ADDIS ABABA UNIVERSITY

SCHOOL OF GRDUATE STUDIES

DEPARTMENT OF BIOLOGY

GERMINATION VIABILITY AND GROWTH RATE OF *CORDIA AFRICANA* IN ANNO TOWN, OROMIA REGIONAL STATE, WEST ETHIOPIA

A THESIS SUBMITTED TO SCHOOL OF GRADUATE STUDIES OF ADDIS ABABA UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR DEGREE OF MASTERS OF SCIENCE IN BIOLOGY

Kebede Gobena

Advisor: Dr. Habte Jabessa

August, 2018

Addis Ababa, Ethiopia

Approval Sheet I

This is to certify that the thesis prepared by Kebede Gobena entitled "Germination viability and Growth rate of *Cordia africana* in Anno Town, Oromia Regional State, and West Ethiopia" and submitted in partial fulfillment of the degree of Master of Science in Biology compiles with the regulation of the university and meets the accepted standards with respect to originality and quality.

Signed by examining committee;

Examiner_____Signature_____Date____/____/_____

Examiner_____Signature_____Date____/____/_____

Advisor_____Signature_____Date____/____/_____

Department head _____ Signature_____Date____/____/_____

Acknowledgement

First and foremost I would like to thank my advisor, Dr. Habte Jabessa Debella who has given me his valuable time `and comments and also has shaped the entire work of this research study.

Also my first and heartfelt gratitude goes to my wife Soreti Feyisa helped me to accomplish my study.

I express my earnest gratitude to my colleague Mrs. Achamelesh Feyisa, Fantu Asefa, Mr. Addisu Tesfaye, Tolesa Idobus, Geremu Dugasa, and Mr. Nugusa Amansisa who helped me in writing different assignment given by our instructor and as well as research proposal and the final thesis gave me enough support.

I also thank the Anno Agricultural Bureau for providing me a plot land and necessary materials to do my experiment.

Last, but not least, I express my heart-felt thanks to members of Biology Department and to those whose name is not mentioned here for they have contributed in some way to enrich this study.

Acronyms

GFRA:	Global Forest and Resource Assessment
GP:	Germination Percentage
GV:	Germination Vigor
MGT:	Mean Germination Time
RGRH:	Relative Growth Rate Height

Abstract

The study was conducted on the germination and growth rate of Cordia africana from March 16, 2010 to May 26, 2010 in Anno nursery. In the distant past, our world covered by different tree species. However, after the arrival of European powers in Africa, the species of Cordia africana began declining. Uncontrolled encroachment and clearing of forest land have been on process and continue until know. Planting and establishment of trees on degraded land should be the first important step in soil rehabilitation and reclamation. The objective of the study was to determine the germination potential and growth rate of Cordia africana. The ripened seeds were collected from dominant trees from the wild. The seeds were soaked in water for three days. After the seeds were purified, it was kept in water for consecutive eight days. Hundred seeds were selected and planted in pre-prepared seed bed of 1x10 m each at the depth of 1 cm and between seeds distance of 15x15 cm. The seeds were covered slightly by soil and then covered by dry Setaria megaphylla. Each seed bed was watered 8 liters three times per day until the seeds germinate. As germination begun before two week, the grass was removed and then the shade was constructed at 1m above the germinated seed and watered 8 liters 2 times per day up to the end of the study. The maximum germination was observed on 14^{th} day. Of hundred seeds only eighty of them were germinate. Each seedling was assigned a random number (1-80). Watering, mulching and guarding measures from herbivore damage and weeding were handled by workers of the center. Data on germination, height and survival percentage were collected every14^{th} day (in 4 rounds) for two months: namely April and May. Of the 80 seedlings, 2 of them dried/wilted and one seedling was damaged at the study site. As a result, from 80 seedlings three of them were discarded from the data. Germination parameters such as germination percentage mean germination time, and germination vigor were calculated and the relative growth rate in height of the seedlings of Cordia africana was determined. The mean heights of the seedlings for 56 days were 5.38 cm and the highest relative growth height was 0.035 cm^{-1} day.- ^{1}The overall rate was 96.25 %. The soil of the study site was lower than the standard. This work concludes that, despite the poor nutrient status of the study site, the germination, growth performance, and percentage survival were reasonably moderate, indicating the potential of Cordia africana to germinate and grow on degraded site provided that intensive management, along with provision of water during hot, dry season are maintained.

Key words: *Cordia africana*, germination, growth rate, survival percentage

Table of Contents

Contents **Pages**

List of Figures

List of Tables

1. Introduction

1.1 Background of the Study

Forest is the assemblage of trees growing together or the association of trees as well as foliage growing together. Mostly *C. africana* was abundant in Africa and the most important tree species prior to the colonial periods (Degaru *et al*., 2003). However, after the arrival of European powers in Africa, the species of *C. africana* began declining; because of deforestation and burning of forest for their own purpose (Finkeldey, 2007). Deforestation accounts great proportion for the degradation of *C. africana.* This is mostly because of the overall environmental deterioration and climatic challenges that highly affect the distribution of C. *africana* in Africa (Grote and Sheikh, 2010). *C. africana* prefers regions with relatively high rainfall and sufficiently warm climate. It can also grow under drier climatic conditions, by minimizing its water consumption through shading its leaves or by closing its Stomata (Legesse, 1992, 1995; Jiregna *et al*., 2004).

Germination begins in two weeks proceeding unevenly for up to two or three months. The ripe fruits are grounded and mixed with water and used as juices in ancient time (Nigatu *et al.,* 2014). *C. afrjcana* fruit is processed in to refreshing juice either by boiling or by adding Luke warm or cold water (Tirunch *et al.,* 2009). It is also multipurpose tree grown in different localities for timber, soil and water conservation and as a shade tree (Legesse, 1995).

C. africana has socio-economic importance, medicinal uses, fodder and environmental uses. Among these economic importance are for selling timber, for charcoal, for fuel wood, where as the social importance of the tree is for burying dead bodies of human being, for making durable high quality furniture, tables, chairs, boxes, doors, windows, cabinet making and drums (Azene *et al*.,1993).

C. africana is a very fast growing tree (attaining a height of 6-8 m within 7 years) (Breitenbach, 1963). It is easily raised from seeds in the nursery out very dense in order to stimulate fast growth and obtain straight (Bekele *et al.,* 1993).

1.2. Statement of the Problem

Cordia africana is found in densely populated forest areas and serves the society in many ways (Deraro *et al*., 2009). However, this large biodiversity resource is under continuous and severe threats of destruction. It is well known that, massive habitat loss or habitat degradation is accompanied by large erosion of genetic resources (Mulgeta, 2004). This is because, large members of terrestrial organisms are found in the natural forests (Taye *et al*., 1999). For instance, 129 endemic plant species of Ethiopia and Eritrea were threatened due to forest destruction (Ensermu *et al*., 1992).

The uncontrolled encroachment and clearing of forest land have been on process and continue until now (Belay, 2004). The planting and establishment of trees on degraded land should be the first important step in soil rehabilitation and reclamation (Evans, 1992). It has been recommended that urgent actions be taken for propagating, cultivating and domesticating indigenous trees (Legesse, 1995). Eshetu (2001) remarked that forest planting in Ethiopia apart from provision of economically and socially valued forest products and services could facilitate the restoration of floral and faunal diversity and eventually also the productivity of degraded lands.

There was no clear cut studies conducted about the germination and growth rate of *C. africana* in the study area. So it is better to relate the cause and impacts of deforestation of *C. africana* on the socio economic aspects, with political, agro ecological and cultural circumstances of the people of the given study area, cutting of *C. africana* without replacing, it brings to ward deforestation which results in destruction of our ecosystem.

The overall purpose of this study was to determine the germination viability and growth rate of *C. africana.* The objective of the study is to determine the growth potential of the species on a degraded site dominated by nutrient depleted black cotton soil. Knowledge on the establishment potential and comparative growth rate of the species has its own contribution for conservation purposes (Vanclay, 1994).

The study attempts to answer the following two questions:

1. What will be the germination percentage of *Cordia africana* seeds?

2. What will be the growth rate of *C. africana* under study over a period of time?

1.3. Objectives of the Study

1.3.1. General Objective

- To study germination and comparative growth rate of *C. africana* in Gobu Sayo Woreda.

1.3.2. Specific Objectives

- To determine the growth potential of *C. africana*.
- To analyze the comparative growth rate of *C. africana* in the study site.
- To determine the germination rate of *C. africana* in the study area.

1.4. Scope of the Study

For the sake of the study, this work was limited to Anno nursery to find out the germination and growth rate of *C. africana* by harvesting the seeds/fruits from dominant or co-dominant tree species.

1.5 Significance of the Study

This research provides relevant information on the germination and growth rate of *C. africana.* The outcome of the study benefits different groups and individuals. From this the society of the study area would be the first beneficiary from the result of the study. Secondly, the result of the study also benefited another researcher who needs to conduct research on the issue. Lastly the result of the study serves policy makers as in put to give attention and work on the issues of *C. afriacna.*

2. Literature Review

2.1. Overview of *C. africana*

C. africana belongs to the family Borginaceae. It occurs in primary or secondary forests or in woodland at altitudes ranging from 1200-2200 m above sea level (Legesse, 1995). The tree in the forest attains a height of up to 30 m, but is much smaller with curved branched and crooked bole when grow in the open. The bark is usually pale-brown in color, rough and fibrous (Breitenbach, 1963).The leaves are alternate, large and broadly oval, in the more mature specimens becoming almost rounded. The flowers are very decorative, sessile, with white and funnel-shaped corolla. They are attractive to honey bees, and pollination is mainly effected by these insects (Legesse, 1995).

It is an early colonizer in the forest re-growth; it often regenerates in clearing and forest gaps. On average, it attains a height between 14 and 21m and a diameter at breast height between 0.6 and 0.90 m and shows great morphological variation. Flowers are complete and pollinated predominantly by bees. The fruits are edible and seed dispersal is mainly carried out by mammals and birds. *C. africana* is a fast growing and highly valued timber tree in Ethiopia. It is moderately hard and durable wood makes it a valuable raw material for making high quality furniture and household material. It is also the most important multipurpose tree species widely occurring on croplands, grazing areas, homesteads and farm boundaries. For example it is a good source of medicine, food (fruit), firewood, and bee forage (Getu *et al*., 2016).

