EVALUATION OF THREE *Entandrophragma bussei* PROVENANCES FOR DIFFERENT TRAITS IN TANZANIA

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF SCIENCE IN FORESTRY AT SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

2021

ABSTRACT

Entandrophragma bussei is a deciduous and endemic tree in Tanzania. The tree contributes largely to social, cultural and economic values in the community. Despite its great importance, the species is still understudied while its natural wild population is declining. This study aimed to evaluate *E. bussei* morphological variations of fruits, seeds, and germination and seedling traits in order to support its domestication in the country. Three provenances (Kigwe - Dodoma, Ruaha - Iringa and Tarangire - Manyara) in the country were selected for fruit collection and the study was coordinated at DTSP, Morogoro. The fruit traits, seed traits, germination traits, and seedling traits were assessed in the laboratory. All the data were tested for normality by using Shapiro-Wilk Test before subjected to ANOVA to test for the variation between the provenances and the correlation between the traits by using Pearson's correlation. The results revealed great variability in morphological traits of *E. bussei* among the provenances. Kigwe and Tarangire provenances displayed strong fruit, seed and germination traits as compared to Ruaha while Ruaha provenance had strong seedlings traits compare to the other two provenances. Despite of that, all provenances are still reliable as potential seed sources. Significant correlation ($p<0.05$) between the fruit traits and seed traits observed in this study makes it possible to use fruit traits as predictor of seed traits during seed collection. These findings form crucial baseline information to support domestication processes of these trees in farmlands and plantations in the country. However more studies are essential to provide information on areas of genetic variations, influence of treatments (mechanical or chemical seed treatments) in seedling growth and development under nursery conditions, and performance of *E. bussei* under different geographical locations in the country.

DECLARATION

I, Kombo A. Siwa do declare to neither the Senate of Sokoine University of Agriculture that, this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

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ACKNOWLEDGEMENTS

I thank God for taking me through all the years of study. I acknowledge the funding support from Tanzania Forest Service (TFS) for supporting my studies and Sokoine University of Agriculture (SUA), Department of Ecosystems and Conservation for facilitation.

I wish to express my sincere gratitude to Dr. S. A. Macrice for his readiness and valuable supervision with constructive criticism which has made this work a success. I extend my gratitude to Prof. S. A. Chamshama for his supervision, good and innovative ideas which shaped the direction of this study. Furthermore, I appreciate technical assistance from Dr H. P Msanga (retired former Chief executive officer – TTSA), G. Ngatena and M. Saidi from the Tanzania Forest Service (TFS) (Laboratory technicians), Directorate of Tree Seed Production Centre at Kihonda Morogoro for their readiness to provide technical guidance in laboratory work which enabled completion of this work successfully.

I acknowledge the cooperation offered by my fellow TFS - DTSC nursery workers for their valuable contribution during my study at the nursery. My fellow students and Mr Said Habibu for spending part of their time to guide, encourage and advise me on this important study. Sincere appreciations to J. Mtika (Former Technical Manager D), R. Khalfani (Tree climber TFS) and P. Mmanda (Former retired driver TFS) for their valuable and technical assistant during field data and fruit collection. Last but not least my beloved wife Mwantumu and my sons and daughters, Mohamed, Khalid, Abubakar, and Fatma, Mariam and Amal Kombo for their perseverance, encouragement and prayers throughout the study period.

DEDICATION

This work is dedicated to my parents, my late father Athumani S. Siwa; my lovely mother Zainab Said, wife Mwantumu and my late sister Fatima Siwa, beloved sister Khanifa Siwa, my brothers Shehe Siwa and Salehe Siwa.

