the resulting emulsion is filtered. This is then added to thick grain preparation to make thinner gruels (Fleuret 1980). Seed and pulp were analyzed for proximate composition, mineral content, and amino acid composition. The seed oil and protein were evaluated for their fatty acid profile and protein solvability. The seed was found to be a good source of energy, protein, and fat. Both the kernel and the pulp contain substantial quantities of calcium, potassium, and magnesium. Amino acid analyses revealed high glutamic and aspartic acid contents and the sulfur-containing amino acids as being the most limited amino acid. The fatty acid profile showed that oleic and linoleic were the major unsaturated fatty acids, whereas palmitic was the major saturated acid. The protein was more solvable at alkaline than acidic pH, with the lowest solvability at pH 4.0 (Osman 2005).

The tree provides food, shelter, clothing and medicine as well as material for hunting and fishing (Venter and Venter 1996). Many of the products sold in markets are an important source of income for the people (Bonkoungou et al. 1999).

1.3 Distribution

A. digitata is widely scattered in the semi-arid and arid regions to the south of the Sahara, throughout Tropical and Sub-Saharan Africa, from Senegal to Sudan, eastern Africa, from Ethiopia to Mozambique and Natal. It is also found in Madagascar and has been introduced to Tropical America (Vogt 1995, Sidibe and Williams 2002). It is usually located at low altitudes (up to 1000 m), with mean annual rainfall of 100-1000 mm, and a mean annual temperature of 20-30°C. However, it does not grow at high altitudes, or in moist tropical forests. It occurs on well drained soils of varying quality and is often left standing when land is cleared for cultivation. It symbolizes the African savanna better than any other plant. Its spongy wood does not burn; therefore the plant is protected from fire. Hollowed out baobab trunks in the vicinity of villages are used for water storage. Extensive deforestation has resulted in a situation whereby the baobab and other fruit trees are the only trees to remain standing (Kurebgaseka 2005).

In Sudan, *A. digitata* is found on sandy soils and in depressions and along seasonal water courses and in the foot of hills and mountains, it forms belt in central Sudan; In Kordofan, Darfur, Blue Nile, Upper Nile and Bahr El Ghazal states (El Amin 1990). In Kordofan, it is a dominant tree species on the sand and clay soil of Kordofan.

1.4 Problem statement

A. digitata populations and number of mature trees are declining in Sudan as commonly observed and reported by the Forest National Corporation. Many factors were suggested as the root cause of the decline. Bush burning in the dry season, grazing and seed diseases limit the number of trees (Osman 2005). Damage to mature trees is often caused by elephants and mortality rates vary from 1 to 4% per year (Sidibe and Williams 2002). Contributing to decline of number of mature trees is the very low natural regeneration or even its absence in North Kordofan. Poor seed germination and damage to emerging seedlings by livestock, which readily eats the young trees, are mentioned as the main cause of regeneration problems (Danthu et al. 1995). However, no studies were conducted to investigate the root cause problems of natural regeneration. There is speculation that premature collection of fruits and their removal for marketing outside the natural sites resulted in low soil seed bank. Also, change in the natural habitats in terms of animals and plants had led to reduction in natural germination and seedling survival. Danthu et al. (1995) reported that chemical scarification by concentrated sulphuric acid and manual improved the germination percentage, which indicates possible seed coat dormancy. It is believed that natural germination is enhanced by animal ingestion of the seeds (like monkeys). Due to disturbance in the eco-system, (absence of monkeys) has resulted in the low germination. Seedlings should be protected from livestock (as the leaves are very palatable) and fire until they are well established.

1.5 Objectives

The aim of this study is to investigate possible causes for the low natural regeneration of *A. digitata* in North Kordofan State**.** The main objective is to test the hypothesis that the regeneration problem is linked with low soil seed bank, reduced germination for absence of seed treatment and grazing of seedlings by animals. The specific objectives of this study are:

1- Determination of soil seed bank.

2- Evaluation of natural seedling density.

3- Determination of the effect of seed scarification treatments on germination.

4- Effect of seedlings protection on field establishment.

CHAPTER TWO
LITERATURE REVIEW

2.1 The Genus *Adansonia*

Kingdom: Plantae

Division: Magnoliophyta

Class: Magnoliopsida

Order: Malvales

Family: Bombacaceae

Genus: Adansonia

There are eight species of the genus *Adansonia* (commonly called Baobabs), six of them are endemic to Madagascar. There are *Adansonia gibbosa*, *Adansonia grandidieri*, *Adansonia madagascriensis*, *Adansonia suaresensis*, *Adansonia perrieri*, *Adansonia rubrostipa*, *Adansonia za* and *Adansonia digitata* (Wyk and Erik 2005).

2.2 Adansonia digitata

It is introduced to Madagascar probably by Arab traders from Sudan, where it is found on sandy soils in depressions and along seasonal water courses and in the foot of hills and mountains. It forms a belt in central Sudan; in Kordofan, Darfur, Blue Nile, Upper Nile and Bahr El Ghazal states. In Kordofan, *A. digitata* is the dominant tree species on the sand and clay soils (El Amin 1990).

A. digitata is a native deciduous tree from the African savannas. The English common name is baobab, local names used in southern Africa: Umkhomo and Muuju in Zimbabwe; Mowana, Moana, Dovuyu, Ibozu, Mbuyu and Mobuyu in Botswana; Mnambe and Mbuye in Malawi; Muuyu, Mbuyu, Mkulukumba, Mlambe in Zambia (Kurebgaseka, 2005). Sidibe and Williams (2002) described the trees Vernacular names in the Sudan are: 'Humar', 'Homeira', or 'Tebeldi'.

It is characterized by an unusual, swollen, relatively short, bottle shaped trunk (about 15 m in height) in which spongy fibers store water for the dry season. For this reason, it is also called "bottle tree". The mature circumference can exceed 20 m; the diameter at chest height is about 10 m. The crown is rounded and shows a stiff branching habit. The tree has an extensive lateral root system, which produces tubers at the end. African baobab is a very long-living tree. It normally lives for about 500 years, but it is believed that some trees are up to 5000 years old (Sidibe and Williams 2002).

The tree sheds its leaves during the dry season, which can last most of the year depending on the climate zone. Leaves are digitate, normally having 5 leaflets when mature, that can reach 20 cm in diameter. Leaflets have entire margins and are elliptic to obviate-elliptic, with acuminate apex and a decurrent base. The flowers bloom during the wet season and the dry season as well. They are very large and suspended on long peduncles. The fruit is bottle or cucumber shaped and develops 5-6 months after florescence. It has a woody outer shell, 7.5-54 cm long x 7.5-20 cm wide, covered by velvety yellowish, sometimes greenish hairs. The internal fruit pulp is split into mealy agglomerates that enclose several reniform seeds (approximately 10 mm long) (Sidibe and Williams 2002).

A. digitata is an extremely impressive tree due to its great size and diffusion, and it symbolizes African Savanna better than any other plant. Its spongy wood does not burn; therefore the plant is protected from fire. Hollowed out baobab trunks in the vicinity of villages have been used for water storage. There are local traditions that prohibit communities from cutting down baobab trees and any other fruit bearing trees. This has resulted in a situation whereby the baobab and other fruit trees are the only trees to remain standing, in areas of extensive deforestation, (Kurebgaseka, 2005).

Baobab trees are good fodder, especially for game animals. Cattle eat the leaves and flowers that would otherwise fall to the ground. Baobab roots can be tapped where water is a problem. On the other hand, where domestic plants are cultivated and/or domestic animals are raised, the natural reproduction cycle of the baobab is often threatened. Also, high elephant densities could endanger baobab as in the dry periods, they chew the wood for its stored water and thereby severely damage the tree.

2.3 Importance of *A. digitata*

2.3.1 Leaves

Young fresh leaves are cut into pieces and cooked in a sauce and sometimes they are dried, powdered and used for cooking. Nordeide *et al.* (1996) demonstrated marked seasonality in use of leaves where they surveyed two village and a town neighborhood to compare rural and urban use of wild food in southern Mali. Out of over 100 rural households, 26% used baobab leaves in the rainy season, and 56% in the dry season; and out of over 150 urban households, 26% used baobab leaves in the rainy season and 13% in the dry season, with roughly a two-fold increased use in the dry season (Nordeide *et al.* 1996). The use of leaves in sauce is usually in association with seeds of *Parkia biglobosa*, onion, okra, pepper, ginger, sometimes meat, but more often with fish. The sauce is used with a thick porridge made from millet, sorghum or maize and rice (Nordeide *et al.* 1996). In other areas leaves are used for soup e.g. miyan kuka of the Hausa in northern Nigeria and ground leaves are boiled in salt water (Yazzie *et al.* 1994) and (Williamson, 1975). In Zimbabwe, they provide fresh vegetable that substituted for the commercially grown leafy vegetables such as cabbages and lettuce (Dovie *et al.* 2001).

2.3.2 Fruit pulp

The fruit pulp can be ground to make a refreshing drink with a pleasing wine gum flavor. In Tanzania, it is added to aid fermentation of sugar cane for beer making (Fleuret 1980). The cattle-owing Fulani and the Hausa tribes of northern Nigeria use the fruit pulp emulsion to mix with milk as a drink (Fleuret 1980). Pulp can be stored for long periods for use in soft drink production but it needs airtight containers (Ibiyemi *et al.* 1988). It can also be frozen if ground to a powder (Obizoba and Amaechi

1993). *A. digitata* powder mixtures are commonly available in many pubic markets.

2.3.4 Seeds

In general, seeds are used as a thickening agent in soups, but they can ferment and used as a flavoring agent, or roasted and eaten as snacks (Palmer and Pitman 1972; Addy and Eteshola 1984). When roasted, they are sometimes used as a substitute for coffee. In some cases, seeds are de-hulled by boiling, rubbing by hand, and then sun drying the kernels before grinding. Seeds are also a source of cooking oil but this is not widespread, although there has been interest in expanding such use due to deficits of vegetable oils. Oil is extracted by pounding the seeds. Fermentation of powdered de-hulled seeds increases protein digestibility, but increases tannin content (Addy *et al.* 1995).

2.3.5 Fibers

Fiber from the inner bark is strong and widely used for making rope, basket nets, fishing lines is even used for weaving. Fibers are also available from disintegrated wood and have been used for packing. Other fibers used for rope are obtained from root bark.

2.3.6 Dye

In East Africa roots are used to make a solvable red dye. The green bark is also used as a dye and for decoration (Dovie *et al.* in press).

2.3.7 Fruit shell

The hard fruit shells are used in the manufacture of pots for food and drink (Dovie *et al,.* 2001).

2.3.8 Fuel

The wood is a poor source of fuel; however, fruit shells are used for fuel in Tanzania and they are used as water dippers (Nkana and Iddi 1991).