The scattered trees of *C. africana* improve soil fertility. It is important as a coffee shade tree in traditional agro-forestry styles. The current distribution and population of *C. africana* are severely affected by deforestation, fragmentation and selective logging without management intervention, it may lead to the extinction of a species and loss associated indigenous knowledge on use and management (Regassa, 2013).

2.2. Taxonomy of *C. africana*

Cordial L. (genetic name after valeriscordus, a German Botanist) is a pan-tropical genus of about 250 species. A plant family composed of about 100 genera and 2000 species that are characterized by flowers in helicoide cymes and by coarsely hairy herbag. *C. africana Lam* (Synonym: *Cordia abyssinica* R. Br. /is a tree (rarely shrubby) species. Its English common names are East African *cordia* or large leafed *cordia* or Sudan teak. There is still no one language that people of Ethiopia have in common. The species has different vernacular names in different parts of Ethiopia; it is locally known by different names (Getu *et al*., 2016).

2.3. Botanical Description of *C. africana*

C. africana is a small to medium sized every green tree, 4-15 m high, heavily branched with spreading umbrella shaped or rounded crown. Bole typically curved or crooked. Bark grayish-brown to dark brown, smooth in young trees, but soon becoming rough and longitudinally fissured with age, young branchlets with sparse long hairs (Orwa *et al*., 2009).

Leaves are alternate, simple, ovate to sub circular, thinly leathery, dark green above, paler green and velvety below, with prominent parallel tertiary net-nerve (about 7 pairs of lateral nerve), rounded to cordate at apex, margin entire, petiole slender 2.5-7.6 cm long oval, stalkless, pleated buds open flower (Legesse, 1995). Flowers funnel-shaped, pure white, sweet scented produced in quite bunch. All the flowers on one tree open at the same time giving a very decorative effect. Flowering starts when trees are 3-5 years old. In Sudan flowering occurs in October to December and fruiting from January to April; in Kenya, flowering is from April to June. It is repeated at intervals over several weeks and is evidently triggered off by rain showers. After pollination by insects, fruit development takes a period of almost 6 months. Fruit is eaten and probably dispersed by birds (Orwa *et al*., 2009).

The sweet sticky flesh is edible. Seeds are ellipsoid, dark brown to black. The seed coat is tough, leathery and waterproof. Seeding time is highly variable, but August-September

appears to be the best season. Seeds remain viable at least for one year germination begins in two weeks, proceeding unevenly for up to two or three months. The ripe fruits are grounded and mixed with water and used as juices in ancient time (Nigatu *et al*., 2014).

Figure 1:*Vegetative and reproductive parts of C. africana Lam A) Rounded crown B) Wood in transverse section C) Wood in transverse section D) Wood in tangential section E) Leaf shape F) Flower G) Matured fruit. (Source: Getu et al., 2016)*

2.4. Reproduction of *C. africana*

C. africana begins flowering when a tree is 3-5 years old. It is conscious species with complete flowers (hermaphrodite) and is known to be pollinated predominant by bees. After pollination by insects, fruit development takes a period of almost 6 months (Orwa *et al*., 2009). In Ethiopia, the tree can be found in flower or in fruit all the year round, but the main flowering period of the species is from October to March. A flowering tree is spectacular; all the flowers open within a short time and give the tree a white snowy cover. Fruits of *C. africana*, are eaten and their seeds dispersed by birds, baboons, monkeys, apes and probably other animals (Getu *et al*., 2016).

2.5. Socio-Economic, Medicinal and Cultural Importance of C. *africana*

C. africana in Ethiopia plays a big role in protecting erosion as a tree roots protect against washout and also help to keep water in the soil and reduce global warming by uptake of carbon dioxide. Because there are not enough trees, the Blue Nile is carrying all the soil and nutrients in the water to the neighboring countries of Sudan and Egypt (Landon, 1984).

2.5.1. Uses as Fodder Trees

C. africana plays an important role in animal production by providing fodder (edible part of *C. africana* provided or used for animal feed). Leaves of *C. africana* provide fodder for the dry season and can serve to provide nutrients for maintenance and milk production, fattening of oxen in order to keep the health and to get surplus income through exchanging means. According to Gina *et al. (*2014), leaves are threshed, cut or pitted and collected for livestock consumption. *C. africana* is left to grow sufficient wood so that it serves as live fence around grazing units and farmyards; the tree is lopped periodically for fodder and sometimes fruits of the tree are consumed by cattle, goat, sheep, donkey, and mule (Agidie *et al*., 2013).

It is also known for its high quality honey production and it serves as an attributes of fodder plant for honey bee which as sweet scented flowers that attract honey bees to manufacture honey by workers bees and harvested as well as supplies abundant pollen and nectar for bees which forage all day that is the major source of honey source for Ethiopia mainly in the western parts. It also often contributes to mixed honeys in which its flavor predominates which is very aromatic with as low granulation and light brown color, consists of crushed seeds dissolved in water, can be used for feeding bees during dry periods in order to increase the number of workers bees that have an ability to produce honey (Bussmann *et al*., 2011).

2.5.2. Household Tools

The wood is light, yet durable, moderately softy, fairly straight grained and relatively termite and fungus resistant as well as a fast growing and highly valued timber tree used for high quality furniture (door, windows, chairs, beds, containers, cabinetmaking, drums, interior construction, beehives mortars and pestles) (International center for research Agro-forestry 1998).

In the western part of the country as long hives for bees and 'Tej' (Honey beer) barrels are made from hallowed out stems of *C. africana* that have been recommended to improve the growth performance of the species and minimize problems posed by big branches on the quality of the wood through mixed planting and closer initial spacing in plantations that increases the demand for wood of *C. africana* by users of its timber products is enormous as well as it is used for agricultural implements including plough, yoke, axe, digger are made from several plant parts supplemented with locally made metal instruments. It has also tough wood, which is used in the hut building for the wall of rural houses which is constructed by planting woody stem of *C. africana* where the roof of it consists of two layers; the inner is attached from vertically laid woody stems of *C. africana* and there is covered by a bunch of grass species (Tamene, 2000).

2.5.3. Binding and Drum Making

The main type of Ethiopian hand written book is the codex, made of folded parchment leaves, which are collected in gathering sewn together and given covers for codex that has dominated the local manuscript culture throughout its history (Cartwright, 2010). The main type of building of the Ethiopian codex is relatively simple, commonly made of *C. africana*, though other kinds of wood are also used and cut roughly with analyze and rarely have a perfectly square form. In addition, like Asante-style drum is one of the earliest known surviving African-American objects, originated in West Africa which is made of wood of *C. africana*.

2.5.4. Medicinal Uses

Medicinal plants have important contributions in the health care system of local communities as the main source of medicine for the majority of the rural population. Plants have medicinal and ritual or magical values (Abbink, 2009). The ethnomedicinal healing systems vary across cultures.

In Ethiopia, there is cultural diversity with various patterns of using the plants (Amenu, 2007). *C. africana* is one of the main sources of traditional medicines of human being and domestic animals. In Ethiopia the medicinal uses of *C. africana* have been reported by different authors from these, for example it helps to cure, acute febrile wood, cough, toothache, stomachache, fire burn, michi, diarrheal, jaundice, eye infection, tonsillitis, eye problem, anthrax of urination cattle epilepsy at night, malaria,, chest pain, skin rash, smell of foot scabies, abdominal pain, evil eye, spider poison, fever and influenza (Luckal *et al*., 2008).

2.5.5. Cultural uses of *C. africana*

Plants can be used for different cultural purpose including ritual, religious or spiritual ceremonies particularly in Oromo culture when butta celebration takes place; especially in the Raaba stage the specific duty of Abbaa koraa is to guide the bull at the head of the two lines of patriots (patriots of the Raaba). During the festival those who have completed their eight years initiation periods, slaughter animals, especially bulls (korma) and they hold a rod known as *C. africana* (Eshete, 2009). *C. africana* as part of ritual performance represents great success and honors as well as it provides shade which is suitable place for conducting ceremonies and get-together for the villages during social gathering and religious holidays where coffee and snacks (of roasted grains) and bread may be served (Seta *et al.*, 2013).

2.5.6. Source of Food

C. africana is used as source of food which is collected and eaten by shepherds, local communities and children when found in the wild, as well as sold by women and children

when grown in forms or backyards between its fruiting seasons of April to June (Tewolde Berhan *et al*., 2013).

2.5.7. Making of Juices from Fruits Subjected to Some Form of Home Processing

Mature fruits have a sweet, mucilaginous, edible pulp. The ripe fruits are collected either from the ground or picked from the tree and the pulps of fruits are eaten and seeds are discarded. The ripe fruit are also grounded and mixed with water and used as juices in ancient time (Nigatu *et al*., 2014). A juice of the tree is usually added to flavor local drinks prepared from other sources and *C. africana* is processed into refreshing juices either by boiling or by adding Lukewarm or end water (Tiruneh *et al*., 2009). Fruits of *C. africana* are brewed either with addition of leaves of *Rhamnus mprinides* to give the local alcoholic drinks. Without it to give the local alcoholic drinks "Beerz." The juice of *C. africana* is sometimes diluted with water and sugar or honey may be added (Getu *et al*., 2016).

2.5.8. Fuel wood

Women tend to dominate the fuel wood supply chain. The wood is transported by the producer to local markets on either their own backs or on a donkey. An average fuel wood collector sells between $0.5m^3$ and $1m^3$ each market day. *C. africana* is used for fuel in zone of Southern Ethiopia (Sidama). A number of protected indigenous trees, including *C. africana* often find their way into fuel wood bundles in many market places. The projected sustainable fuel wood supply is estimated to reach 8.6 million m^3 in 2030 (Getu *et al*., 2016).

The traditional fuel sources (woody biomass, crop residuals, dung and charcoals) put together is reported to have claimed 95.3% of the total domestic energy consumption. In Ethiopia, the modern sources (petroleum and electricity) accounted for only 4.7% in 1999 (Mekete, 1996).

2.5.9. Environmental Use

The cultivation of coffee involves planting of coffee plants in the under stores of a remaining native tree cover, which principally includes *C. africana*. Further in Southern Ethiopia, natural forests are also common where *Coffee arabica* grows as under storey plant. *C. africana* is favored as a shade tree for coffee because of its short bole. *C. africana* often found in cropland and where it is managed for shade. It provides very good mulch and can be used in other mixed cropping systems on cropland, pasture land or rangeland to improve microclimatic conditions. Generally, the tree provides shade and mulch for the integrated onset coffee systems resulting in control of soil erosion, regulation of soil moisture and temperature, improved soil nutrition, eventually creating favorable conditions for crop growth (Orwa *et al*., 2009).