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LIST OF ACRONYMS

ANOVA	Analysis of Variance
CRBD	Completely Randomized Block Design
DBH	Diameter at breast height
DTSP	Directorate of Tree Seed Production
ISTA	International Seed Testing Association rules
NAFORMA	National Forest Resources Monitoring and Assessment
pDNA	Plasmid Deoxyribonucleic Acid
rDNA	Ribosomal Deoxyribonucleic Acid
SAS	Statistical Analysis System institute, Cary, North Carolina, USA.
SE	Standard errors
SUA	Sokoine University of Agriculture
TANAPA	Tanzania National Parks
TFS	Tanzania Forest Services Agency
TSPS	Tree Seed Production Station
UNDP	United Nations Development Program
URT	United Republic of Tanzania
USA	United State of America

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

The earth has more than 500,000 plant species that exist on land (Corlett, 2016). Higher diversity of these species has been recorded in the tropical regions of South America, Africa and Asian continents (Sosef *et al*., 2017). These regions are characterized by diverse climatic conditions, different soils and topographical features (Awodoyin *et al*., 2015). Such features have contributed to plant species endemism to most countries within the tropical regions (Krupnick, 2013). Along the tropical region of Africa, Tanzania is endemic to 10% of all vascular plant species and holds one third of the total plants in Africa (Nyandoro, 2014; URT, 2014).

Such richness of indigenous and endemic plant species in the country forms a part of the world's lungs, a home to most of the earth's terrestrial biodiversity and a source of products and services to communities. Within the country, 90% of local communities rely on plants products (e.g. timber, firewood, charcoal, poles, food, and herbal medicines through fruits, leaves, roots and barks) and services (such as water and clean air) (Abihudi, 2014; NAFORMA, 2015). The observed high dependency on plants by local communities creates increasing pressure to plant species while jeopardizing their sustainability (Nahashon, 2013).

High utilization pressure on plant species has been experienced in most natural forests for years and has resulted in the loss of forest cover in the country (Kacholi, 2014). Such pressure includes accidental and/or deliberate fire burning, overgrazing, agricultural expansion, shifting cultivation, logging, energy (firewood, charcoal) production, urbanization and infrastructure development such as dams, roads and power line (Msuya *et al*., 2008). Other pressures include extraction of non-timber/wood forest products such as collection of herbal medicines through the collection of leaves, ring barking, and root extraction, and the collection of nutritious fruits and leaves for food (Dery *et al*., 1999; Dery and Otsyina, 2000).

The induced pressure has accelerated ecosystem degradation and a decline of indigenous plants in the country (Krupnick, 2013; Kacholi, 2014). A decline in the population of indigenous plants on natural habitats follows the loss of natural regeneration potential for particular species after the disruption of natural ecosystem (Dicko *et al*., 2019). To reverse the situation, it is necessary to develop effective interventions for the protection and conservation of the remaining indigenous plant species for the benefits of the present and future generations (Fandohan, 2016).

Domestication is among biodiversity conservation methods that have saved many threatened indigenous plant species worldwide (Vodouhe *et al.*, 2012). This method aims at increasing tree quality and productivity particularly for poor regenerating wild plant species (Mwase *et al.*, 2006) such as *Entandrophragma bussei*. Within the country, the government has been advocating domestication of indigenous plant species over exotic plant species through its tree planting initiatives (Msuya *et al*., 2008). Such initiatives have shown positive results leading to many planted indigenous plant species in different ecological zones.

The current species richness status for indigenous plants species domesticated in the country has surpassed species richness for exotic ones, 73% and 27% respectively (Msuya *et al*., 2008). However, the coverage area of domesticated exotic plant species is much larger as compared to that of indigenous plant species, 86% and 14% respectively (Msuya *et al*., 2008). The situation calls for the need to invest more efforts in increasing the abundance of domesticated indigenous plants to meet the intended government's goal on domestication.

In most circumstances, domestication of indigenous species has been sustained by the knowledge of indigenous people in the country (Kajembe, 1994). Empirical biological information for most indigenous plant species is very scarce as compared to exotic plant species (Akinifesi *et al.,* 2004). Such lacking information includes fruit and seed morphological characteristics, genetic variations, nutrient content (Munthali *et al*., 2012; Parkouda *et al.*, 2012), germination (Susilowati *et al*., 2019) and information on environmental factors necessary for growth and development (Hall *et al*., 2003).

This information is necessary to guide domestication of specific indigenous plant species. Variability studies are therefore necessary in the country to enrich the available information on the biology of these indigenous plant species. Availability of such diversified information in the future will enhance improvement of breeding and production of particular social, ecological and economical plant species in the country (Godefroid *et al*., 2011; Dicko *et al*., 2019).