2.3.9 Medicinal uses

Leaves and fruit pulps are traditionally used in folk medicine as an antipyretic. Fruit pulp and powdered seeds are used in cases of dysentery and to promote perspiration (Dweck 1997). Powdered leaves can be used as an anti-asthmatic and they are known to have antihistamine . They are variously used to treat fatigue, as a tonic and for insect bites, guinea worm and internal pains, and to treat dysentery (Kings 2002). Leaves are used for diseases of the urinary tract. Seeds are also used in cases of diarrhea, and hiccough (Dweck 1997).

Seed oil is used for inflamed gum and to ease teeth pain. Seed oil is used to treat skin complaints, to a degree it is used cosmetically (Wickens 1982). Maybe the widest use in folk medicine is the use of the bark as a substitute for quinine in cases of fever or as a prophylactic. Decoction of the bark decomposes rapidly due to the mucilaginous substances present. This can be prevented by adding alcohol or a small quantity of sulphuric acid (Kings 2002). An infusion of roots is used in Zimbabwe to bathe babies to promote smooth skin. A summary of traditional medicinal uses was listed by Dweck (1997).

2.4 Regeneration of *A. digitata*

2.4.1 Natural

Baobab regenerate naturally from seeds and it is reported to coppice well (Kings 2002). However, young trees are rarely found and natural regeneration is scare leading to the endangerment of *A. digitata*. Reasons may be due to the intensive browsing of young plants by livestock and the excessive use of leaves for food by people. Severe droughts of recent years have also affected the natural regeneration similar to the general effect to the thorn woodlands of the savannahs. Elephants find the whole tree palatable up to 3 years of age (FAO 1988). With fruit being collected from wild stands of trees, seed stocks are decreasing. Germination is poor due to seed coat dormancy and the disturbance of the eco-system that reduced natural treatment of seed coat dormancy. It is believed that natural germination is enhancedly animal ingestion of seeds (like monkeys). The disturbance in the eco-system, (absence of monkeys) has resulted in the low germination (Danthu et al. 1995). The germination period is extremely variable, between 3 weeks and 6 months. In the wild, seeds are thought to germinate only in exceptionally good rainy seasons (Palmer and Pitman 1972).

Environmental variables and the dispersal syndrome have led to the selection for and production of variable seed sizes, with implications for germination and seedling establishment, and for the build up of persistent soil seed bank. Seeds have evolved mechanisms to recognize environmental clues, which enable them to confine their germination in particular periods and locations to allow for a greater probability of seedling establishment and survival (Nielson 1999).

The seeds of *A. digitata* have a very low germination rate due to seed coat dormancy (Danthu et al. 1995). According to Palmer and Pitman (1972), seeds apparently keep their viability for years. In the field, seedlings do not emerge immediately after seeds released from fruits due to dormancy imposed by the hard seed coats, which appear to be non-permeable (Owen 1974). Naturally**,** acid treated seeds in animal stomach, germinate even with slight moisture which some times lead to death of the germinating seedlings if the soil get dry too soon (Ahmed 1986). Seedlings are very fragile during early stages of growth and therefore need protection especially from animal trampling. The success of seedlings was mentioned by village leaders require shading for early growing seedlings by other trees and plants.

2.4.2 Artificial

Baobabs have traditionally been propagated by transplanting naturally regenerated seedlings. However, seedlings are rare due to intensive browsing by livestock. Seeds require pretreatment, and the normal method is to scarify with concentrated sulphuric acid for 6-12h. This leads to germination of more than 90% (Danthu et al. 1995). Alternatively, concentrated sulphuric acid or nitric acid for only 15min gave germination of 98 and 86% respectively (Esenowo 1991). In Mali, the forest research Institute uses sulphuric acid for 90 min followed by water rinsing for 24h, giving germination of 92% or more (Danthu et al. 1995). In rural areas, the acid pretreatment can be replaced by manual scarification (chapping). In some cases seeds were boiled in water for 15 min, but this is a more risky procedure (Danthu et al. 1995).

Danthu et al. (1995) tried and described seedling production in the nursery. Seeds sown in nursery potting mixture (3 parts topsoil, 1 part sand and 1 part compost); can be sown in beds, pots or polybags. After pretreatment, emergence is 4-6 days after sowing, and all those that will germinate will have emerged by 18 days. When seedlings emerge, it is best to shade them for 8 days, provide half shade for 4-7 days and then expose to full light at 12-15 days after emergence. Seedlings require watering in the morning and evening (but not excessively otherwise there is a danger of stem rot) and also protection from rodents such as rats and mice by using a small mesh wire netting. Seeds germinate well in the nursery where adequate moisture can be provided regularly (Palmer and Pitman, 1972). Nursery seedlings can be fertilized using bi- or tracalcic phosphorus and urea with 46%Nitrogen (Danthu et al. 1995).

Early transplantation is not possible. Normally seedlings need to be at least 3-4 months old, when they have reached a height of 40-50cm, for transplanting. Danthu et al. (1995) reported that nursery seedlings and seeds from direct sowing had high mortality rate, in spite of provided protection.

2.5 Phenology of *Adansonia digitata*

The flowering varies greatly and can occur anytime except during the height of the dry season and whether leaves are present or not. Timing of flowering appears to differ between geographically isolated populations but this could be due to regional climatic differences (Wickens 1982). Flowering fits the particular climatic season; ranging from October-December in the Southern Africa; November-December in Madagascar; sporadically through the year except January-March (dry season) in Sudan; to May-June in Western Africa. In Sudan, flowering occurs between May and July and fruiting extends from August to October (EL Amin, 1990).

Fruits develop 5-6 months after flowering. Wickens (1982) indicated that there is limited data on age of trees when first flowering begins. And noted 16-17 years in south Africa and 22-23 years in Zimbabwe. In part, lack of data is understandable for long-lived perennial trees and noting the difficulties in estimating ages of baobabs using simple girth measurements.

2.6 Seed Collection

According to Arum (1989), several methods can be employed in collecting baobab seed. The simplest is collecting dropped fruits from the ground, but this has disadvantages since some immature fruits may have fallen from the tree. The fruits may also have stayed on the ground for along time, there by causing the seeds to lose viability or become infected. Fruits from short trees are harvested from the ground or by climbing up a ladder. The most common method of harvesting fruits from tall trees is by climbing the trunk and plucking from the crown.

2.7 Eco-climatic zones of A. digitata

FAO has characterized the eco-climate zones in Africa and this fall into bimodal climates of East Africa and monomodal climates of West Africa. The subdivisions relate to total annual rainfall amount and duration of the rainy season. The distribution of baobabs in relation to climate zones can be seen in table (2.1).

The areas included in row 2 in table (2.1) comprise West Africa, the Sahelian, Sudano-Sahelian, northern Sudan and Southern Miombo ecological zones. In East Africa they include the Acacia-Commiphora and Combretum-Acacia woodland ecological zones (FAO, 1981) as well as semi-desert grassland.

In term of temperature baobab can tolerate very high temperature (mean maximum 40-42^{O}C in West Africa) and for minimum temperatures, can survive as a long as there is no frost (Simpson, 1995). Typically mean annual temperature is 20-30^{O}C.

Table (2.1) Baobab in relation to climatic zones of Africa

Baobab growth	Climate type	Annual rainfall (mm)	Rainy season (months) E.Africa	Rainy season (months) W.Africa
1. Baobab growth very marginal	Typical	90+		
	Very arid	100-400	1-3	1-3
2. Baobab growth typical	Typical	300-800		
	Arid	200-400	2-3	2-3
	Semi-arid	400-600	4-5	3-4
	Dry sub humid	600-8oo	5-6	5-6
3. Baobab growth occasional	Typical	800-1000		
	Sub-humid	800-1200	6-7	5-7

Source: FAO, 1981; FAO, 1988

CHAPTER THREE

Materials and Methods

3.1 General Description of the Study Area:

3.1.1 Geographical Location.

Seed collection and field studies were carried out at Eldoodia site (Elkhouyi locality, North Kordofan State), marked by latitude 13° 6¯ North and longitude 29° 19¯East (88 km west of Elobeid town) (Khair Elseid 1998). The Laboratory and nursery studies were conducted at Faculty of Natural resources and Environmental study, University of Kordofan.

3.1.2 Climate

Tropical continental climate of North Kordofan prevails. Two air movements determine the general nature of the climate. The dry air movement from the north and the northeast prevails through out the year, and the moist southerly wind. Rains fall in June to September and annual rainfall is variable and follows a north-south gradient, 350 mm in the north and 450 mm in the south. According to rainfall and vegetation types, the state is considered in the semi-arid zone (Khair Elseid, 1998).

There is no meteorological station at Elobied, so meteorological data from Omsimaima station (23 km east to the site) was used. The mean monthly rainfall prevailed during (2005) and (2006) are shown in (Table 3.1).

Table (3.1) Mean monthly rainfall (mm) at Omsimaima station season 2005 and 2006.

Month	season (2005)	season (2006)
April	__	__
May	10.7	18.5
June	40.1	1.7
July	75.3	162.4
August	95.6	67.2
September	31.8	28
October	33.5	__
Total	287.0	277.8

Source: Elobeid Meteorological Station collected from Omsimaima station.

3.1.3 Vegetation:

The low rainfall savannah, with rainfall between 300 and 500 mm, covers 24% of the country, with 340,000 ha on clay and 240,000 ha on sandy soils. It is characterised by open woodland in some areas and by open grassland in others. The dominant trees are *Acacia sp*p. such as *Acacia. mellifera*, *Acacia nubica*, *Acacia* seyal, *Acacia senegal* and *Acacia tortilis*. Other species include *Adansonia digitata, Anogeissus leiocarpaus, Boscia senegalensis, Cadaba glandulosa, Capparis decidua, Commiphora africana, Dalbergia melanoxylon, Faidherbia albida, Grewia tenax, Indigofera oblongifolia, Tamarix articulata, Terminalia spp. and Ziziphus spp. Herbaceous species include Aristida spp., Blepharis spp., Cyperus rotundus, Shoenefeldia spp. and Zornia spp* (Fadlalla , 1987).

On the other hand, the main grasses grown were Gau (Annual *Aristida spp*.), Bino (*Eragrostis spp*.), Huskaneit (*Cenchrus spp*.), Simaima (*Hyparrhinia hirta*), and Shelini (*Zoria diphyll glochidiata*).

3.1.4 Soil Characteristics:

This study was conducted on such soil locally named as Gurraba soil. It is characterized by it's brown color and of more fine particles than sand. It is more closely related to Eltabaldi low plain which is scattered widely in western part of Kordofan. Gurraba soil may be originated from alluvial sediments deposited by streams. It is varied widely in particle size and surface characteristics which forms a hard surface layer when dry.

However, Eldoodia site which is selected for conducting the experiment was thought to be typically representing the Gurraba soils found in many sites in western Kordofan.