Leaf fall in the dry season is heavy, and the leaves make good mulch and it is not only served as mulch but also contribute to nutrient cycling through decomposition. *C. africana* has good attributes for soil conservation. Generally tree species of *C. africana* play a great role in maintaining soil fertility and providing various products and services to the farmers. However, the performance of the native tree species *C. africana* in south central high lands of Ethiopia in relation to understory species diversity in general was found to be intermediate. It appears that, it is the over story species physical characteristics (crown size and density, clear lobe length, tree height, etc), root competition and its influence on soil biological and chemical activities which affects understory species composition (Getu *et al*., 2016).

2.6. Natural Distribution and Habitat

C. africana is a native to Angola, the Democratic Republic of Congo, Djibouti, Eritrea, Ethiopia, Ghana, Guinea, Kenya, Malawi, Mozambique, South African, Sudan, Tanzania, Uganda, Zimbabwe, Saudi Arabia and Yemen (Orwa *et al*., 2009). In Ethiopia, it is widespread in broad leaved Afromontane rainforest, undifferentiated Afromontane forests, and (‘mixed podocarpus forest’) and in riverine forests as well as in the western lowlands. Open places in moist montane forest, forest edges, in forest remnants around churches and other traditionally protected areas, as isolated trees in grassland and

cultivated fields, in village and public of Tigray, Arsi, Bale, Gamo Gofa, Gojam, Gonder, Harerge, Ilubabor Sidamo, Shewa, and Welo Flora regions (Getu *et al*., 2016).

The rate of establishment of the diversity, distribution and composition of the regeneration depend on many factors. The light environment is one of the factors, which affects natural regeneration and germination of seeds. The immediate and perhaps greatest effect of canopy opening is an increase in duration and intensity of direct sunlight to lower strata of the forest. The amount of sun radiation received by the gaps depends on gaps size, shape orientation, local topography and the height of the surrounding forest (Denslow, 1987).

The retention of enough seed trees of good phenotype well distributed through the stand is important for future sustainable productivity and for genetic resource conservation, particularly where there are imbalances and inadequate levels of established seedlings and advance growth of desirable species and where there is an inadequate soil seed bank (Mengesha, 1996).

In West Africa, this species is said to be restricted to montane and sub-montane habitats; it has limited distribution in the lowland habitats of the Democratic Republic of Congo. Generally, the species where grown in areas with altitudes between 550 and 2600 m.a.s.l. and annual rainfall of 700 to 2000mm. It is an early colonizer in forest re-growth and is often found along forest margins; it often regenerates in clearing and forest maps. It has a light quality sensing mechanism that hinders it from germinating beneath leaves (Yirdaw *et al.*, 2002).

It occurs in primary or secondary forest and woodlands. It prefers regions with relatively high rainfall and sufficiently warm climate. It can also grow under drier climatic conditions, by minimizing its wider consumption through shading its leaves or by closing its stomata. *C. africana* has fast growth performance is culturally accepted and widely used and is adapted to local conditions.

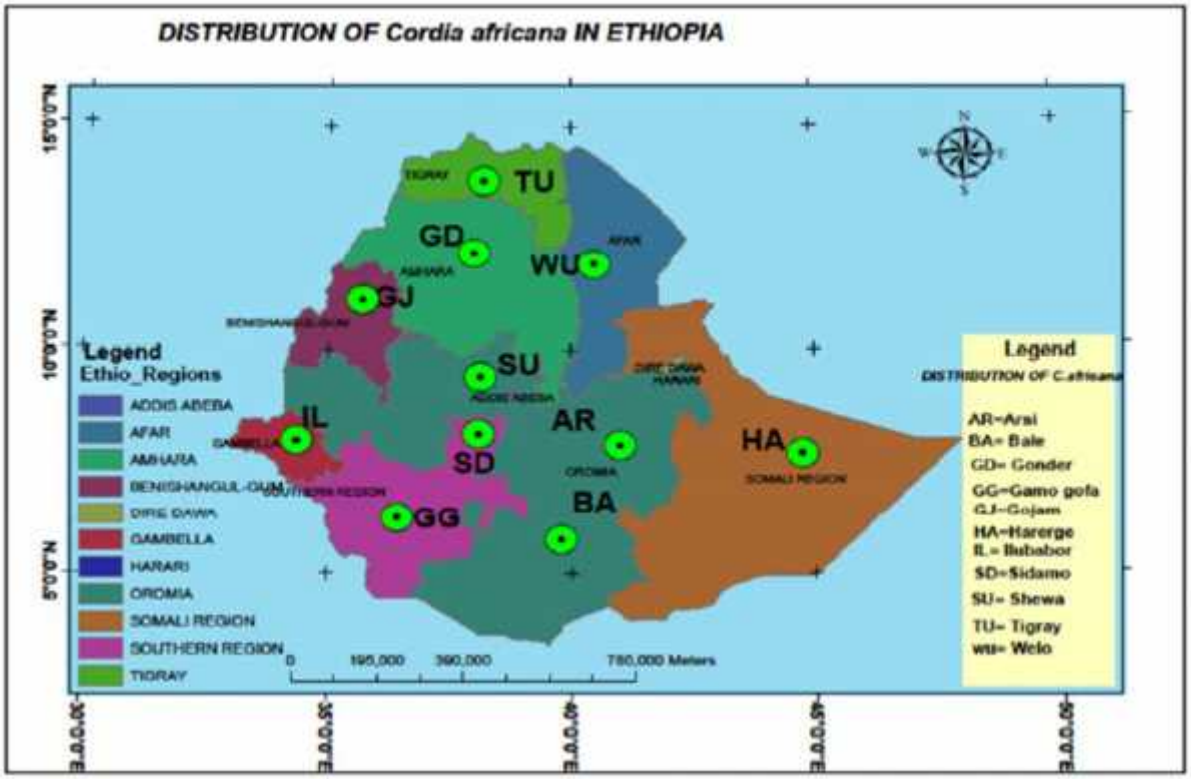

Figure 2: ***Natural distributions of Cordia africanain Ethiopian Flora regions (Source: Getu et al., 2016).***

2.7. Conservation Status of *C. africana*

The current distribution of *C. africana* relies on deforestation. Severe natural forest destruction in Ethiopia particularly in the northern part of the country has forced the tree to have scattered occurrences in patchy natural forest, on farmlands, in graveyards and church compounds. *C. africana* is the most threatened, which is evidently shown by its scarce distribution in Goma woreda Jima zone of Oromia region, except in some protected coffee forests. This is due to overharvesting for not only medicinal, but also for other uses particularly for timber production. Business obtained from timber production severely accelerated the high rate exploitation of *C. africana*. Because of it is commercially important indigenous tree species (Getu *et al.*, 2016).

Thus, the demand for wood of *C. africana* by users of its timber and timber products is enormous. However, supply is not keeping race with the demand. This caused a rapid depletion of the species. The tree is now proclaimed as one of the most threatened tree

species in Ethiopia. *C. africana* is one of indigenous tree species that have currently been identified and given conservation priority naturally by using *in-situ* and *ex-situ* conservation in the country. Nechsar National Park is one of the important conservation sites in the country with diverse component of biological resources which are ecologically and economically important. Field gene banks, botanical gardens and duplicate gene banks along with cryopreservation centers are being established in various localities to supplement the *in-situ* conservation sites. The *ex-situ* sites have been established in Lephis, Arsi Negelle woreda, Farta woreda, Debre Tabor for *C. africana*. The Forest Genetic Resources Conservation Department of the Institute of Biodiversity Conservation in collaboration with GTZ has started reintroducing the most threatened woody species including *C. africana* into their natural habitats. Deforestation poses a serious threat to the conservation of biodiversity in general and forest genetic resources in particular. In Ethiopia, rural people look for land to grow crops and graze animal, use wood as a source of household energy, for construction and farm implements as a mean of survival. In addition to the above reasons, fire, road construction and the investment activities are also the major reasons for the reduction of forest in Ethiopia.

According to the Forestry Conservation, Development and Utilization Proclamation N. 94/1994 of Ethiopia, no person shall utilize or harvest trees. Private individuals are prohibited from cutting the threatened indigenous species like *C. africana,* in both state and private forests. Utilizing products from within a state forest without a permit is punishable by between one and five year imprisonment as well as a fine of 10,000 birr (USD 1,053). In addition very few economic tree species such as *C. africana* are now managed by some farmers in their farm land as agro-forestry tree and/or garden tree. This shows that such management and acquisition of economic benefits from species might promote local peoples' interest in conservation and maintenance of such locally important and threatened species (Getu *et al*., 2016).

2.8. Importance of Tree Seedlings Care and Management

After seeds are germinated, there should be proper care and management to ensure good survival and rapid early growth (Evans, 1992). The care to be undertaken may be the following:

2.8.1. Soil Survey and Testing

Evans (1992) reiterated that a soil should fulfill tree important for plant growth: supply of moisture, nutrient and provision of mechanical support. The objectives of soil survey are essentially to assess these three functions and general features affecting its management. Information gained from soil testing is used in many ways. It could be helpful to build and/or maintain the fertility status of a given field; and evaluate the fertility status of soils on a country soil area, or statewide basis by the use of soil test summaries (Tisdale *et al.***,** 1985).

2.8.2. Maintaining soil fertility

Before the advent of commercial fertilizers, the principal method of supplying essential nutrients to the soil was by incorporating animal manures (Tisdale *et al*., 1985). Animal dung has to be returned to the land to maintain soil fertility. However, as the scarcity of fuel wood has grown, these organic matters have increasingly been used to meet household energy requirements (Anonymous, 1994). For every tone of animal dung not returned to the soil to improve soil fertility, there is a loss of some 50 kg of food grain (Evans, 1992).Using animal dung to maintain soil fertility is a cheaper in capital when compared with chemical fertilizer (Tadesse, 2004).