1.2 Problem Statement and Justification

Entandrophragma bussei is a deciduous endemic tree species that has been mentioned in different studies in Tanzania (Dery and Otsyina, 2000; Makonda and Batiho, 2018). Wood from this tree contributes much in the construction, flooring, joinery, interior trim, shipbuilding, vehicle bodies, toys, novelties, boxes, turnery, veneer, and plywood (Lemmens, 2008; Yakusu *et al*., 2018). Roots, barks, and leaves from *E. bussei* are a good source of herbal medicine in the treatment of several diseases among most communities in Tanzania (Dery *et al*., 1999; Dery and Otsyina, 2000).

An increase in the demand and lack of comprehensive programmes on species conservation including domestication has negatively affected the remaining *E. bussei* population in the wilderness (Yakusu *et al*., 2018). This trend calls for appropriate mitigation measures to increase *E. bussei* conservation and production through domestication to avert its genetic extinction (Monela *et al*., 2005). However, domestication of indigenous species in the country is limited by inadequate available silvicultural information to facilitate the introduction of this tree in the farmlands and plantations by the local people and foresters (Msuya *et al*., 2009).

Limited silvicultural knowledge on particular species is partly a consequence of previous reforestation efforts that favoured planting of exotic tree species due to their faster growth than those of indigenous ones in the country since 1960s. Most of the available literature on *E. bussei* has focused on social-economic importance of the tree while information on its biology is limited (Dery, 1999; Nibret *et al.*, 2010). A shift of attention on reforestation programmes towards indigenous trees and the need to prevent their extinction in the wild makes it clear that scientific efforts should be directed to the understanding of the biology of native plants including high value tree species such as *E. bussei* (Msuya *et al*., 2008).

This study was designed to generate novel information on the variation of the *E. bussei* population in Tanzania. The generated information will be useful to guide the initiatives that aim at increasing *E. bussei* domestication, production, and conservation. Unless such information is made available, it would be difficult to predict the success of *E. bussei* domestication in farmlands and plantations, considering higher demand and the lacking information on the status of *E. bussei* and its provenance in the wild. Findings from this study contributes to the development of future domestication programmes of *E. bussei*.

1.3 Objectives

1.3.1 Overall objective

The main objective of this study was to establish useful information on traits of Ruaha, Tarangire and Kigwe provenances of *E. bussei* in Tanzania for domestication and conservation.

1.3.2 Specific objectives

i. To examine variation of fruit size, fruit weight and the number of seeds per fruit of *E. bussei* in the three provenances.
ii. To determine the effect of seed size and weight of *E. bussei* in the three provenances.
iii. To describe seed germination traits in three *E. bussei* provenances.
iv. To evaluate the performance of *E. bussei* seedling traits from the three provenances in the nursery.

1.4 Hypotheses

i. Fruit size, weight and the number of seeds per fruit of *E. bussei* do not vary in the three wild provenances due to variation in geographical location and altitudes.
ii. There is no significant differences in the means of seed size and weights of *E. bussei* of the three provenances due to variation in locations and altitudes.
iii. Variations on locations and altitudes of three *E. bussei* provenances have no significant effect on seed germination traits.
iv. There is no significant variation in seedlings traits for *E. bussei* between the three provenances as a result of their geographical location and altitude variations.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 The species of genus *Entandrophragma*

Entandrophragma genus (Meliaceae) is among the famous genera in the provision of commercial wood of mahogany (Kalawole, 1994). The genus has 14 tree species that are restricted within three African regions of endemism in the tropical area. These regions include Guineo-Congolese region that has six species, Zambezian, and Afromontane regions of endemism with five species each (Bickii *et al*., 2007). These symbolic African trees are among the most economically important African genera for timber production (Yakusu *et al*., 2018), and other socio-economic benefits such as herbal medicine (Dery *et al.*, 1999, Dery and Otsyina, 2000).

Ten species of *Entandrophragma* (*i.e. E. bussei, E. angolense, E. caudatum, E. candollei, E. congolense, E. cylindricum, E. delevoyi, E. palustre, E. spicatum,* and *E. utile*) within the genera are generally recognized as distinct due to their genetic and morphological variations (Monthe-Happi *et al*., 2018). The remaining four species (*i.e*. *E. macrophyllum, E. deiningeri, E. excelsum,* and *E. stolzii*) are probably not of specific rank (Monthe-Happi *et al*., 2018).