3.2 Methods

3.2.1 Survey of Soil Seed Bank

This survey was carried out in three sites along strip of natural *A. digitata* in El Doodia of Elkhouyi area as shown in Figure 3.1. Walking along the strip 25 trees were randomly picked from each site and then the soil seed bank was assessed around each tree in the three directions, North, South and West or East in turns. In each direction, three points were marked at distance 10 m, 20 m and 30m. At each point, three holes were dug up at depths 5 cm, 10 cm and 20 cm) and soil was taken by Oger. The soil volume was then estimated as follows:

$$\mathbf{V = (d/2)^2 \Pi h}$$

V= Volume of cylinder (Oger shape)

h = height of Oger (5, 10, 20 cm)

d = diameter of Oger (12 cm)

Volume 5cm = $(12/2)^2$ X 3.14 x 5 = 565.2 cm^3

Volume 10cm = $(12/2)^2$ X 3.14 x 10 = 1130.4cm^3

Volume 20cm = 1130.4 X 2 = 2260.8 cm^3

Per m^3 = [N X 1000000(cm^3)] /565.2 or 1130.4

N: number of seeds

The soil from each depth was then sieved using mesh (5mm) to separate seeds from soil particles (mostly sand). The number of *A. digitata* seeds was then recorded per each soil sample.

3.2.2 Natural regeneration survey

Using the same trees, directions and around each points mentioned above (Figure 3.1), a circular plot of area of 3.14 m^2 (circle diameter was 2 m) was drawn. The number of seedlings (1 m or less in height) was counted inside each circular plot.

3.3 Seed treatment experiment

3.3.1 Collection Date

Nine trees have been selected from the three sites with the help of farmers who identified the productive trees. Three fruits were then cut manually from each tree in mid October, November, December 2005 and January 2006. The fruits collected at each date were pooled together and considered as collection date forming four collection dates. Seeds from fruits of each collection date were extracted separately by immersion of the pulps in water for three hours with well shaking, until the seeds become black in color (Natural color). The seeds were then dried under the sun light (one day). The extracted seed per collection date were randomly divided in seedlots with 50 seeds per lot. About 17 seedlots were obtained for each collection date. Seed weight for each seedlots (50 seeds) was determined using sensitive balance.

3.3.2 Planting dates

Four seedlots for each collection period were then randomly assigned to each of three seed treatment dates: January, April and July 2006.

3.3.3 Seed Treatments

Four treatments were then applied for seeds according to collection date in January, April and July. One seedlots per collection and treatment date was assigned randomly of each of the following treatments:

- Concentrated Sulphuric Acid (96%): Seeds were immersed in sulphuric acid with concentration 96% in pottery dish for one hour, then washed by clean water and dried.
- Electric burner: Seeds were scratched by electric burner at one site (not to injure the embryo) forming a hole in each seed
- Dry heat**:** Seeds were put in mesh and exposed to hot dry plate set at 100 C^o temperature for ten seconds.
- Control: Seeds were used without treatment.

3.3.4 The nursery

The nursery part consists of germination of seeds per treatment and collection date at each treatment date (January, April and July 2006), monitor germination and follow seedling growth. Seeds were treated (as described in 3.3.3) one day before planting in polythene tubes. Polythene tubes with dimension of 22×7 cm, when flat, were filled with soil (2 sand: 1 clay) and arranged seedling beds (15 tubes each row) with total of 800 tubes. The polythene tubes were then divided into 16 units with 50 tubes per unit (Figure 3.2). Each unit was then randomly assigned to one of the 16 treatment by collection date units (4 seed treatment x 4 collection date). Temperature and relative humidity was monitored during the planting period (Table 3.2)

The following parameters were measured:

1) Germination was recorded weekly for 13 weeks for each of the three planted dates:

- Mid January to mid April,
- First of April up to end of June,
- First of July to end of September.

2) Seedling length was followed and recorded weekly between week 5 and week 13,

3) Number of leaves per plant was counted at week 13.

Table (3.2): Mean temperature and relative humidity during the planting periods (January to September) University of Kordofan nursery, Elobied.

Month	Temperature C°	Moisture %
January	24.5	16
February	31.5	18
March	27	12.7
April	35	9
May	37	25
Jun	38	27
July	39	32
August	39	47
September	39.7	52
October	38	44

3.3.5 Field-site Protection

Seed and seedling performance was evaluated in protected and unprotected sites in El Doodia, ElKhouyi during the rainy season of 2006. Protected sites were chosen in agriculturally used sites that were protected from animal by farmer. While unprotected sites were not farmed and about 1 km from the protected sites. The protected site (30 m x 30 m) was divided in two units (30m x 15 m). One unit was assigned for transplanted seedlings and the other for direct seeding. Similar arrangement was made in the unprotected site.

Seedlings (total of 240) were transferred from the nursery in Elobied to the field sites at the beginning of August (the autumn). Seedling length was more than 30 centimeters. 100 seedlings were transplanted in the protected area unit (30 m ×15 m) and 140 seedlings were planted in unprotected site. In the meantime treated seeds with electric burner were seeded in other protected and unprotected units, with 100 seeds per unit (total of 200 seeds).

Transplanted seedlings were evaluated after three month (beginning of August up to end of October 2006) in the protected and unprotected sites for seedling survival.

Similarly, planted seeds were regularly monitored and evaluated at both sites at the end of 3 month period (beginning of August to end of October 2006) for Germination and survival.

3.3.6 Data Analysis

The Statistical Analysis System (SAS) was used for data analysis. Analysis of variance (ANOVA) followed by mean separation procedures. The analysis was carried to determine treatments significance and ranking of the means, respectively. Frequency distribution and chi square test were used for germination and survival data. Duncan test was used for mean separation for soil seed bank and natural regeneration parameters while Lsmeans range test was used for seedlings length and number of leaves.

Figure (3.1): Design of soil seed bank and natural seedling regeneration of *A. digitata* in Elkouyi site, North Kordofan State.

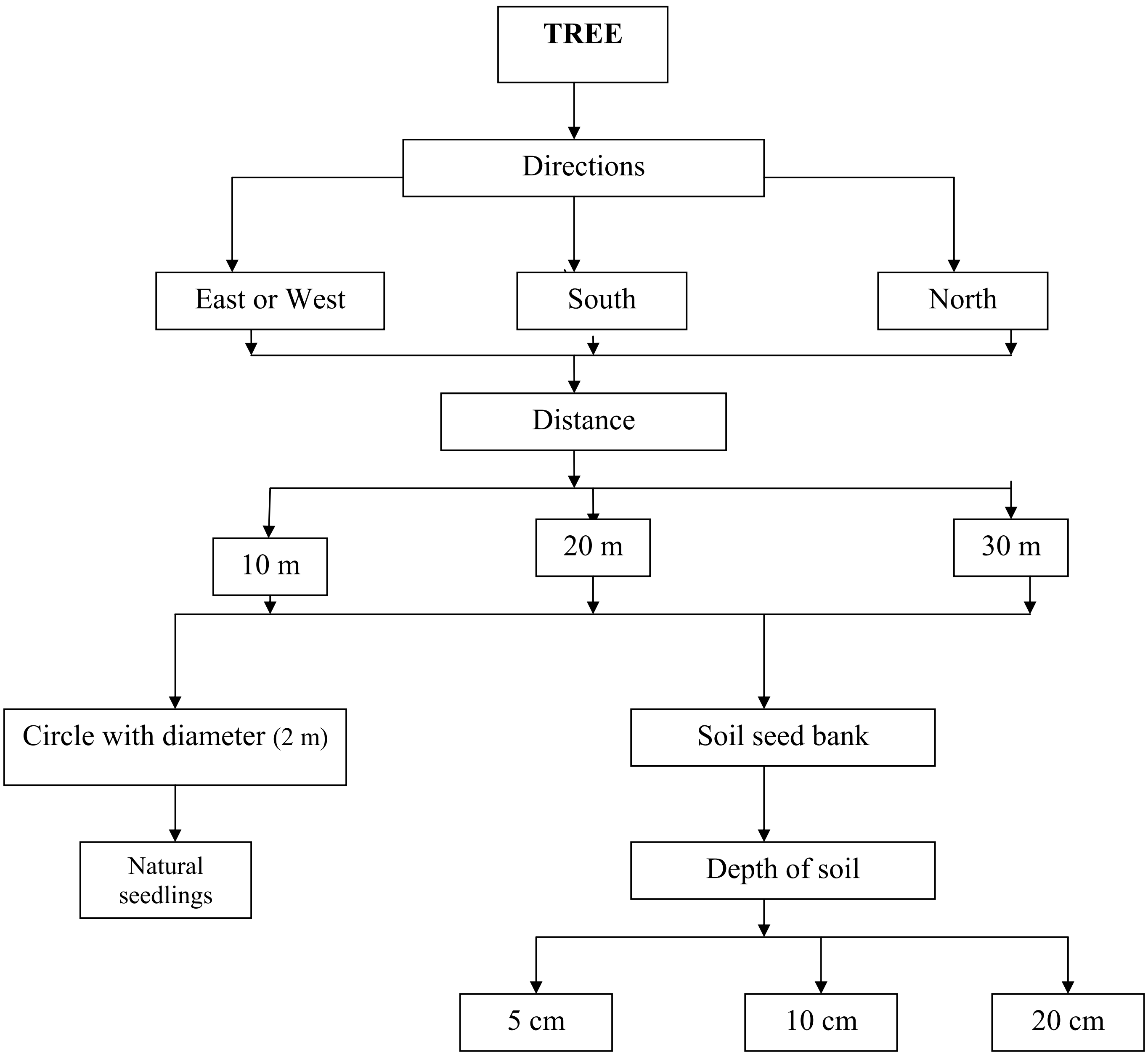


Figure (3.2): Distribution of experimental plots (seed treatment x collection date) in nursery beds.

→ 450cm ←

A1	**B2**	**B1**	**A4**	**C1**	**C2**
D3	**B3**	**A2**	**B4**	**D1**	**D4**
		C3	**D2**	**C4**	**D4**

Each plot contains 50 polythene tubes and letters and numbers per plot indicate collection date and seed treatment, respectively as follows:

A: Seeds collected in October 2005.

B: Seeds collected in November 2005.

C: Seeds collected in December 2005.

D: Seeds collected in January 2006.

1: Sulphuric acid treated seeds.

2: Dry heat treated seeds.

3: Electric burner scarred seeds.

4: Control seeds without treatment.