2.8.3. Mulching

Any material used at the surface of a soil to assist in soil productivity may be designated as mulch. Mulches comprise plant material and residues, litter and other products (Ong, 1996). The purpose of mulching is many and varied. Direct evaporation from the soil surface could be reduced by the mulch. It also reduces wind speed and radiation at the soil surface. Thus mulching is regularly utilized to conserve moisture improve

microclimate and soil erosion. Mulching, through increased activities of soil fauna, improves soil structure and fertility (Wallace, 1996). Mulching influences organic matter content, a viability of soil nutrient and soil compaction which are helpful for better plant growth (Ranganathan and Wit, 1996).

2.8.4. Watering

Sever water stress is the dominant factor that limits the establishment off seedlings in the field in Ethiopia (Jiregna *et al*., 2004). After soil fertility, water availability is the second serious limiting biological constraint for agricultural production in Ethiopia.

About 60% Ethiopia's agriculture frequently experiences serious drought stress (Takele, 2004). Water is required by plant for manufacture of carbohydrate, as a vehicle for the translocation of food and materials. Internal moisture stress causes reduction both in cell division and cell elongation, thus affecting tissue and organ growth (Tisdale *et al*., 1985). Exposure of plant to drought stress affects not only growth but also lead to the disruption of metabolic processes. Depending on the severity of the stress, drought reduces the ability of the plant to survive and reproduce (Fitter and Hay, 1987).Watering therefore, ensures better survival and growth of seedlings.

2.8.5. Hoeing

Weeds can damage trees in different way; they compete for light, moisture, and nutrients. Removal of weeds is essential for good early growth of seedlings (Evans, 1992), and this is achieved by frequent hoeing of good tree seedlings.

2.8.6. Maintaining Soil Fertility

Before the advent of commercial fertilizers, the principal way of providing important nutrients to the soil was by incorporating animal manures (Tisdale *et al*., 1985). Animal dung has to be returned to the land to provide soil fertility. For every tone of animal dung not returned to the soil to improve soil fertility, there is a loss of some 50 kg food grain (Evans, 1992). Using animal dung to improve soil fertility is a cheaper fertilizer (Tadesse, 2004).

2.8.7. Seedling Protection

Almost all seedlings are vulnerable to browsing unless they are protected. Animals, particularly the domestic animals, can seriously damage young trees and they have to be excluded from stands until trees are 3-4 m tall. In addition to domestic animals damage to the leading shoot, cattle will lie against a tree, which leads to physical damage on the whole plant body. Therefore, protection against animals where browsing pressure is high must be enforced. Erection of fences or walls or use of shepherds are expensive, but may be the only solution available (Evans, 1992).

2.8.8. Seeds

Seeds are important starting materials for propagation of many vital tree species developed embryo that can survive the period between seed maturation germination (Mo" gamba, 2007). New plant germination starts with a speed, which usually contains a fully developed embryo that can survive the period between seed maturation and germination (Mo" gamba, 2007). Propagation from seeds ensures genetic diversity that is maintained by allowing genetic recombination to occur through sexual reproduction. The genetic diversity makes possible the survival and the natural evolution of species in continually changing environmental conditions. The arrangement of genes leading to the production of individual that is different from their parents (Piotto and Di Noi, 2003).

2.8.9. Seed Germination

Seed germination incorporates those events that commence with the uptake of water by quiescent dry seed, and terminate elongation of embryonic axis (Bewly and Black, 1994). Seed germinate only after the dormancy is overcome or broken through artificial means such as scarification, seed coat cracking removing chemical inhibitors through leaching by water (Legesse, 1995, 2002).

Seed germination is a critical event in the plant life cycle, because, time of emergence from protective seed coat is crucial for survival productive success (Nelson *et al*., 2009). Physiologists often consider seed germination to be the period from imbibitions up to the

point that embryo growth is initiated and the embryo protrudes through any covering tissues. Seed quality analysts do not consider germination to be complete until the seedling has grown sufficiently to be able to observe the root hypocotyls, and cotyledons (ISTA, 1999).

2.9. Seedling Growth

2.9.1. Growth and Measurement Techniques

Growth in plant can be an irreversible increase in volume. The largest component of plant growth is cell expansion because of the pressure (turgidity). During this activity, cells increase in volume and become highly vacuolated (Taiz and Zeider, 2002).

Beside this, growth is measured in terms of change in fresh weight: that means the weight of the living tissue over a particular period of time. However, the fresh weight of plant growing in the status, so the criterion may be less indicator of actual growth. Thus, measurements of dry weight are often more accurate than the fresh (Taiz and Zeiger, 2002).

3. Materials and Methods

3.1. The Study Site

The study was conducted from March 16, 2010 to May 26, 2010 in the Anno nursery (Oromia Region West Wollega Zone, Gobu Sayo Woreda). Anno is located at 9^0 8' latitude and 37^0 36' longitudes, geographic coordinates and is about 262 km from Addis Ababa along the highway of Nekemt. An altitude of the study area was 1878 m. a. s. l (fig. 3).

The Map of East Wollega Gobu Sayu Woreda Ano Town Area Site Selection

Research Area Nursery Site Selection

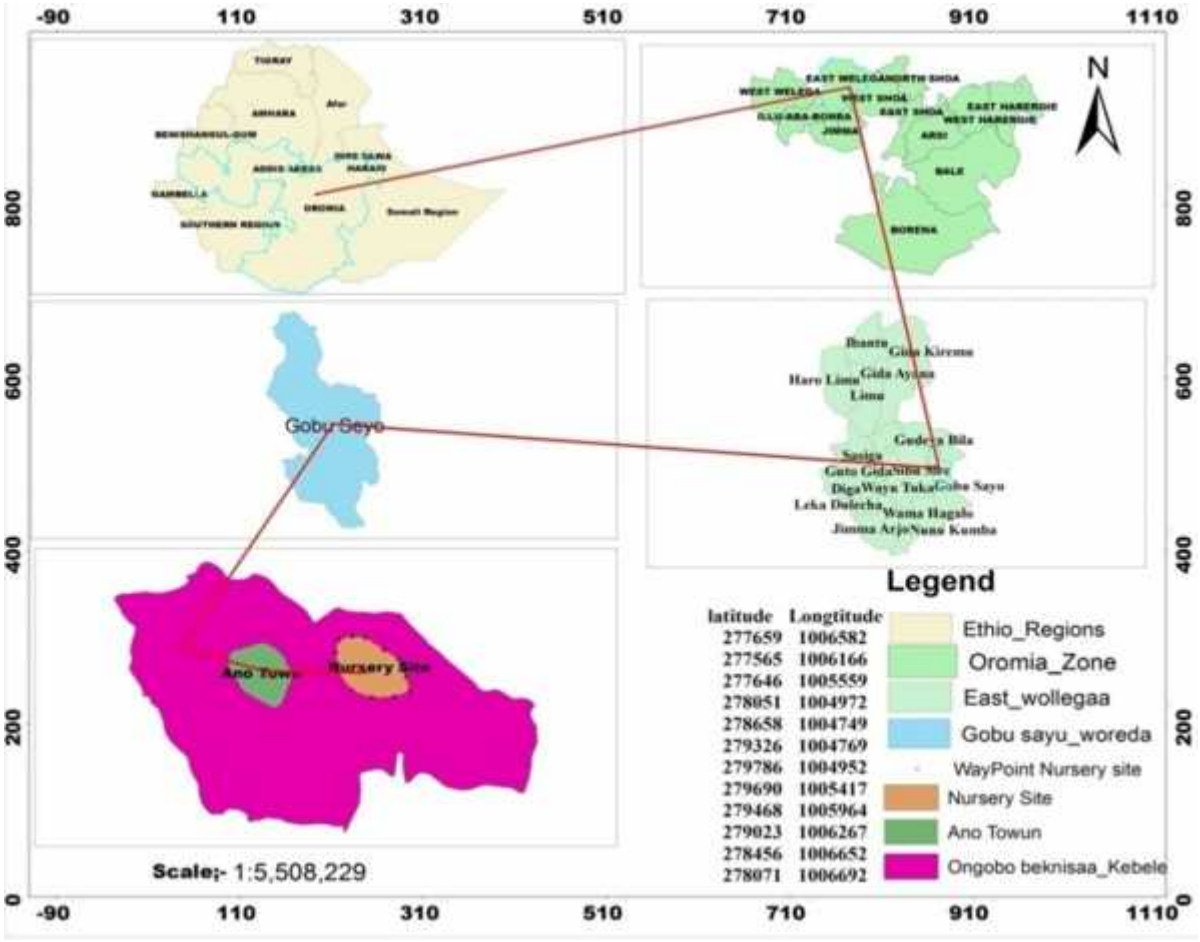

Figure 3: ***Map of the study area (Source: Gobu Sayo Woreda Rural Land Administration)***

The dominant crop cultivation is teff, maize and sorghum. The area receives an average annual rain fall of 950 mm in two seasons: short rains (March and April) and relatively mid-rains (May). The short rains are mainly used only to break and make ready the soil for crop cultivation. The rainfall patterns starting at end of March and ending November and the mean minimum and maximum temperatures are 23 and 27^{o}c respectively (Dagne, 2002).

The soil of study site is Nitsols. Its vernacular name is “Biye dima” meaning red soil. On the average, the soil is deep and relatively highly weathered well drained clay in texture and strongly to moderately acidic in reaction. As a result, the farm economy of the study area is based on mixed crop livestock production system and subsistence nature (Dangne, 2002).

The natural forest is almost totally removed by human activities. A few remnant natural tree species are *Acaccia abyssinica, Cassipourea maosana*, *Ficus sur*, *Juniperu sprocera*, *and Croton macostachyus*. Some of the shrubs are *Clausena anistata, Carissa spinarum*, *Calpurnia aurea*, *Bersama abyssinica*, *Acanthus eminens* and *Justicia schimperiana*. Of the herb species *Andropogon abyssinicus* and *Giradinia bullosa* is the main one. Grasses like *Cynodon dactylon* and *Digitaria spp*. are inhabitants of the area. Land degradation due to soil erosion and loss of soil fertility is one of the visible phenomena on deforestation area (Mulgeta and Demel, 2004). Almost the same situation is observed in this study area. Shortage of nitrogen occurs as a result of poor drainage and relatively low content of organic matter. Symptoms of both phosphorous and nitrogen deficiency was observed (Dagne, 2002).

3.2. Experimental Design

The matured ripened seeds/fruit were collected from dominant or co-dominant trees in February 2010, an estimated of 10-15 years old directly from wild. For fruit collection, an expert in tree climbing was employed. The seeds were soaked in water for three days to remove the seed coat and mucilaginous from the surface of the seeds (Fig. 4).