In the East African region, five species have been recorded out of which three are indigenous in Tanzania. These species include *E. utile* (Uganda), *E. angolense* (Kenya), *E. excelsum* (Burundi, Kenya, Rwanda, Tanzania, and Uganda), *E. delevoyi* (Tanzania), and *E. bussei* (Tanzania). *E. delevoyi* is a semi-evergreen tree species with rounded crown (Malaisse *et al*., 2020). The tree has been harvested from the wild for local uses and can be planted as an ornamental shade-providing tree (Malaisse *et al*., 2020).

Entandrophragma excelsum (Mukusu in Swahili) is both an upland and riverine forest species that has been domesticated as a shade tree in coffee plantations.

The tree (*E. excelsum*) contains one of the tallest (81.5 m) indigenous plants in Africa (Hemp *et al*., 2016). *Entandrophragma bussei* (wooden banana in English, Muondo in Swahili and Mondo in Sukuma) is a deciduous plant species that has a spreading crown. Other distinct species in the genera appear to occur in west, central, and south of the African continent. The central and western parts of Africa are dominated by *E. cylindricum*, *E. candollei,* and *E. palustre*. The wood of *E. cylindricum* resembles that of *E. candollei* and both appear to have the same common English name of West African cedar. However the use of molecular characterization techniques could further elucidate the degree of relationship among *Entandrophragma* provenances.

On the other hand, *E. candollei* and *E. palustre* are sister species in both pDNA and rDNA (Monthe *et al*., 2019). These large deciduous trees with height that ranges from 40 m to 65 m are widely spread from Cameroon, Liberia, Sierra Leone, the Democratic Republic of Congo, to Uganda and Angola (Bahati, 2005; Lourmas *et al*., 2007). The southern part of the continent encompasses *E. caudatum* (Angola, Namibia, Botswana, Zimbabwe, Swaziland, Zambia, Malawi and South Africa), and *E. spicatum* (Namibia) (Amusa *et al*., 2020).

2.2 Growth and Development of *Entandrophragma* species

Under natural conditions, seeds of *Entandrophragma* species germinate abundantly but with high mortality of seedlings that show slow growth rate. Seedlings growth in nurseries require a light shade environment in the initial stages but after some time they should be gradually exposed to more light (Adewunmi *et al*., 2014). Light intensity has proven to affect leaf chlorophyll content of the seedlings during their growth and developmental stages. However, there is no direct relationship between an increase in light intensity and seedlings growth parameters such as seedling height and biomass accumulation (Adewunmi *et al*., 2014).

Seedlings growth rate varies from one area to another with striplings' height approximated to be about 1.5m after a year (Bechem *et al*., 2013). The growth performance for *Entandrophragma* seedlings in nurseries is influenced largely by the fertility of the substrate applied (Bechem *et al*., 2013). In addition the success of *Entandrophragma* seedlings in the field depends on the altitude, climatic conditions, and suitable environmental factors for specific species. Such factors include soil fertility, soil moisture content, and the gap between the trees to allow for more light (Hall *et al*., 2003).

The full-grown stem of *Entandrophragma* trees can reach 60 m tall (with exceptional height observed in *E. excelsum*) and a trunk diameter of 2 m to 5 m (Hemp *et al*., 2016; Ambebe and Achankeng, 2019). The wood of *Entandrophragma* species possesses rings that are formed at the beginning of each consecutive growing season (Hummel, 1946). The leaves are pinnate, with paired leaflets each with an acuminate tip, while the fruits possess a capsule that contains numerous winged seeds that are dispersed by wind upon seed dispersal (Monthe *et al*., 2018).

2.3 Distribution *of Entandrophragma bussei* and Other Species within the genera

Entandrophragma bussei is limited to Tanzania and has been reported in Tabora, Singida, Dodoma (Dery *et al.*, 1999), Shinyanga (Dery *et al.*, 1999; Dery and Otsyina, 2000; Monela *et al*., 2005), Iringa (UNDP, 2010), and Manyara regions (Makonda and Batiho, 2018). It exists over a wide distribution range of habitats including woodlands, savannas, rainforest, lowland rainforests, dry forests, and montane forests (Yakusu *et al*., 2018). Within the genera, *E. bussei* is a sister to *E. caudatum* and *E. spicatum* according to rDNA and pDNA respectively (Monthe *et al*., 2019).