Figure (3.3): Steps of studying effect of field protection on survival of *A. digitata* seedling at Elkhouyi site, North Kordofan

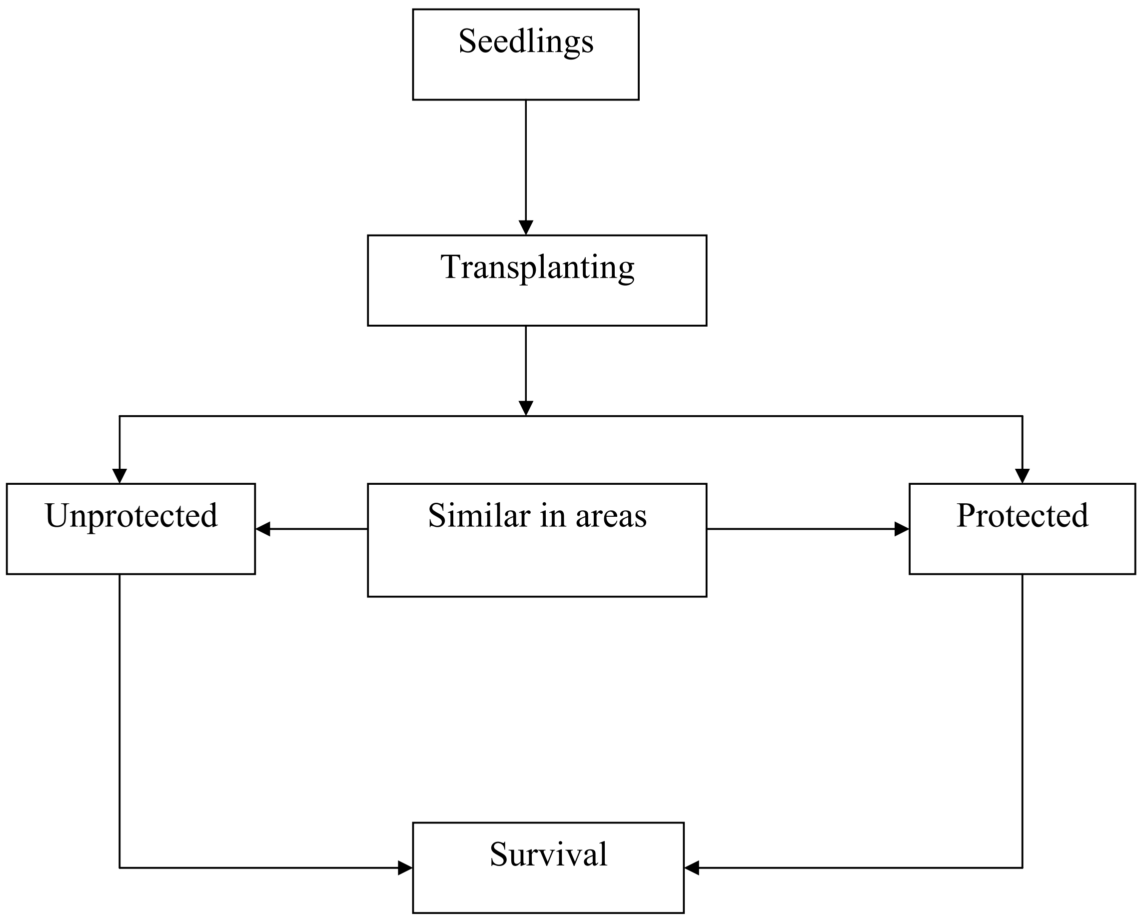
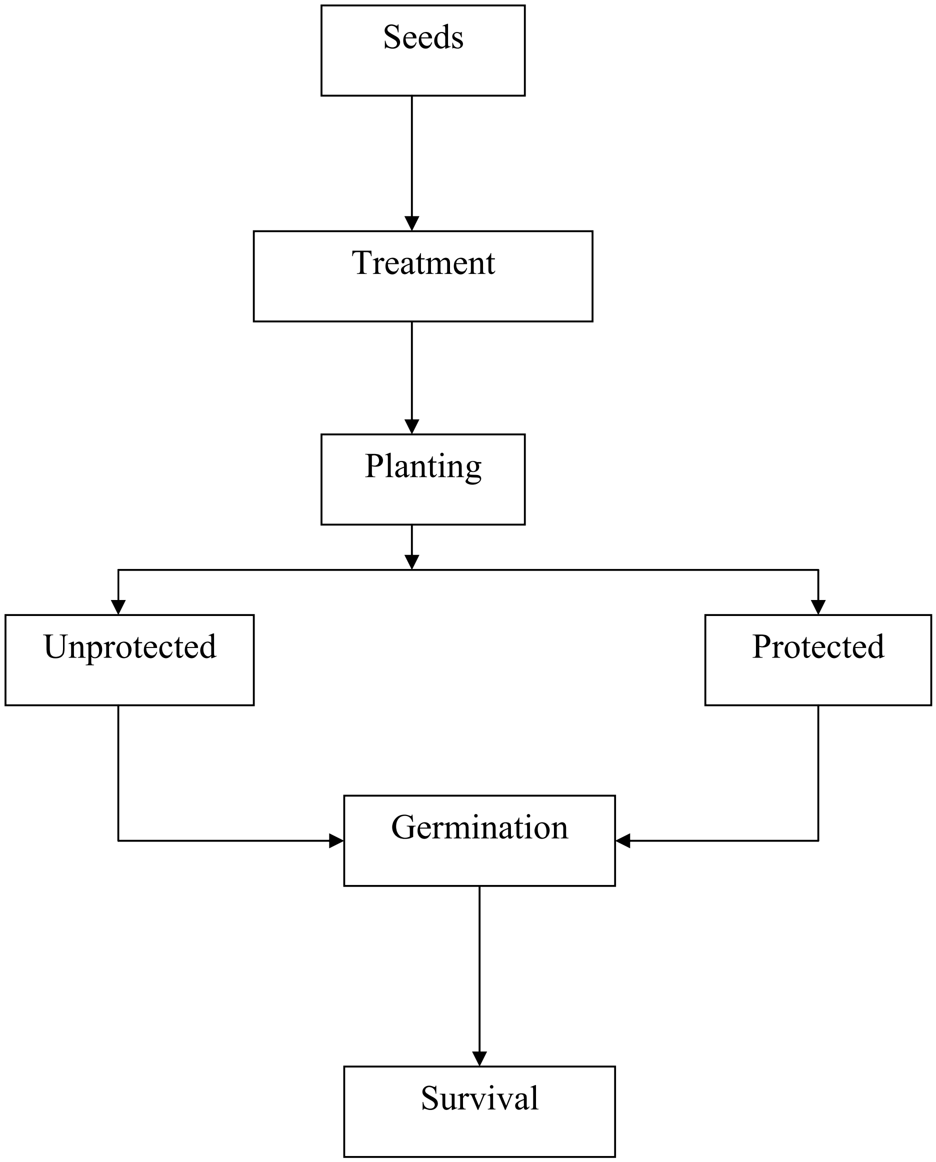


Figure (3.4): Steps of studying effect of field protection on germination of *A. digitata* seeds at Elkhouyi site, North Kordofan and subsequent ssurvival of seedlings.



CHABTER FOUR
RESULT AND DISCUSSION

4.1 Soil seed bank

The natural reproduction cycle of the baobab is threatened as the soil seed bank was very low in the study site at ElKouyi**.**

4.1.1 Effect of direction, seed in soil depth and distance from trees

Effect of direction from tree on seed number was significant when averaged over all locations (p= 0.007). Seeds number was significantly higher at North direction from tree than South and East or West direction (Table 1a and Figure 1).

Effect of soil depth on seeds number was significant at all locations (p= 0.0001). Number of seeds decreased with increasing soil depth, where seed number was significantly higher at 5 cm from tree than 10 and 20 cm (Table 1b and Figure 2).

Effect of distance from nearest tree on the number of seeds was significant (p= 0.0001). The number of seeds was higher closer to trees and decreased with the distance away from trees (Table 1c and Figure 3). Seeds number was significantly higher at distance 10 m from tree than 20m and 30 m.

From the above results, it is evident that the soil seed bank is very low and number of seeds was affected by distance, direction and soil depth from trees. The generally low seed bank may be due to the transfer of the fruits of *A. digitata* to cities where there is high demand like Elobied and other cities. Also, the remaining seeds were concentrated near the mother trees and in soil surfaces (depth 5 cm). This uneven distribution of seeds in the area would affect future regeneration of *A. digtata*. Many factors were reported to be responsible for the poor soil seed bank of *A. digitata* either singly or jointly with their interaction; members of the family Bombacaceae produce empty seeds (sterile). *A. digitata* produces pulp connected with seeds. Also, certain insect of the order *Hymenoptera*

Table (1): Number of *Adansonia digitata* seeds in soil (seed bank) according to a) direction, b) soil depth. (Per volume) and c) distance from nearest tree at Elkhouyi site, North Kordofan.

A) Direction

Direction	Location 1	Location 2	Location 3	All location
North	57 A	26	6	30 A
East or West	23 B	14	2	13 B
South	22 B	10	0	11 B
Probability	**0.024**	**0.154**	**0.307**	**0.007**

B) Soil depth (m)

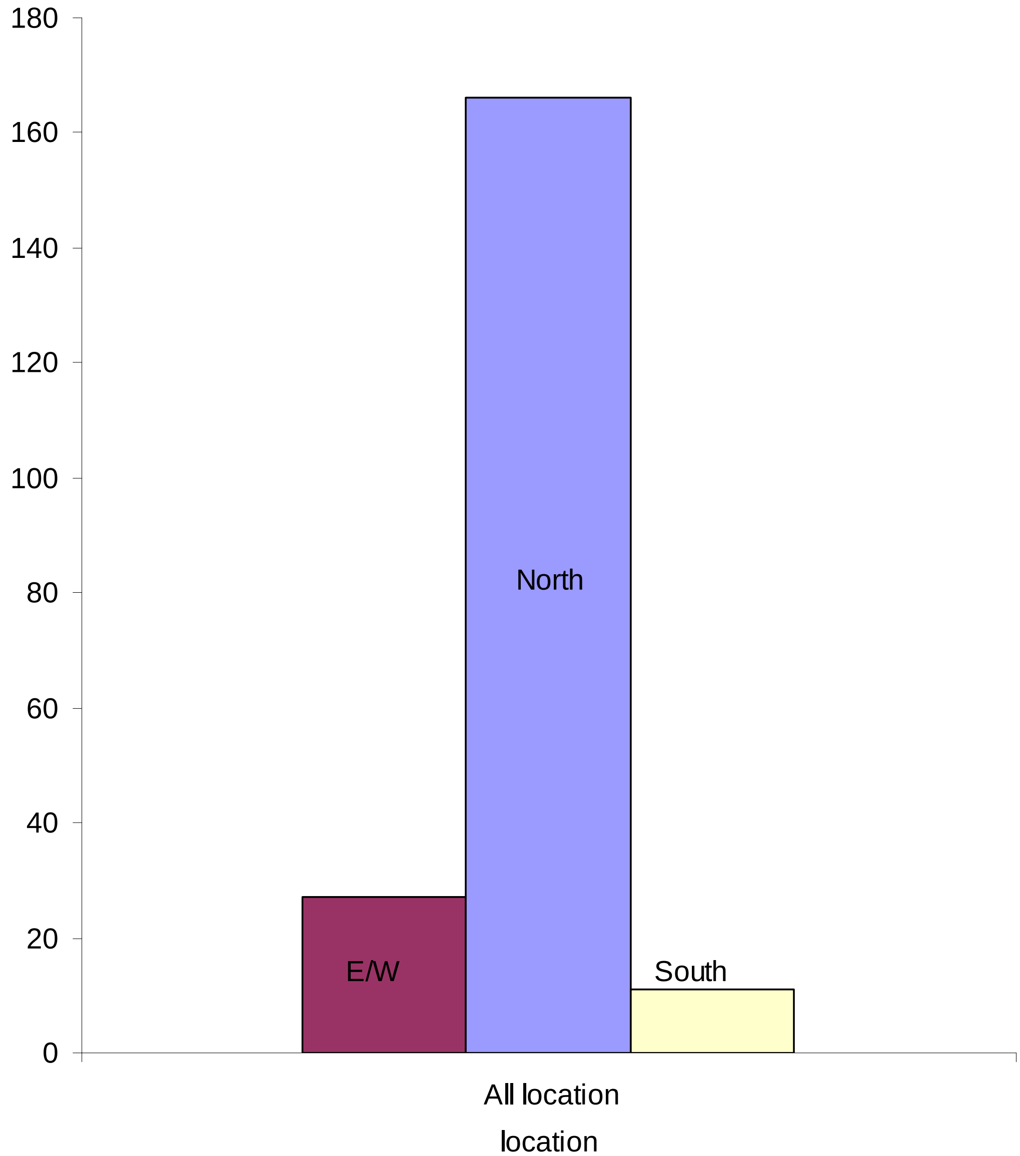
Depth	Location 1	Location 2	Location 3	All location
5	347 A	119 A	32	166 A
10	39 B	39 B	0	27 B
20	12 B	20 B	0	11 B
Probability	**0.0001**	**0.028**	**0.068**	**0.0001**

C) Distance from nearest tree.