Figure 4: ***Purified C. africana seeds from seed coat and mucilaginous after soaked in water for three days.***

The purified seeds were kept in pure water for consecutive eight days (Fig. 5).

Figure 5: ***C. africana seeds kept in water for consecutive 8 days.***

Hundred seeds were selected randomly and planted in pre-prepared seed bed of 1x10m each at the depth of 1 cm and between seeds distance of 15x15 cm (Fig. 6).

Figure 6: ***Soil bed prepared for germination of C. africana seeds.***

After the seeds were planted on pre-prepared seed bed, covered slightly by soil in to the depth equal to the diameter of the seed and then the seed bed was covered by dry grass

(*Setaria megaphylla*). Each seed bed was watered eight liters three times per day until the seeds germinate.

Figure 7: ***The seed bed covered by grasses that promote good aeration and facilitating germination.***

The grass was removed from the seed bed and then the shade was constructed at 1m above the germinated seed and watered eight liters two times per day up to the end of the study.

Figure 8: ***Shade constructed over the germinated seeds.***

To make the measurement process easier, boundaries were 50 cm wide along all sides of the plot**.** Each seedling was assigned a random number (1-80) for further follow up (Fig 9). Watering, mulching, and guarding measures from herbivore damage and weeding were handled by workers of the center.

Figure 9: ***The seedlings given a tag with its corresponding numerical code (1-80).***

Care was provided to the germinated seedlings by watering, mulching, hoeing and protection from browsing animals.

3.3. Watering

Water was fetched from the dam by sprayer and the plot was watered 8 liters 3 times every days of the month: March, until the seedlings were germinated. Since the soil was very dry this month. After the seed was germinated, the seedlings watered eight liters two times per day in April and May.

3.4. Additional Activities

Hoeing the germinated seedling using hoes and mowing grass and weeds using sickles was also an important action for better soil aeration and for avoiding weeds for facilitating seedlings growth and for conserving soil moisture.

3.5. Data Collection

3.5.1. Seedling Height

Seedling height was measured from the base to the highest point of the plant every 14 days (from April1, 2010 to May 26, 2010) and the mean height of the plant was recorded.

3.5.2. Survival percentage

Number of wilted/died seedling from the study area were counted and recorded every 14 days (for 56 days) and then at the end of the study period the survival percentage was calculated.

3.6. Data Analysis

Germination parameters such as germination percentage (GP), mean germination time (MGT), and Germination vigor (GV) was calculated according to Lbourian and Agudo (1987), as follows:

1. Germination percentage (GP)

$$GP = (n/N) \times 100$$

Where: n=total number of germinated seeds

N=total number of seeds

2. Mean germination time (MGT)

$$MGT = (\sum niti)/n$$

Where: ni= percentage of seeds germinated between consecutive counts.

ti= time (in day) taken since germination experiment started.

n= total number of germinated

3. Germination vigor (GV)

$$GV = \sum (Gi/ti) * 100/N$$

Where: Gi= number of seeds germinated up to the days under consideration

ti= time taken for all germination seeds

N= total number of seeds used

Data collected on the seedling height were also to provide the relative growth rate (RGR).The relative growth rate for height (RGRH**)** of the seedlings of *Cordia africana* was analyzed using SPSS window version 20 determined by using the formula (Evans,1972).

$RGRH\ (cm\ cm^{-1}\ d^{-1}) = \ln TSL_2 - \ln TSL_1 / t_2 - t_1$

Where: ln=natural logarithm;

TSL_2= total shoot length at final measurement

TSL_1= total shoot length at initial measurement;

t_2-t_1=days between measurements.

3.7. Soil Sampling and Analyses

From the plot of a study area, 1 kg of composite soil sample was taken from two opposite corners as well as from the middle areas, of the study site from depth of 0-15 cm. The analyzed parameters were pH, nitrogen, phosphorus, bulk density texture and organic carbon. This analysis was done in the laboratories of Bako Agricultural Research Center.

For soil pH measurements a 1:2.5 soil to water ratio was used (London, 1984). The pH was determined after 30 minutes using a pH meter, standardized by buffer solution of pH 4 and 7. The soil texture was determined by hydrometric method of mechanical analysis (London, 1984). Soil suspension was allowed to stand for 30 minutes, then stirred for 15 minutes, and transferred to a measuring cylinder. The first hydrometric and temperature were taken. The next hydrometer and temperature reading were taken after two hours and the percentage of various soils were determined by the standard formula (London, 1984).

The bulk densities of the soil measurement were by driving a metal cylinder about on a level and neat soil surface. The volume of the soil core was estimated from the internal radius of the metal cylinder.

Total nitrogen was determined using Kieldahl method. The organic matter of the soil sample was oxidized by treating it was concentrated sulfuric acid, where nitrogen in the nitrogenous compounds were converted in to $(NH_4)_2SO_4$.The amount of nitrogen is estimated from the amount of ammonium ion released by distilling the digest with sodium hydroxide.

Organic carbon of the soil was determined by wet oxidation method of Walkley and Blak. Organic carbon is oxidized by a valued amount of excess K_2CrO_7 in the presence of H_2SO_4 in Erlenmeyer flask. The presence of carbon was calculated using the formula of (Jaiswal, 2003).

4. Result

4.1. Seed Germination

Seed germination was started on 11th day. However, the maximum germination was observed on 14th day. Even it extended to 17th day and other proceeds up to one month (Fig. 10).

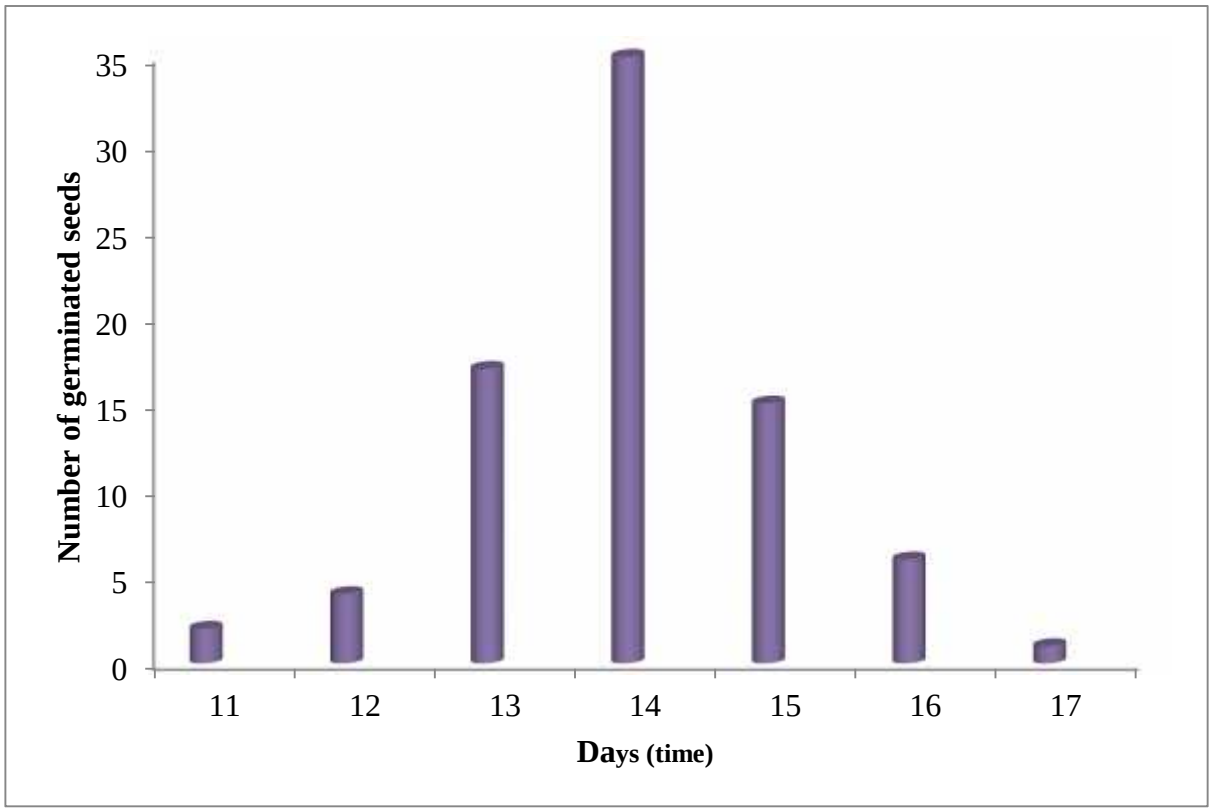

Figure 10:*The number of germination of Cordia afaricana seeds from 11-17 consecutive days (11 day=2, 12 day=4, 13 day=17, 14 day=35, 15 day=15, 16 day= 6, and 17 day=1).*

Even though, germination was started on 11th days, the maximum germination was observed on 14th days (43.75 %).

Out of 100 *C. africana* seeds, only 80 of them germinated. So the overall germination percentage during the study period was 80 %.

4.2. Comparative Growth of Seedlings

4.2.1. Growth in Height

The difference in the mean height between the initial and the final measurements (from 14 to 56 days) were increased (Fig. 11).