Entandrophragma caudatum (mountain mahogany) on the other hand is an indigenous plant species that grows quite well in sandy, loam soils, rocky ridges and on mountain slopes of Angola, Botswana, Malawi, Namibia, South Africa, Swaziland, Zambia, and Zimbabwe (Ansell and Taylor, 1998; Ngoma *et al*., 2018; Amusa *et al*., 2020). On the other hand, *E. spicatum (*Owambo wooden-banana as it is known in Angola and South Africa) is a deciduous tree with a spreading canopy found on plains, hill slopes, and rocky outcrops habitats of Angola and Namibia (Connolly *et al*., 1981).

2.4 Fruits and seed traits of *Entandrophragma bussei* and other species within the genera

Trees of *E. bussei* have an estimated height of 20 m and mostly flower in October and bear fruits from February to September (Dery *et al*., 1999). Fruits have a woody capsule, club in shape, rounded at the apex and approximately 15 cm long (Dery *et al*., 1999). During the seed dispersal process, the capsule explodes to release the seeds a few meters away from the trees as observed in other species within the genus *Entandrophragma* (Medjibe and Hall, 2002).

Sister species of *E. caudatum and E. spicatum* have an estimated 30 and 20 m height, respectively. Leaves of *E. caudatum* are up to 25 cm long with 6 to 7 pairs of leaflets while, fruits have a club shaped capsule of around 40 to 1.5 cm length and the seeds are large and winged measuring 2.5 cm and spin as they fall (Yakusu *et al*., 2018). Fruit’s traits of *E. angolense* and *E. cylindricum* in tropical forests of West Africa have been reported to have an average weight of 0.48 and 0.41 g, respectively (Dike and Aguguom, 2010).

Entandrophragma angolense is reported to be among the forest species in West Africa in Nigeria with long and wide fruits of about 15.44 and 5.517cm respectively (Dike and Aguguom, 2010). *Entandrophragma* tree species contain winged seeds that favour helical trajectory with a maximum seed dispersal distance of between 21.37 m (for *E. cylindricum*) and 26.89 m (for *E. angolense*) (Dike and Aguguom, 2010).

Seed morphological variations (i.e. seed weight, length, and width) within the genera are poorly documented. Lack of such information may potentially hinder the development and success of silviculture practices and domestication efforts and as such, it is a matter of greater concern (Msanga, 1998).

2.5 Seed germination traits for *Entandrophragma* species

Seed germination and vigour are important components in the survival and development of plant species (Hall *et al*., 2003). The complex physiological mechanism of seed germination and vigour determine seed quality, development, growth and quantity of the future harvest (Rajjou *et al*., 2012). There is limited information of *E. bussei* on the germination traits. However, several factors have been reported to affect germination traits of other species within the genus. To a large extent seed germination is influenced by environmental and seed treatments

According to Koger *et al*. (2004) and Vazquez-Yanes *et al*. (2018), environmental factors such as light, soil pH, osmotic pressure, salt stress, depth, and moisture content of the soil have been found to affect germination of *E. angolense* and *E. cylindricum* seeds in West

Africa. Germination rate for *E. cylindricum* was highly favoured by an increase in temperature (from 24 ^{0}C to 33 ^{0}C, with an optimum of 28 ^{0}C) and water potential (Pangou *et al.*, 2008). On the other hand, experimental study testing the influence of pre-sowing treatments and substrate on germination and seedling growth found that treatment responses to germination are species-dependent whereby *E. cylindricum* was affected by pre-sowing treatments and *E. angolense* was not related to the treatment but rather substrate (Ambebe and Achankeng, 2019).

2.6 Social-economic importance of *Entandrophragma* species

Entandrophragma bussei trees are respected as a source of wood for fuel and furniture that includes chairs, beds, windows, local beehives, and milk containers (Dery *et al*., 1999). The quality and usefulness of its products are also marked in other species within the genera *Entandrophragma* internationally. Some of these species include *E. angolense, E. candollei, E. cylindricum,* and *E. utile* (Hall *et al*., 2004). Apart from timber, parts of *E. bussei* tree have been regarded as a useful source of ethno-medicine in Tanzania (Dery *et al*., 1999; Dery and Otsyina, 2000; Nibret *et al.,* 2010).