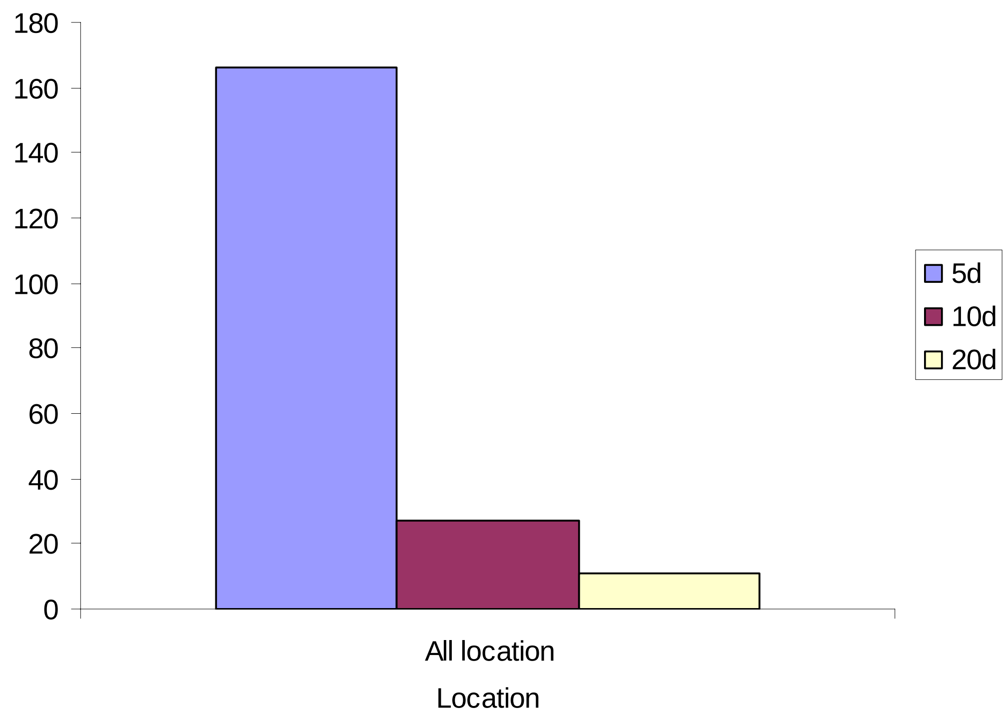
Distance	Location 1	Location 2	Location 3	All location
10	23	23	8	18 A
20	22	22	4	16 B
30	19	21	4	15 B
Probability	**0.100**	**0.100**	**0.068**	**0.0001**

Means with the same letters in same column are not significantly different at probability = 0.05 using Duncan test.

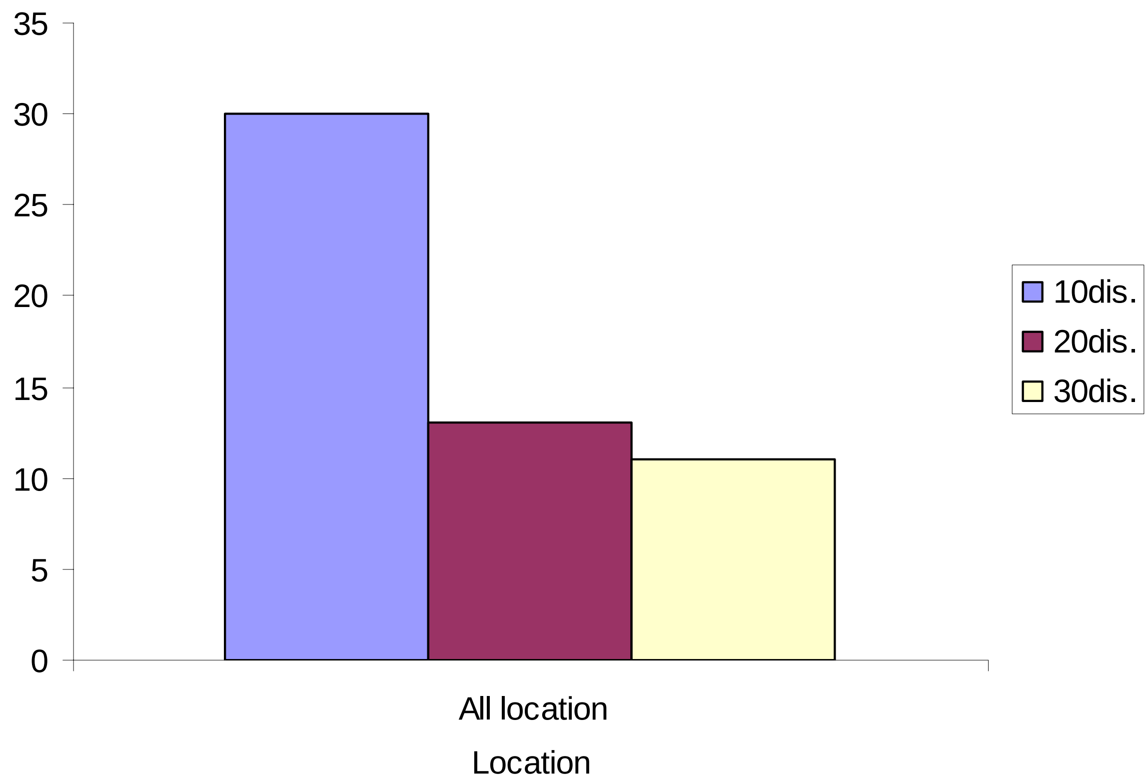
Figure(1): Noumber of *Adansonia digitata* seeds in soil (seed bank) of according to direction from nearest tree at Elkhouyi site- North Kordofan.



Figure(2): Number of *Adansonia digitata* seeds in soil (seed bank) according to soil depth (per volume) from nearest tree at Elkouyi site- North Kordofan.



Figure(3): Number of *Adansonia digitata* in soil (seed bank) according to distancefrom nearest tree at Elkhouyi site- North Kordofan.



attacks quantities of seeds (Thonner 1962). Also, Osman (2005) reported similar factors reducing seed bank of *Adansonia digitata* in Sudan. He recommended seed collection and planting of trees.

4.2 Natural regeneration

The natural regeneration in the study area was very low as by seedling density shown in Table 2. Effect of direction from the nearest tree on number of seedlings per area was not significant ($p< 0.1978$). The number of seedlings per unit area on each direction is presented in Table 2A and Figure 4). However, effect of distance from nearest tree on the number of seedlings was significant ($p<0.0001$). The number of seedlings averaged over all location was higher at10 m than that at 20 m and 30 m from nearest trees (Table 2B and Figure 4).

From the above results, the natural regeneration of *A. digitata* was very scarce as judged by density of seedling (Table 2). In Addition, the seedlings were concentrated around close to *A. digitata* trees. It was observed that the seedlings have small diameters and weak appearance similar to that reported by Danthu at el. (1995).

The low natural regeneration density of *A. digitata* may be due to heavy grazing, over cultivation and some times cutting of the seedling during cultivation, and were also damaged by human, insects, and rabbits it as reported by (Owen 1974, Obied and Seif El Din 1986). It was indicated that seedlings of *A. digitata* are highly palatable, and animals favor and select them as reported by Von Maydell (1986). Also, the seedlings can easily be extracted or pulled by human beings. Removal of the vegetation (trees and shrubs) also affected seed number and vigor. It was reported that natural regeneration of *A. digitata* is good and the seedlings show good growth if protected by other trees (Owen 1974). Accordingly, propagation of *A. digitata* was improved by raising seedlings under controlled nursery environment and transplanting them to the field.

Table (2): Number of *Adansonia digitata* seedlings according to direction, around each point in a circular area of 3.14 m^2certain circle with diameter (2 m) and distance from nearest trees at Elkhouyi area, North Kordofan.