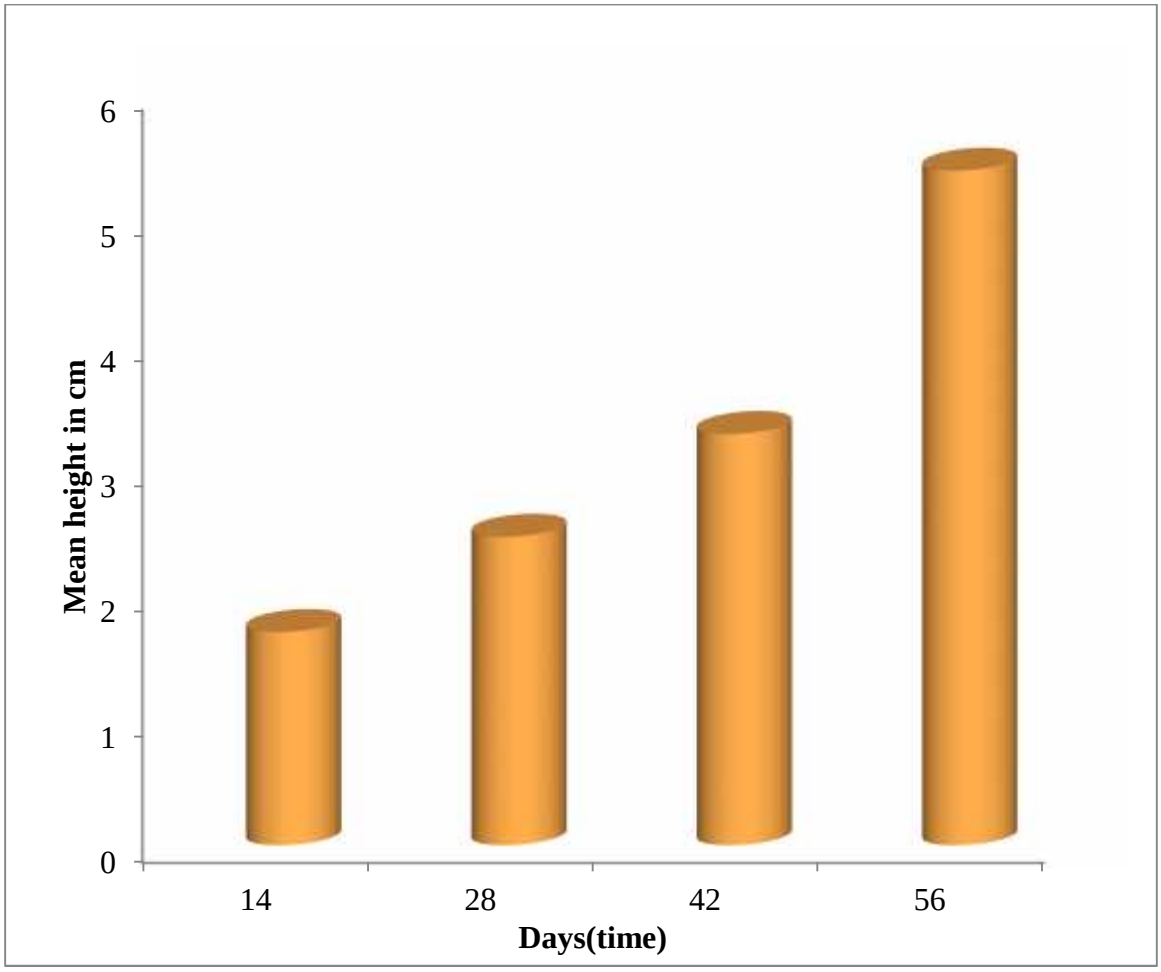

Figure 11: ***Mean growth of the seedlings of Cordia africana over period of 56 days. The increments of height were recorded every 14 days in 4 rounds (14 day=1.7cm, 28 day=2.46cm, 42 day=3.28cm, and, 56day=5.38cm).***

The seedlings mean height between consecutive measurements were compared, the values for each measurement of every 14 days were different (Fig. 11).

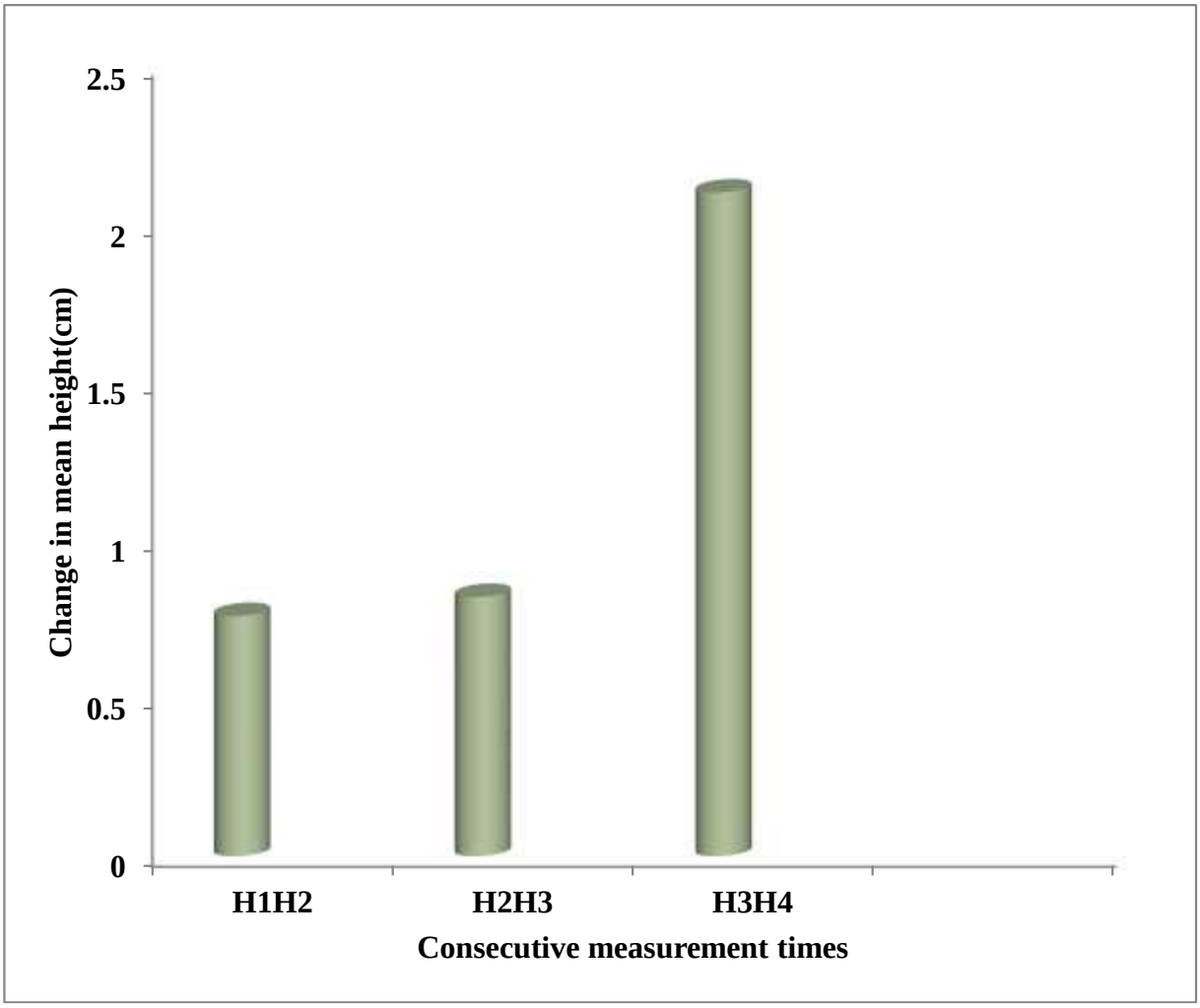

Figure 12*: Values of consecutive mean height of measurement (H1, 2= 0.76cm; H2, 3=0.82cm; and H3, 4=2.1cm refer to mean height increments between two consecutive measurement times 1&2, 2&3, and 3&4 respectively).*

The maximum change in height growth on the last measurement was between H_3 and H_4 with a mean height of 2.11cm and the minimum is 0.76 cm, which is between H_1 and H_2.

4.2.2. Relative Growth Rate of Seedlings in Terms of Height (RGRH)

The relative growth rates in height (RGRH) of the young tree species were different among one another during the entire study period. The result RGRH of the seedlings of *C. africana* declined at the mid of May. The highest RGRH was observed at the end of the measurement period (May) season (Table.1). The RGRH measurements were

$RGRH_1$< RGRH. However, there was no significant difference ($p \leq 0.05$) observed between the values of $RGRH_2$ and $RGRH_3$.

Time (days)	RGRHcm^{-1}day^{-1}
14	0.003
28	0.026
42	0.025
56	0.035

Table 1.*Mean relative growth rate in height (RGRH) of young tree species of Cordia africana at the study site.*

4.3. Survival Percentage

The overall survival percentage during the study period was 96.25 % for 56 days. But, the idea of survival is relative since some of the seedlings (young trees); those survived during the entire study period may die / wilted for the following period. However, the survival percentage of individual measurement every 14 days was listed below (Table 2).

Days/ Time	Number of wilted/Dried	Survival percentage
14	1	98.75
28	1	98.75
42	_	100
56	_	100

Table 2.*Number of seedlings wilted/dried seedlings over a period of 56 days. Out of 80 seedlings, only 2 of them were dried at the beginning of the study.*

4.4. Animal Damage

Animal damage (cattle and wild animals) was observed in one measurement period of time. Almost there were no animal damage seedlings. There was only one seedling damage and nothing damaged in the other measurement period of time.

4.5. Results of the Soil Analyses

The result of soil analyses from the study site at a depth of 0- 15 cm for $_{P}$H, texture, total nitrogen, organic carbon, and phosphorus and bulk density are presented in (Table 2). All the major soil properties of the study area were below the standard, nitrogen (0.1% as compared to the average value of 0.2-0.5%), organic carbon (1.1compared to the standard average value of 4-10%), phosphorus (2 ppm than those of the standard average value 14-19 ppm), and PH (4.1 as compared to the average standard 7-8) (Table 3).

Soil property	U nit	Salt test result in study site
$_{P}$H	-	4.1
N	%	0.1
Organic Carbon	%	1.1
AVP	Ppm	2
Bulk density	g/cm^3	1.3

Table 3.*The status of Anno soil property*

5. Discussion

The way of collecting *Cordia africana* seed/fruit showed similar among most studies. The seeds were collected between in February, when they were ripened and ready for collection. Seed collection needs careful selection of mother trees. Because the maturity of the trees affects germination, growth of seedlings, the quality and quantity of products obtained from the trees. Collected seeds from health and vigorous trees were better in form and height. As mentioned by Abraham *et al* (2008) and Aalbe (1993) dominant or co-dominant trees with clear bole, well developed crown and with abundant drupes were collected for seed collection. The drupes were collected between January and February phenotypically superior trees according to among other things, stem form, branching, etc.

However, methods of purified seeds followed different procedure among the studies. In the current study, the seeds were soaked in water for three days, and rubbed over to remove the seed coat and mucilaginous from the surface of the seeds. Unless the mucilaginous and seed coat was removed, it lowers germination capacity (Vision, 2012).