Previous studies in Tanzania reported that *E. bussei* roots, leaves, and bark have been used for a long time to cure several diseases including, abdominal problems, diarrhoea, anaemia, laxatives, worms, hypertension, general ailments, charm, body pains, asthma, urinary infection, and chest problems (Dery *et al*., 1999; Monela *et al*., 2005). As for other species in the genera, *E. bussei* is among the species that possess potential secondary plant metabolites (limonoids and terpenoids) for diseases treatments (Nibret *et al*., 2010; Monthe-Happi *et al*., 2018). The use of roots, leaves, and bark of the tree has been reported as effective in the treatment of several diseases as in other species such as *E. angolense*, *E. caudatum*, and *E. utile* within the same genera.

Entandrophragma utile roots, leaves, and bark have been used in the treatment of sickle cell anaemia in West Africa (Adejumo *et al*., 2010). *Entandrophragma caudatum* roots and fruits are used in the treatment of gonorrhoea and genital warts in Zambia (Chinsembu, 2016). The extracts of the stem bark of *E. angolense* release compounds (methyl angolensate and methanol) isolated from dichloromethane and methanol for malaria treatment in Cameroon (Bickii *et al.,* 2007).

2.7 Domestication of indigenous tree species

The history of domestication of indigenous plants can be traced back from the ancient times before Christ (Spiegel-Roy, 1986). Initially indigenous plant species were exploited from the wild for food, wood, shelter, and religious reasons (Turnbull, 2002). As human provenance increased on earth, most of the forested lands were cleared for various purposes. During the process, important indigenous plant species were retained on farms or around homesteads (Msuya *et al*., 2008). During that time, these plant species established themselves on the land through natural regeneration and transferring of seedlings and cuttings by humans to other areas (Msuya *et al*., 2008).

The loss in plant’s natural regeneration potential and increased land cover change on earth has threatened the survival of most indigenous plant species. In such occasions, domestication methods have proven to save many threatened indigenous plant species on their natural habitats (Msuya *et al*., 2008). This method is an evolutionary process and an end in a continuum of wild plants adaptation to the agro-ecology (Vadouhe and Dansi 2012).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study area

This study was coordinated at TFS the Directorate of Tree Seed Production (DTSP) Headquarters in Morogoro, Tanzania between December 2019 and July 2020. Morogoro region is located at 6.8278° S, 37.6591° E with an average yearly temperature of 24.6°C and an annual rainfall of about 935 mm. Before seed collection, a reconnaissance survey (based on published reports and *E. bussei* distribution) was done for six provenances (Dodoma, Iringa, Kilimanjaro, Manyara, Singida, and Tabora) to identify areas with major concentrations of the species.

Finally only three provenances with elevation and climate variations namely Dodoma, Iringa, and Manyara were purposively selected for the study (Figure 1; Table 1). For each provenance, sites for fruit collection (seed sources) were located based on the availability and higher concentration of *E. bussei* trees at one location.