A) Direction (ha^2)

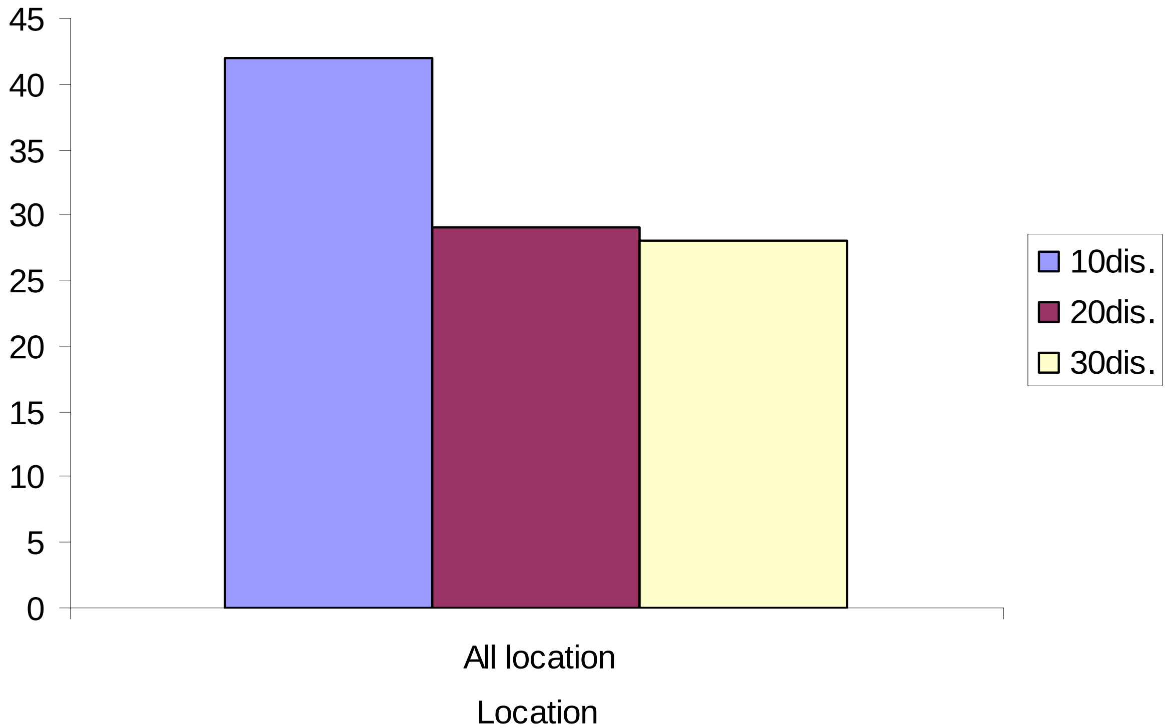
Direction	Location 1	Location 2	Location 3	All location
North	127	45	0	57
East and West	41	32	0	25
South	127	32	0	38
P	**0.3111**	**0.3380**	**-**	**0.1978**

B) Distance (ha^2)

Distance	Location 1	Location 2	Location 3	All location
10	86	41	0	42 A
20	71	16	0	29 B
30	71	13	0	28 B
P	**0.5124**	**0.3752**	**-**	**0.0001**

Means with the same letters in same column are not significantly different at pr= 0.05 using Duncan multiple range test.

Figure(4): Number of *Adansonia digitata* seedlings according to around each point in a circular area of 3.14 m^2 certain circle with diameter (2m) and distance from nearest at Elkhouyi area. North Kordofan.



4.3 Seed Weight

Seed weight was significantly affected by the date of collection (p = 0.0001). The highest values were for seeds collected in November than the other months (table 3 and figure 5). The high weight of seeds collected in November might be due to high moisture content of fully developed fruits and seeds and then the moisture content decreases from the seeds.

4.4 Germination

4.4.1 Effect of date of seeds collection

The effect of date of fruit collection was found to have significant effect on total germination percent (pr= 0.0001). The average number of seeds germinated was higher with the fruits collected in January than the other month (Table 4 and figure 6).

4.4.2 Effect of germination date

Germination had significant effect on seed germination for fruits collected in October (pr = 0.0001), November (pr = 0.0001), December (pr = 0.0001) and January (pr = 0.0001). In each of the fruit collection dates, germination was higher for seeds started in July than the other two periods. Followed by April and the least were for January (Table 5).

The effect of germination date on total germination percent was significant (0.0001). The average number of seeds germinated was higher for seeds planted in July than the other month (Table 5).

4.4.3 Effect of seeds pretreatments

The effect of seeds treatments of date planted was significant (p= 0.0001).The higher percentage to the seeds treated with Electric burner of seeds planted in January than the other month (table 6).

Table (3): Seed weight of *A. digitata* collected monthly between October 2005 and January 2006 from Elkhouyi area Northern Kordofan state.

	Average weight per 50 seed (g)	**Average weight** per seed (g)
October2005	20.42 B	0.41 B
November2005	22.13 A	0.44 A
December2005	19.49 C	0.39 C
January 2006	20.37 B	0.41 B
Probability	0.0001	0.0001

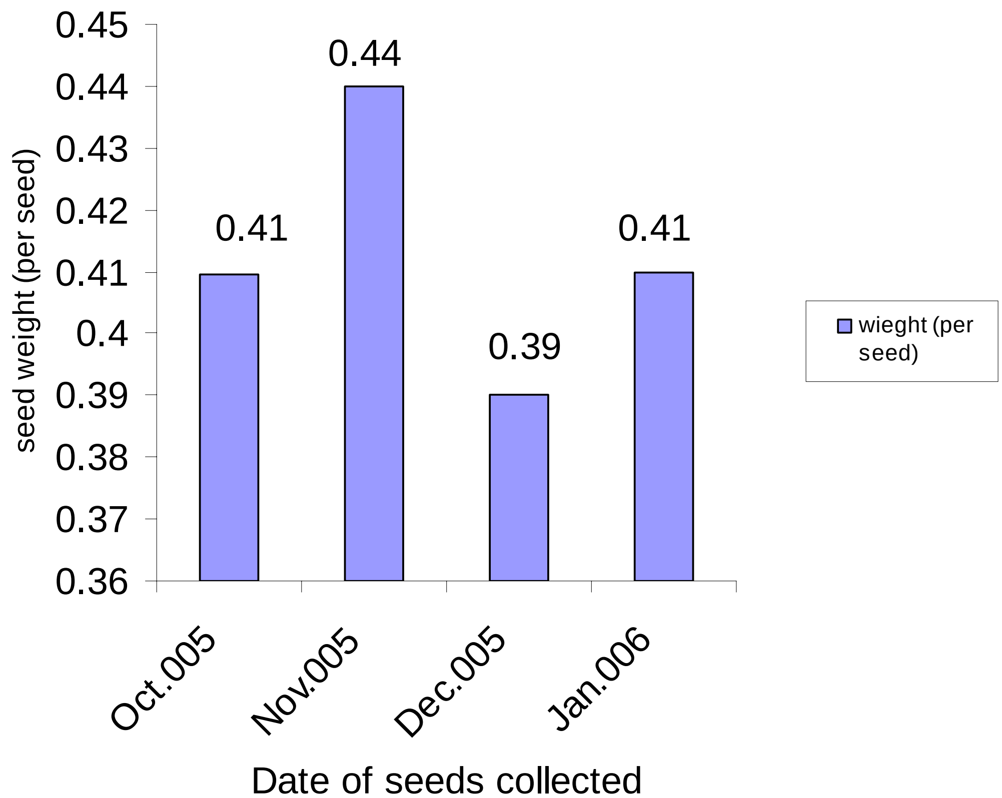
Means with the same letters in the same column are significantly different using Duncan's multiple range tests at 0.05 levels.

Table (4): Germination percentage of *A. digitata* seeds collection in different dates from Elkhouyi area Northern Kordofan state.

	Number of seeds	**Seed %**	**Total**
October 2005	99	19.7	600
November 2005	82	16.3	600
December 2005	142	28.3	600
January 2006	179	35.7	600

Pr of Chi square test = 0.0001

Figure (5): Seed wieght (per seed) of *Adansonia digitata* collected monthly between October2005 and January2006 from Elkhouyi area- North Kordofan.



Figure(6): Germination percentage of *A. digitata* seeds collection from Elkhouyi area Northern Kordofan state.

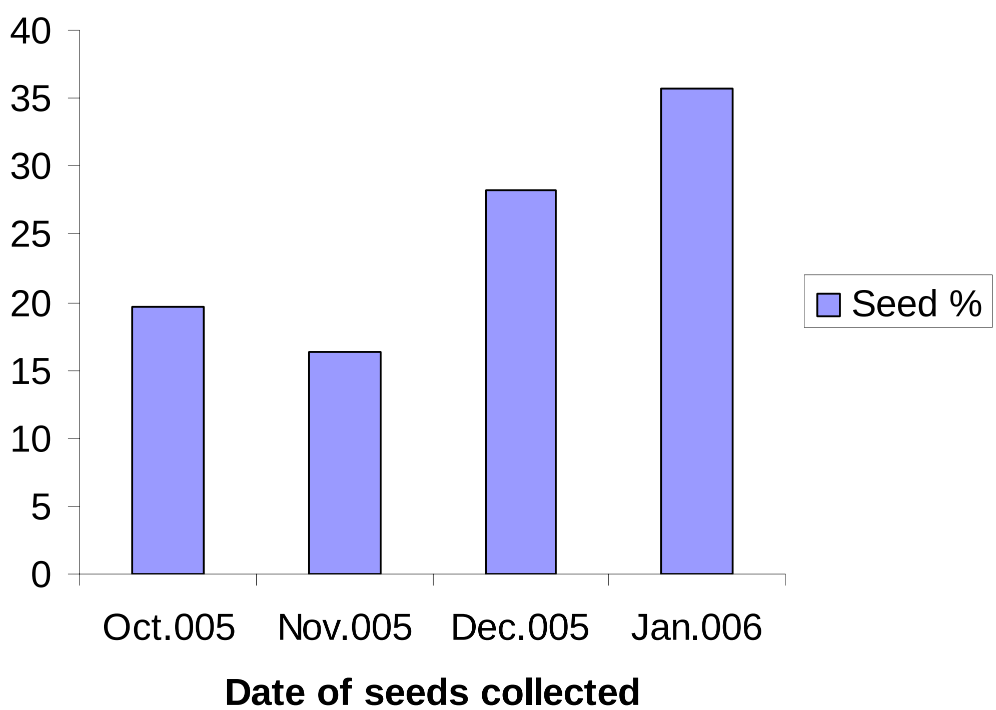


Table (5): Germination percentage of date planted of *A. digitata* seeds collection in October, November, December and January.

	Date of collection							
	October		**November**		**December**		**January**	
Date of planting	No. seed	Seed germ,	No. seed	Seed germ.	No. seed	Seed germ.	No. seed	Seed germ.
January	19	9.6	1.2	3.5	46	32.4	46	25.7
Pr of Chi square test	**0.0001**		**0.0590**		**0.0001**		**0.0001**	
April	22	11	1.2	3.5	16	11.3	39	21.8
Pr of Chi square test	**0.0001**		**0.4214**		**0.0001**		**0.0001**	
July	58	29	11.4	34	80	56.3	94	52.5
Pr of Chi square test	**0.0001**		**0.0001**		**0.0001**		**0.0001**	

Table (6): Germination percentage of treated seed of *A. digitata* collected in October, November, December and January.

	Control	Dry heat	Electric burner	Sulpharic acid
January 2006	4	2.18	61.98	0.88
April 2006	2.28	12.13	48.75	37.88
July 2006	0.88	15.75	41.33	42.18

Pr of Chi square test = 0.0001

4.4.4 Effect of treatments of seeds collected in other date and planted in other date

The effect of pre-germination treatments of seeds collected in October, November, December and January was significant of germination (p= 0.0001) The higher percentage to the seeds treated with Electric burner of seeds planted in January and collected in October, November and January Table 7, Table 8, Table10. Also, the higher percentage to the seeds planted in December Table 9.

4.4.5 General discussion of germination

From the above results, effect of *A. digitata* fruit collection dates on seeds germination is shown in Table 4 and Figure 6. The significantly higher germination percent obtained by seeds collected in January (35.7%) followed by December (28.3%), November (16.3%), and October (19.7) indicates variation in seed maturity. This variation may be due to variability in flowering between May to July (El Amin 1990, Adam 2003).