The earlier studies showed that seeds were further cleaned to remove mucilaginous substance remaining on the surface and surface sterilized for 3 min in ethanol (85 %) mixed with tweed detergent. After wards seeds were briefly dipped in ethanol (95 %) rinsed with distilled water and left to dry on blotting paper or two hour (Abraham *et al*., 2008).

In this study, purified seeds were kept in pure water for consecutive 8 days to facilitate germination and planted in pre-prepared seed bed of 1x10m each at the depth of 1 cm and between seeds distance of 15x15 cm, to reduce competition after germination among them. Seeds were covered slightly by soil and dry grass *(Setaria megaphylla)* that protects the seeds from being washed away during watering and provided moist for the seed. The shade constructed 1 m high at the roof of the germinated seeds provided protection against heavy rain, burning sunshine and strong winds. Similar trends were reported by Vision (2012) and Ukulima (2013). Seeds should be planted at space of 15

cm between rows, covered slightly and mulch the bed with dry grass and provided enough shade to the seedling after germination 1 m above bed.

The germination of *C. africana* seeds varied significantly among and within population. Several studies have shown that seeds vary in their germinability between and within individuals (Benowicz *et al*., 2001).

Wubet (2017) mentioned that seed germination of *C. africana* began on 38^{th} days in nitosol while those germinated on vertisol emerged 44^{th} days. Rapid seed germination of *C. africana* occurred between 42^{th} to 56^{th} days in both soil types. As Getu *et al* (2016) reported that germination begins in two weeks, proceeding up to two or three months.

In current studies, seed germination started on11^{th} days. However, the average germination was observed on 14^{th} day, and other extended to 17 days even it continued up to one month. Among 100 seeds, 80 seeds germinated. The germination rate was 80% from 11-17 consecutive days. The overall germination percentage was 80% at mean temperature of 25 ^{o}c.

Probert (2000) mentioned that temperature is the most important environmental factor responsible for synchronization of germination establishment. Temperature regulates germination of *Cordia africana* by determining the capacity and rate of germination by removing primary and/or secondary dormancy (Bewley and Black, 1994). The minimum germination temperature is 20 ^{o}c and the optimum is 25-30 ^{o}c. The germination rate is 50-80 % in 40-60 days, slow and uneven germination (Yirdaw and Leinonen, 2002).

Cordia africana achieved a good performance in its height growth. It is a very fast growing tree, attaining a height of 6-8 m within 7 years (Breitenbach, 1963). Mebrate and Belachew (2004) reported that the mean height of one year old seedlings of *C. africana* was 1.2-1.7 m, depending on the provenance. But, the soil parameters under which the trees were grown were not reported in their study. Since soil is one of the major factors that affect the growth of plant.

As Mebrate and Belachew (2004) mentioned that the survival percentage of *C. africana* was 92.23%.The overall survival percentage of *C. africana* was 98.86 % (Misrak, 2007).

But, in this work the survival percentage of *C. africana* to be 96.25 % (Misrak, 2007).This difference was because of low soil fertility, in addition to operational input.

The current mean seedling height for 56 days was 5.38 cm. The values of the relative growth rate height of C. *africana* were declined within 14 days of the month (April 1-14). Those days were relatively dry and short rain as compared to the period of measurements and the highest relative growth rate was at the end of May which was 0.035 cm. As Misrak (2007) reported that the mean height of *C. africana* for 225 days was 66.1cm, a mean height between the initial and last measurement (225 days) was 28.6cm and $2.60cm^{-1}day^{1}$of RGRH. The value of RGRH of C. *africana* declined from November to January. These two months were very cold during nights, hot, and windy during days. Amanual (2005) reported the sensitivity of *C. africana* to forest.

According to Wubet (2017) the mean germination time of *Cordia african* were 19.68% for nitosol and 20.24% for vertisol. In current study the mean germination time was 17%. The effect was determined because of different soil type in addition to environmental factors.

When the soil of Anno was correlated with the reference for rating physical and chemical properties (London, 1984), it was low pH, low nitrogen, low available phosphorus and low organic carbon. Because of these soil properties mentioned above, *C. africana* seedlings had moderate growth performance. The value of its bulk density showed that it was previously used as a farmland. The land had previously been used to produce maize.

Growth of tree seedlings (in reforestation processes) at the site could be faster or slow depending on the degree of previous land use effect (Mulgeta and Demel, 2004). Fast growing broad leaved species such as *C. africana* require fertile soil and do not grow well on poor soil conditions (Evans, 1992). The growth rate of *C. africana* in this study was moderate when compared with the previous reports. The reasons for this difference could be the poor soil condition of the study site.

6. Conclusion and Recommendation

6.1. Conclusion

1. The result of the study showed that *Cordia africana* started germination on the 11^{th} day with highest germination on14^{th} day.
2. The mean height of the seedling for 56 days were 5.38cm and the mean relative growth rate height of *C. africana* was high at the end of measurement period (May) and lowest at the beginning of the measurement period (April).
3. Germination percentage was 80 %, and the survival percentage of 96.25 %.
4. The soil property of the study was low.

6.2. Recommendation

1. Currently, C. *africana* declining at alarming rate. Thus such a high survival percentage as observed in the study could be a promising condition for the reestablishment of C. africana tree species.
2. Including *C. africana*, millions of seedlings have been planted every year by different people. But, many of these seedlings fail to grow.

3. Maintaining vegetation cover and presenting tree species:

- Promoting level of education and environmental awareness package based on the existing indigenous knowledge. Promoting farmers knowledge by giving education how to germinate and conserve the seedling of *C. africana* by providing conservation programs or measures that can keep the ecological balance of the environment (keeping the aesthetic values of the environment and regulating local climate change).
- Develop the habit of planting indigenous tree species like *C. africana.*
- The government should create job opportunities for those unemployed people to propagate and conserve *C. africana*. This study recommends further work on the germination and growth rate of Ethiopia's indigenous tree species.

7. References

Abraham Loha, Mulualem Tigabu, and Anders Fries (2008). Genetic variation among and within populations of *Cordia africana* in seed size and germination responses to constant temperatures B. V. Project.

Abbink J. (1993). Me'en Ritual, Medicinal and Other Plants: A Contribution to South-West Ethiopia Ethno-Routiedge Research, London and New York

Admas W.M (2009). Green Development Environmental and Sustainability in the Third World journal, 3rd Edition.

Agidie A, Ayele B, Wasie A, Hadgu K, Aynukulu E, Mowo J. (2013). Agro-forestry Practices and Farmers' Perception in Koga water Shed, Upper Blue Nile Basin, Ethiopia, Agriculture and Forestry; problems and prospect, eds, Keohane, R.O. and Level, MA. Research. Indian Institute of Science. Rome, Italy.

Aalba A. (1993) Tree seed zones for Ethiopia. Forestry research center/National tree seed project, Addis Ababa and Danida forest seed center, Humlebaek, Denmark.

Amenu E., (2007). Use and Management of Medicinal Plants by Indigenous people of Ejaji area (ChalyaWoreda), West Showa, and Ethiopia: an Ethno-botanical Approach. M. Sc. Thesis. Addis Ababa University, 2007

Azene Bekele, Birnie, A. and Tengances, B. (1993). *Useful Trees and Shrubs for Ethiopia.* Journal of SIDA's Regional Soil Conservation Unit, Kenya.

Azene, B.T. (2007). Useful trees and shrubs for Ethiopia: Identification, propagation and management journal for 17 Agro-climatic Zones thesis World Agro-forestry Center, Easter Africa Region, Nairobi, Kenya.

Bekele Tesemma A, Birnie A, Tengnas B. (1993). Useful trees and shrubs for Ethiopia. Regional Soil Conservation Unit (RSCU), Thesis Swedish International Development Authority (SIDA).

Belay Kebede, (2004), Adoption of soil Conservation Measures in Southern Ethiopia, A case of Gununo. Journal of Agricultural and Rural Development in the Tropics and Sub Tropics.

Bewley and Black (1994). *Seeds: Physiology of development and germination*2nd ed. Plenum press, New York.

Breitenbach, V. (1963). *The Indigenous Trees of Ethiopia*. Second Revised and Enlarged Edition, Published by Ethiopian Forestry Association, Addis Ababa, Ethiopia.

Bussman RW. Swartzinsky p, Worede A, Evangelista P. (2011).Plant use in Odo-Bulu and Demaro, Bale Region, Ethopia. Journal of Ethnobiology and Ethno medicine.

Cartwright CR (2010). The Identification of wood used for ninetaino artifacts in the British Museum collections (unpublished research. Burlington, Massachusetts)

Dagne Chimdessa (2003). The Soil type and Crop Production Anno, Ethiopia.

Denslow J.S. (1989). Tropical rainforest gaps and tree species diversity. Ann Rev Ecol. Syst.

DereroA, BekeleT.and Nashund BA. (2003). Population Structure and regeneration of woody species in a broadleaved Afromontane rain forest, south-west Ethiopia.

Ehete, G, (2009). African Egalitarian values and indigenous Genres: The Functional and Contextual studies of Oromo Oral Literature in a contemporary perspective.

Eshetu Yirdaw (2001). Diversity of naturally regenerated native woody species in Forest Plantationin the Ethiopia highlands. *New Forests.*

Eshetu Yirdaw (2002). Restoration of the native woody-species diversity, using plantation species Diversity,using plantation species as foster trees in the degraded highlands of Ethiopia.

Evans, G.(1972) *The Quantities Analysis of plant growth*. Berrkeley, University of California.

Evans J. (1992). *Plantation Forestry in the tropics*, Journal Oxford University press, Britain.

Finkeldey R. (2007).Tropical forest genetics ,Journal Springer, Berlin.

Gina T, Nigatu L, Animut G, (2014). Evaluation of potential Yield and chemical composition of selected indigenous multi-purpose fodder trees district of Wolayta zone southern Ethiopia. IDOSI publication, World ApplSciJ.

Gorte, R.W and Sheikh,P.A (2010) Deforestation and Climate change, Congressional Research service, March 24, 2010.

IRAF (International center for Research in Agro forestry data base). (1998).*Cordia africana Lam.*

ISTA. (1999). International rules for seed testing association. *Seed Science and Technology*.

Jaiswal, P. (2003). *Soil, Plant and Water Analysis* Journa Kalyani, New Delhi.

Jiregna Gindaba, Rozanov, A. and LegesseNegash (2004). Response of seedlings of two Eucalyptus and three deciduous tree species from Ethiopia to severe water stress.Forest Ecology and Management.Journal.