This may indicate that January is the best time for fruit collection to obtain high germination percent. Also, this may explain the scarcity of natural regeneration due to pre-mature seed collection. This is in agreement with the general hypothesis that pre mature fruit collection movements of fruits to cities are the reason for low seed bank and low regeneration density.

Treatment of *A. digitata* seeds with electric burner and planted in January gave significantly higher seed germination percentage (61.98%), followed by sulphuric acid treatment. This result is similar to that obtained by Mahgoub (1998). Danthu et al. (1994) reported that the acid improved germination significantly compared to control. The electric

Table (7): Germination percentage of treated seed of *A. digitata* seeds collected in October and planted in January, April and July.

	Control	Dry heat	Electric burner	Sulpharic acid
January2006	16	0	79	5.3
April 2006	9.1	0	64	27
July 2006	3.5	26	48.3	22.5

Pr of Chi square test = 0.0001

Table (8): Germination percentage of treated seed of *A. digitata* seeds collected in November and planted in January, April and July.

	Control	Dry heat	Electric burner	Sulphuric acid
January2006	0	0	71	29
April 2006	0	18	28	54
July 2006	0	9.5	43	46.8

Pr of Chi square test = 0.0001

Table (9): Germination percentage of treated seed of *A. digitata* seeds collected in December and planted in January, April and July.

	Control	Dry heat	Electric burner	Sulpharic acid
January2006	0	6.5	56.5	37
April 2006	0	12.5	75	12.5
July 2006	0	17.5	30	52.5

Pr of Chi square test = 0.0001

Table (10): Germination percentage of treated seed of *A. digitata* seeds collected in January and planted in January, April and July.

	Control	Dry heat	Electric burner	Sulpharic acid
January2006	0	2.2	60.9	37
April 2006	0	18	28	54
July 2006	0	10	44	47

Pr of Chi square test = 0.0001

burner and acid treatments effects may be through increased permeability to water and gases resulting in high germination percent. The dry heat treatment resulted in higher germination percent than the control but less than the mechanical and chemical scarification treatments. The may point to the positive effect of the dry heat treatment and the need for more research on the level and duration of this treatment. The low germination percent of the control points to seed have physical dormancy (coat dormancy) (Mahgoub 2002).

The seed treatment results indicate the need for mechanical or chemical seed pretreatments to obtain high germination percent. Although, the electric burner treatment gave the highest germination percent, it can be used in limited situation due to difficulty of performing it with large number of seeds. On the other hand, the sulphuric acid treatment can be used when large amount of seeds are needed for germination. These recommendations are in agreement with Mahgoub (1998).

In each of the fruit collection dates, germination was higher for seeds started in July, followed by April and the least were for January (Table 5). This may indicate that in addition to seed coat in permeability, there are internal factors affecting the germination that are related to maturity or response to surrounding temperature. Baskin and Baskin (1998, 2004a) reported the effect of temperature in germination of seedlings in nurseries and showed that good establishment is related to the period of suitable degree of temperature for germination. Variation in moisture content may also be implicated as observed with *Acanthocarpus preissii* seeds where there need for adequate moisture (Palmer and Pitman, 1972). Seeds are thought to germinate only in exceptionally good rainy seasons.

These results indicate the importance of timing for germination of *A. digitata*. Furthermore, studies to understand the mechanism involved and to determine the best time for germination are needed for this important and endangered species.

The results from the germination experiments indicate that the seeds maturity is an important factor, as reflected by the effect of date of fruit collection and the initiation of germination. Also, the seed pretreatments showed that seed permeability to water and gases is another important factor affecting seed germination.

4.6 Effect of seed treatments on seedlings length

4.6.1 Seeds collected in October

Effect of seed pre-germination treatments on seedling length was significant at week 5 to week 13 ($pr > 0.05$) for seeds planted in April and July and significant for weeks 5 to 9 for January planting period (Table 11 A, B and C). Electric burner treatment resulted in seedling with significantly higher lengths at week 5 to 13 for seeds planted in April and July (table 11 B and C). Although, the sulphuric acid continued to have higher means for seeds planted in January at weeks 5, 6, 8 and 9 but it was not significantly higher than all the treatments (Table 11 A). For example, at all weeks it gave seedlings with significantly higher lengths compared to sulphuric acid treatment while they were significantly higher than dry heat treatment at weeks 5, 11 and 13 (Table 11 C). Similarly, the number of leaves at week 13 was significantly affected by seeds pretreatment at each of the planting periods (April and July) (table 11 B and C). Also, the electric burner treatment continued to show significantly high number of leaves for planting period April and July (Table 11 B and C).

4.6.2 Seeds collected in November

Effect of seed pre-germination treatment on seedlings length for weeks 5 to 13 was significant ($pr > 0.05$) at January planting period, not significant for April planting period and significant only at week 7 for July period (Table 12 A, B and C). The Electric burner treatment resulted in seedling with significantly higher length at week 5 to 13 for seeds planted in January (Table 12 A). The treatments means were not significantly different for April planting period (Table 12 B). However, for seeds planted in July, the sulphuric acid treatment resulted in seedlings with significantly higher length in at week 7 (Table 12 C).

Similarly, the number of leaves at week 13 was significantly affected by seeds pretreatment for each seeds planting period (January and April) (table 12A and B). Also, the electric burner treatment continued to show significantly high number of leaves for planting period January and April (Table 11 A and B). However, at July planting period there was no significant effect for the treatments (Table 12 C).

4.6.3 Seeds collected in December

Also, effect of seed pre-germination treatment on seedlings length was significant (pr > 0.05) at week 5 to week 13 at January planting period, week 7 to week 13 at April planting period and only at week 5 and 6 for July planting period (Table 13 A, B and C). The Electric burner treatment resulted in seedlings with significantly higher length at 5 to week 13 than sulphuric acid for seeds planted in January, week 7 to 13 for April, and weeks 5, 6 and 13 for July planting period (Table 13 A, B and C).

Similarly, the number of leaves at week 13 was significantly affected by seeds pretreatment for each seeds planting period January and April and not significant for July seeding period (Table 13 A, B and C). Also, the dry heat treatment and electric burner continued to show significantly high number of leaves for January and April seeding periods as compared to Sulphuric acid treatment (Table 13 A and B).

4.6.4 Seeds collected in January

Also, effect of seed pre-germination treatment on seedlings length was significant at week 5 to week 13 (pr > 0.05) at January and April planting periods (Table 14A and B). However, the seed pre-germination treatment on seedlings length was significant at week 5 to week 11 (pr > 0.05) for July planting period (Table 14 C). Electric burner and dry heat treatments gave seedlings with significantly higher length than sulphuric acid treatment at week 5 to 13 for seeds planted in January and 7 April longer (Table 13 A and B). The electric burner gave longer seedlings at weeks 5 to 10 for July seeding period (Table 14 B). Similarly, the number of leaves at week 13 was significantly affected by seeds pretreatment at each of the planting periods January and April (Table 14 A and B). Also, the electric burner treatment continued to show significantly high number of leaves for planting period January and April (Table 14 A and B).

From the above results, the seeds planted in July showed the highest seedling lengths between weeks 5 to 13 and number of leaves at weeks 13 as compared to January and April planting periods (Tables 11 to 14). This similar to the germination results (Tables 5) where the higher germination percentages were obtained with seeds planted in July. The seedling shoot growth in length was less affected by seed collection date and to lesser extent by seed treatment, indicating the importance of seed planting date. Comparing these results with the natural germination in the dry land which starts in the rainy season (after June) indicate that seeds have maturity requirements to match the germination and seedling growth with the suitable moisture conditions.

Seeds treatment showed significant effect on shoot growth for seeds planted in January and April (tables 11 A and B to 14 A and B). This indicates that the enhancing effect of the treatments is connected with the seed stage of maturity, which indicate there is internal factors that are affected by the increased imbibitions rate of water and gases for treated seeds. Generally, electric burner and sulphuric acid resulted in higher shoot growth, which similar to germination percentages for the January and April seeding period.

Danthu et al. (1995) reported that the length of seedlings up to 40-50cm between 3 to 4 months in the nursery, and this agrees with result of this study, particularly seeds planted in July.

4.7 Evaluation of seeds and seedlings in the field:

4.7.1 Effect of protection on germination of seeds

Table (15) shows that protection had significant effect on the number of germinated seeds (pr = 0.0001). The germination in the protected area was (26%) while that of unprotected was 3 %.

4.7.2 Effect of protection on seedlings survival

Table (16) shows the protection had significant effect on seedlings survival (pr = 0.0001). The seedlings survival in the protected area was 100% while that of unprotected was (10.34%).

4.7.3 Effect of protection on seeds survival

Table (17) shows the protection had significant effect on seeds survival (pr = 0.0001). The seeds survival in the protected area was (26%) while that of unprotected was (3%).

From the above results, the protected areas had significantly high number of germinated seedlings (26% in protected areas compared to 3% in unprotected). The same values were obtained in the survival data (Tables 17). These results show that seeds and seedlings are damaged and grazed by animals. Similar conclusions were reached by Adam (2004) after studying *Boswellia papyrifera* regeneration in Darfur states.

Table (11): Effect of seeds treatments on seedlings length for seeds collected in October planted in January, April and July.

January										
Treat.	H5	H6	H7	H8	H9	H10	H11	H12	H13	LN
Cont.	0 C	0 B	0 B	4.5 B	6.5 B	8.3	18.5	18.5	18.5	6
Elec.	7.5 B	10 A	18.6 A	13.1 A	14.1 A	14.3	14.5	18.8	18.8	6.1
Sulph.	13 A	13 A	1.3 A	14.1A	14.1 A	14.2	14.2	14.2	14.2	4
Pr.	0.0054	.0021	0.0001	0.0028	0.0265	0.1382	0.1131	0.1879	0.1879	0.4291
April										
Treat.										
Cont.	0 B	0 B	0 B	3.2 B	1.8 B	6.3 B	6.3 B	6.3 B	10 B	3 B
Elec.	9.8 A	16 A	18.6 A	20.7 A	22.1 A	25.1 A	28.1 A	30.5 A	30.5 A	14.3 A
Sulph.	0 B	1.2 B	1.3 B	1.8 B	2.1 B	2.6 B	2.7 B	2.7 B	8.3 B	3.0 B
Pr.	0.002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
July										
Treat.										
Cont.	14.8 AB	17.3 A	20 A	22.5 ABC	25 AB	28 AB	31 AB	31.3 ABC	32.5 AB	25 B
Dry heat	13.6 B	17 B	20.4 A	23.2 AB	25.6 A	28.4 A	30.1 B	31 B	31.4 B	19.3 B
Elect.	17.6 A	21 A	24.6 A	27.3 A	29.8 A	32.9 A	35.2 A	38.2 A	40.5 A	28 A
Sulph.	4.2 C	7.1 C	11.2 B	13 C	15.5 B	16.7 B	20.7 C	23.5 C	26.5 B	16.9 B
Pr.	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0014	0.0142

Means with the same letters in the same column are not significantly different using L S Means range test at 0.05 levels.