Khun, I. (1987). *Water lands Afforestation journal*. IBU publishing, Bombay.

Legesse Negash (1992). Stomatal Responses of *Cordia africana Lam.* and four other indigenous tree species of Ethiopia to increasing water stress, journal. SINET*: Ethiop. J.Sci.*

Legesse Negash (1995). *Indigenous trees of Ethiopia*: uses and propagation technique journal, printed by the SLU Reprocentralen, Umea, Sweden.

London, J. (1984).Thesis on *Tropical soil Manual*. Longman Inc, New York.

London. J.R (ed), (1984). Booker tropical soil manual. A hand book for soil survey and agricultural evaluation in the tropics and sub tropics. Booker agricultural international limited Bath.

Lulekal E, Kelbessa E. Bekele T, Vineger H. (2008). An Ethnobotanical study of medicinal plants in Mana Angetu District, South eastern Ethiopia. Journal of Ethnobiology and Ethno Medicine.

Mebrate Mihretu (1999). Growth performance of *Cordia africana* Journal, *EJNR*.

Mebrate Mihretu and Belachew Gizachew (2004).Seed source variations in early survival and height growth of *Cordia africana* at Aman, South-Western Ethiopia.

Mekete (996). Environmental Degradation and Management in Ethiopian High lands, journal. Addis Ababa University.

MisrakTafesse (2007). Growth performance of three Indigenous and one Endemic tree species of Ethiopia on a degraded site Msc.Thesis in Central-West Ethiopia

Mog"omba, S. A. DuToit, E. S. and Akinnfiesi, F. K. (2007). Germination characteristics of Tree Seeds: Spotlight on Southern African Tree Species. Tree and Forestry Science and Biotechnology, South Africa.

Mulugeta Lemenih and Demel Teketay (2004). Restoration of native forest flora in the degraded highlands of Ethiopia. SINET: *Ethiop. J. Sci*.

New Vission (2012). How to make a good nursery bed. Journal, Uganda.

Nigatu L, Gina T, Animut G. (2014). Evaluation of potential yield and chemical composition of selected indigenous multi-purpose fodder trees in three districts of Wolayta Zone, Southern Ethiopia. IDOSL publication, World Appl Sci J.

Ong C. K. (1996) *Tree Crop Internationals*. A physiological approach journal. (Ong C. K. and Huxley, P. eds). CAB international, UK.

Orwa C. Mutu A, Jidt R, Jamnadass R, Anthony S. (2009). Agro-forestry data base: a tree reference and selection guide version 4.0 world agro-forestry center Journal, Kenya.

Osunkjoya, O., Ash, J., Hopkins, M. and Grahun, A.(1992). Thesis on Factors affecting survival of tree seedling in North Queensland rainforests.

Piotto, B. and Di Noi, A. (2003). Seed propagation of shrubs. Agency or the protection of the environment and for technical services journal via Vitaliano Brancati. Roma. Italy.

Rangunathan and K. and Wit, T. (1996).Tree Crop Interactions. A physiological approach Journal (Ong, C.K. and Huxley, P. eds.) CAB International UK.

Regassa R. (2013). Diversity and conservation status of some economically valued indigenous medicinal plants in Hawassa College of Teacher Education Campus, Southern Ethiopia. International Journal of Advanced Research.

Seta T., Demissew S. Asfaw Z. (2013). Home gardens of Wolayta, Southern Ethiopia: An Ethno-botanical profile. Journa,l Academia of medicinal plants.

Tadesse Woldemariam (2004). Organic agriculture as a sustainable development. Alternative to achieve food security. *Proceeding of National Workshop organized by the Biological society of Ethiopia*. Faculty of Science, Addis Ababa University, Addis Ababa

Taiz,L. and Zeiger, E. (2002). *Plant physiology*. Sinauer Associates, Inc., USA.

Tamene. B, (2000). A Floristic Analysis and Ethno-botanical Study of the Semi-Wet Land of Cheffa Area, South Welo, Ethiopia, M.sc, thesis, Addis Ababa, Ethiopia.

Taye Bekele, Haase, G. and Teshome Soromessa (1999). Forest Genetic Resources of Ethiopia: Status and proposed Actions. *Proceeding of the National Forest Genetic Resources Conservation Strategy Development Workshop* (eds. Edwards, S., Abebe Demissie, Taye Bekele and Haase, G.

Tewolde Berhan S, Fargertunrs, Abegaz K, Judith N, Abay F, Trude W. (2013). Ferric Reducing Antioxidant Power and Total Phenols in *Cordia africana*. African of Journal of Biochemistry Research.

Tiruneh Fentahun, M. and Hager H. (2009). Exploiting locally available resources for food and nutritional security enhancement: Wild fruits diversity potential and state of exploitation in the Amhara region of Ethiopia food sec.

Tisdale,S. Nelson,W. and Beaton,J.(1985).Soil fertility and Fertilizers. Mecmllan Publishing Company, New York.

Ukulima Smart (2013). Nursery bed preparation. Journal, Uganda

Vanclay, J. (1994). *Modeling Forest Growth and Yield*. Journal, Biddles Lted, UK.

Vavilov, I. (1997). *Five Continents. (*Reznik, S. and Stapletton, P., eds.) Academy of Science,Thesis, USSR.

Wallace, T. (1996). *Tree Crop Interactions. A physiological approach Journal (*Ong, C. K. and Huxley, P. eds). CAB international, UK.

Wubet Gebeyehu (2017). Thesis on Germination and earl growth performances of *Cordiaafricana* in potted vertisol and nitosol Msc Thesis in Bichena town, Gojjam Zone, Amhara Regional State.

Yirdaw E. Leinonen K. (2002).Thesis on Seed Germination Responses of four afromonatne tree species to red/farredration and temperature.Forest ecology and management

8. APPENDICES

Appendix.1

Seedling height measurement (every 14 days) in cm at the last measurement of height.				
Seedling number	H1	H2	H3	H4
1	2.5	2.4	3.2	6.4
2	1.6	2.3	3.1	5.5
3	2.1	2.8	3.5	7.2
4	1.5	2.0	2.9	6.1
5	2.6	2.1	2.8	5.6
6	2.4	2.9	3.4	5.2
7	1.9	2.6	3.6	7.2
8	2	2.5	3.5	6.2
9	2.1	2.8	3.4	5.3
10	1.7	2.5	3.1	5.1
11	1.2	2.2	3.2	5 .2
12	1.3	2.3	2.9	4.5
13	1.5	2.4	3.2	5.4
14	1.6	2.7	3.1	5.2
15	1.8	2.9	3.6	5
16	2.1	2.8	3.5	5.1
17	1.5	2.1	2.8	4
18	1.6	2.1	3	4.8
19	1.5	2.3	3.1	4.9
20	2.4	2.7	3.2	5
21	2.2	2.8	3.4	4.8
22	1.5	2.2	2.9	3.6
23	1.9	2.6	3.2	4.6
24	1.6	2.4	2.8	4.1
25	1.8	2.3	3.6	5.5
26	2.3	3.1	3.9	6.1
27	1.6	3	4	6.5
28	1.5	2.6	3.5	5.9
29	2.1	2.5	3.6	5.5
30	2.2	2.8	3.5	4.6
31	2	2.8	3.7	6.1
32	1.9	2.7	3.7	5.9
33	1.4	2.6	3.4	5.8
34	1.5	2.3	2.9	5.1
35	1.8	2.4	3	5.1
36	1.7	2.6	3.1	5.8
37	2.2	3	3.9	6.3
38	1.7	2.4	3.1	5.1

39	2.3	2.9	3.2	4.5
40	2.1	2.3	2.9	4.7
41	2.5	2.9	3.7	6.6
42	2	2.6	3.5	5.5
43	1.7	2.5	3.6	5.7
44	1.1	2.2	3.1	4.8
45	1.5	2.7	3.8	5.8
46	1.6	2.5	3.6	5.4
47	1.3	2.4	3.5	5.4
48	1	2	2.9	4.2
49	1.2	2.1	3	4
50	1.4	2	3	4.1
51	1.6	2.4	3.4	5.3
52	1.4	2.1	2.8	4.9
53	1.5	2.5	3.2	5.8
54	1.6	2.4	3.1	5.6
55	1.6	2.4	3.3	5.9
56	1.7	2.5	3.4	6.1
57	1.6	2.3	3.3	5.2
58	1.2	2.4	3.3	5.1
59	1.5	2.3	3.2	5.2
60	1.3	2.7	3.3	6.1
61	1.4	2.2	2.9	5.1
62	1.2	2.3	3.2	4.6
63	1.4	2.2	3.1	4.9
64	1.5	2.1	2.8	4.7
65	1.8	2.8	3.8	5.4
66	1.7	2.5	3.5	5.8
67	1.8	2.1	3	5.1
68	1.9	2.6	3.7	6
69	2.1	2.7	3.2	5.4
70	2	2.4	3.4	5.9
71	1.6	2.6	3.5	6.1
72	1.2	2.7	3.8	6.2
73	1	1.8	2.9	4.5
74	1.4	2.1	2.8	5.8
75	1.5	2.6	3.4	6.2
76	1.8	2.8	3.6	6.3
77	1.6	2.5	3.5	6.2

Appendix. 2

Number of germinated seeds per days	
Days	Number of germinated seeds
11	1
12	4
13	17
14	35
15	15
16	6
17	2

Appendix. 3

Seedling mean height in cm over the study period of 56 days	
Days	Mean height in cm
14	1.7
28	2.46
42	3.28
56	5.38

Appendix.4

Seedlings damaged by herbivore in the study site	
Days	No. damaged seedling/s
14	-
28	-
42	-
56	1

Appendix. 5

Change in mean height(H_1H_2, H_2H_3,and H_3H_4) in cm	
Consecutive measurement times	**Change mean height in cm**
H1H2	0.76
H2H3	0.82
H3H4	2.1

DECLARATION

I decline that this thesis entitled "Germination Viability and Growth Rate of *Cordia africana* in Anno Town, Oromia Regional State, West Ethiopia," is my original work and all references used are duly acknowledged. It also has never been presented in any university for fulfillment of any degree program

Name: Kebede Gobena Deyas

Signature_____ Date_____

This work has been done under my supervision

Name: Habte Jabessa Debella (PhD)

Signature ___ _____ Date_____