H= height of seedlings at week (5,…,13)

LN= Number of leave per seedlings in the week13th

Treat. = treatment, Elec.= Electric burner, Sulph.= sulphuric acid, Pr.= probability

Cont. = control.

Table (12): Effect of seeds treatments on seedlings length for seeds collected in November planted in January, April and July.

January										
Treat.	H5	H6	H7	H8	H9	H10	H11	H12	H13	LN
Elec.	6.9 A	11 A	12.5 A	13.2 A	13.9 A	13.9 A	14 A	14 A	14 A	6 A
Sulph.	0 B	0 B	2.5 B	2.5 B	3 B	4 B	4.5 B	4.5 B	7.5 B	3 B
Pr.	0.0363	0.0058	0.0041	0.0027	0.0027	0.0094	0.0158	0.0158	0.0059	0.0102
April										
Treat.										
Dry heat	4	11	18.4	22.2	26.9	31.2	35	38	41.5	19 AB
Elec.	9.7	14	16.8	19.4	23.7	26.6	31.5	33.2	35.7	28.7 A
Sulph.	5	8.5	8.5	9	14	19.1	21.5	22.3	23.3	10 B
Pr.	0.4417	0.7041	0.4161	0.2460	0.1578	0.1537	0.1971	0.1744	0.1680	0.0514
July										
Treat.										
Dry heat	11.9	18	21 B	23.4 B	26.6	28.7	31.5	32.3	32.9	21.2
Elec	14.4	18	20.4 B	24.1 AB	27.1	30.6	34.8	35	36.2	23.2
Sulph.	11.1	17	24.4 A	26.7 A	29.1	30.9	33.2	35.7	37.6	25.7
Pr.	0.2963	0.9143	0.0189	0.0577	0.1654	0.4490	0.1424	0.4153	0.2719	0.2486

Means with the same letters in the same column are not significantly different using L S Means range test at 0.05 levels.

H= height of seedlings at week (5,…,13)

LN= Number of leave per seedlings in the week13th

Treat. = treatment, Elec.= Electric burner, Sulph.= sulphuric acid, Pr.= probability

Cont. = control.

Table (13): Effect of seeds treatments on seedlings length for seeds collected in December planted in January, April and July.

January										
Treat.	H5	H6	H7	H8	H9	H10	H11	H12	H13	LN
Dry heat	4.3 B	6.7 B	10.3 B	13.8 A	14.7 A	15.6 A	15 A	16 A	16 A B	6.7 A
Elect.	8 A	12.4 A	14.5 A	15.9 A	16.3 A	16.4 A	14.4 A	16.6 A	16.6 A	6 A
Sulph.	0 C	0 C	0 C	0 B	1.2 B	3.2 B	4.6 B	7.8 B	11.3 B	4 B
Pr.	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0005	0.0001
April										
Treat.										
Dry heat	7.5	14	18.9 AB	21.1 A	23.5 A	26.2 AB	28.5 A	30.5 A	32.5 A	16.5 A
Elec.	8	15.5	19.5 A	22 A	25.4 A	28.5 A	33.5 A	36 A	39.1 A	21.1 A
Sulph.	5	8.5	8.5 B	9 B	14 B	19.1 B	21.5 B	22.3 B	23.3 B	10 B
Pr.	0.6087	0.3495	0.0419	0.0146	0.0187	0.0881	0.0762	0.0762	0.0253	0.0248
July										
Treat.										
Dry heat	14.3 A	17.7 AB	20.4	23.4	26	28.7	30	33	33.2 B	21.4
Elec.	15.55A	19.63 A	23.07	25.1	28.1	30.9	33.4	36.1	37.9 AB	25.3
Sulph.	9.7 B	14.8 B	23.1	25.1	28.8	31.7	34.9	38.4	41.2 A	27.3
Pr.	0.0005	0.0057	0.2699	0.6083	0.3000	0.2984	0.2010	0.1224	0.0511	0.1902

Means with the same letters in the same column are not significantly different using L S Means range test at 0.05 levels.

H= height of seedlings at week (5,…,13)

LN= Number of leave per seedlings in the week13th

Treat. = treatment, Elec.= Electric burner, Sulph.= sulphuric acid, Pr.= probability

Cont. = control.

Table (14): Effect of seeds treatments on seedlings length for seeds collected in January planted in January, April and July.

January										
Treat.	H5	H6	H7	H8	H9	H10	H11	H12	H13	LN
Dry heat	9 A	11 A	12 A	13.5 A	13.5 A	13.5 A	13.5 A	13.5 AB	13.5 AB	14 AB
Elec.	10.2 A	13.9 A	17.4 A	17.3 A	17.7 A	17.7 A	17.8 A	17.8 A	17.8 A	5.8 A
Sulph.	0 B	0 B	0 B	0 B	1.9 B	3 B	4.3 B	7.3 B	10.6 B	3.8 B
Pr.	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
April										
Treat.										
Dry heat	3.4 B	10 A	14 A	16.9 A	21.9 A	23.5 A	26.6 A	28 A	29.6 A	14.4 A
Elect.	8.2 A	12.1 A	15.7 A	15.9 A	18.3 A	20.3 A	22.9 A	24.3 A	26 A	14.8 A
Sulph.	0 C	0 B	0 B	1.2 B	3 B	6.2 B	9 B	10.5 B	14.4 B	5.2 B
Pr.	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
July										
Treatment										
Dry heat	14.9 A	19.9 A	22.5 A	24.3 A	26.8 B	28.3 B	31.6 B	33	34	22.7
Elec.	18.4 A	22.5 A	25.9 A	28.8 A	32.4 A	34.9 A	37.7 A	38.8	39.3	27.8
Sulph.	10.3 B	14.7 B	21.3 B	20.23 B	27.8 B	31.4 B	34.1 B	37.07	38.9	26.6
Pr.	0.0001	0.0001	0.0001	0.0001	0.0002	0.0043	0.0202	0.1723	0.3457	0.4528

Means with the same letters in the same column are not significantly different using L S Means range test at 0.05 levels.

H= height of seedlings at week (5,…,13)

LN= Number of leave per seedlings in the week13th

Treat. = treatment, Elec.= Electric burner, Sulph.= sulphuric acid, Pr.= probability

Cont. = control.

Table (15): Germination percentage of physically protected seed in Elkhouyi area Northern Kordofan state.

Treatments	Germination seed	Total
Protected	26	100
Unprotected	3	100
Pr	**0.0001**	

Pr of Chi square test = 0.0001

Table (16): Survival percentage of *A. digitata* seedlings in Elkhouyi area Northern Kordofan state.

Treatments	Number of seedlings	Survival
Protected	100	100
Unprotected	145	10.34
Pr	**0.0001**	

Pr of Chi square test = 0.0001

Table (17): Survival percentage of *A. digitata* seed in Elkhouyi area Northern Kordofan state.

Treatments	Survival	Total
Protected	26	100
Unprotected	3	100
Pr	**0.0001**	

Pr of Chi square test = 0.0001

Comparing germination in the field and the nursery for seeds receiving same electric burner treatments showed that the nursery had high germination percent due to availability of moisture and the controlled nursery environment.

There are some suggestions for making protected areas before seeds or seedlings planting or the cultivations being mixed inside land ownerships. After effective extension work, explain the importance of *A. digitata* trees.

In the situation of seeds collection the maturity must be enough, in order to achieve high germination percentage. On the other hand, where domestic plants are cultivated and/or domestic animals are raised, the natural reproduction cycle of the baobab is often threatened (Nordiede et al 1996).

CHAPTER FIVE
CONCULUSIONS

The main conclusions of this study are the following:

1- Soil seed bank at Elkhouyi site was low and most of the available seeds were near the standing mature trees in the upper 5 cm of the soil. The low seed bank indicates massive removal of fruits from the *A. digitata* sites as hypothesized by the study. Also, it could be explained by grazing of new germinating seedlings. The results indicate the need for human intervention to enrich the soil seed bank.
2- Similarly, judging by number of seedling per unit area, natural regeneration was very low. This also related to the poor soil seed bank and to heavy grazing. Change in vegetation, due to climatic condition, may have affected the natural regeneration.
3- Seeds collection date showed significant effect on seed germination. Collection of fruits in January resulted in significantly high seed germination percentage (35.7%), the following year, had significantly higher than those collected in October 2005. The germination percent was as fallows (19.7%), November 2005 (16.3%), December 2005 (28.3%) and January 2006 (35.7%). This indicate importance of seed maturity fruits collection date.
4- Fresh seed weight showed significant variation between collection dates. Fruits collected in November showed heavier seeds than the other collection period, probably due to high moisture content of fully developed fruits and seeds and then the moisture content decreases with time from seeds.
5- Seed planting date had significant effect on germination and shoot growth. Seeds planted in July showed higher germination

percentages and longer seedlings and more leaves than earlier planting (January and April). This also, showed the importance of seed maturity. The effect of seed treatments was less evident for seed planted in July than those planted in January and April.

6- Seed coat scarification using electric burner or concentrated sulphuric acid gave higher germination percentage. However, their effect was pronounced in January and April planting date as compared to July. This may indicate that seed age and its maturity enhance water and gases exchange leading overall higher germination percent in July. Accordingly, seeding is recommended to occur in July and if earlier seedling production is needed, there must be seed treatment.

7- The field evaluation of transplanted seedlings and directly sown seeds showed significantly higher seedling survival and germination in protected sites. This indicates the importance of protection of *A. digitata* sites against animals. In addition, these results may explain that the poor natural regeneration is mainly due to grazing by livestock.

8- From the results of this study, it is recommended that the natural sites should be enriched with seeds and protected against animals to insure successful establishment of *A.digitata*, the endangered species in Sudan.

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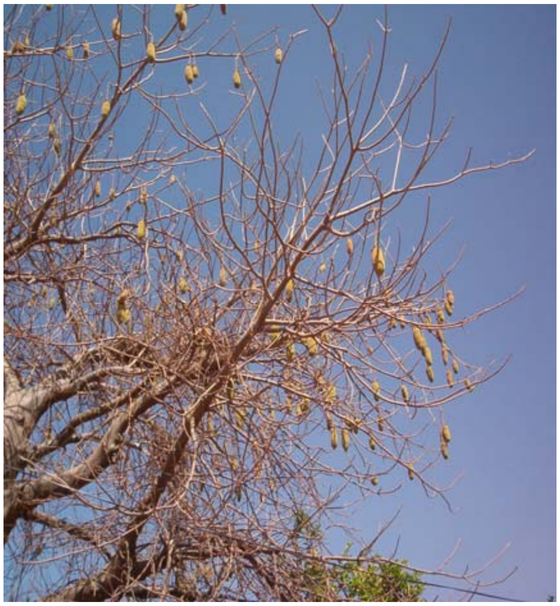
Seedlings of *A. digitata* in the nursery



Fruits of *A. digitata*

Elobied market

Adansonia digitata in Elkhouyi area

Seedlings of *A. digitata*