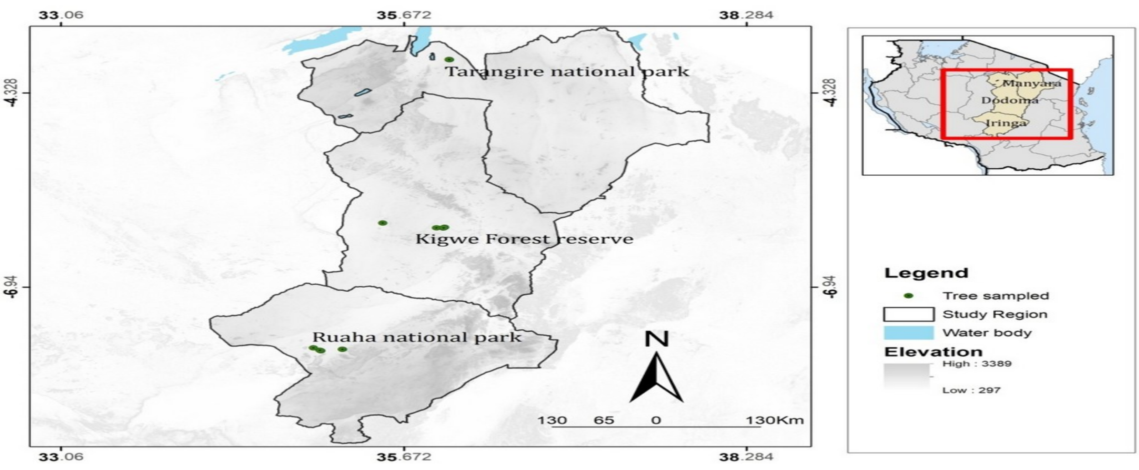

Figure 1: Map showing collection sites of *Entandrophragma bussei* provenances in the selected southern highlands, central and northern Tanzania.

3.2 Seed collection sources

3.2.1 Ruaha-Iringa provenance

Seeds were collected from Ruaha National Park between altitude 915 and 974 masl. The temperature within the National park ranges from 15ºC to 25ºC while the amount of rainfall ranges from 500 mm to more than 1600 mm per year (Table 1). The landscape consists of flat treeless savannahs, miombo woodlands (from which fruits were collected), dry bush lands, swamps, and riverine forest vegetation that harbour about 1650 plant species (TANAPA, 2013). Within the park, no human activities are allowed except nature-based tourism although some few illegal activities and wild fires were encountered.

3.2.2 Kigwe-Dodoma provenance

Seeds were collected from Kigwe Forest Reserve in Dodoma provenance between altitude 979m and 1098m. The region experiences a semi-arid climate with an average temperature ranging from 15º C to 32º C and annual rainfall ranging from 530 mm to 660 mm (Table 1). The area is dominated by various plant species such as *Dichrostachys*, *Commiphora-Adansonia* woodland (Msanya *et al.*, 2018). The reserve is under the management of Tanzania Forest Services Agency (TFS) that has the mandate of protecting and controlling resource consumption in the country. However, the area has experienced some illegal activities that include timber harvesting, wood fuel collection, and farming which largely have turned the area into an open miombo woodland.

3.2.3 Tarangire-Manyara provenance

In Manyara provenance, seed were collected from Tarangire National Park between altitude 1167 and 1222 masl. The temperatures in the National park range from 16ºC to 27ºC with yearly rainfall of around 650 mm (Table 1). The landscape in the park is characterized by Acacia-Andansonia-woodland, Combretum woodland, grasslands, and

Adansonia digitata vegetation. Although no human activities are allowed except those intended for resource protection, research and conservation within the area, especially during seeds collection, several cases of wildfires were encountered at different parts and are thought to having an overriding effect on the plant species community including *E.bussei*.

Table 1: *Entandrophragma bussei* provenance sites in Tanzania where data were collected

Provenance name	**Location**	**Elevation (m)**	**Annual rainfall (mm)**	**Temperature (^{0}C)**
Dodoma	6.5738^O S- 36.2631^O E	979 -1098	500 - 800	15 - 32
Iringa	7.7681^O S- 35.6861^O E	915 – 974	500 - 1500	15 - 25
Manyara	4.3150^O S- 36.9541^O E	1167 -222	450 - 1200	16 - 27

3.3 Sampling design

At each seed source, one sampling unit (100m×100m) was selected purposively to ensure availability of at least 20 matured trees bearing fruits. Selection of a seed source with at least 20 matured trees bearing fruits was mandatory and in this study was due to failure to allocate any source with at least 30 trees at one area. 20 matured trees were purposely selected and marked with numbers. Within each unit, 15 trees were randomly selected from numbered trees. Diameter at breast height (DBH), height of a tree (h), and geographical location of each numbered tree used was recorded and used only in the selection of plus trees. Height and diameter of candidate plus trees were measured by altimeter and tape measure respectively (Table 2).

Table 2: Characteristics of plus trees used as sources of fruits and seeds

Site	Variable	n	Mean	Standard Error	Coefficient of Variation	Minimum	Maximum
Kigwe	DBH (cm)	5	117	8.89	16.99	100	150
	Height (m)		16.2	0.58	8.05	15	18
Ruaha	DBH(cm	5	79.4	9.44	26.59	54	108
	Height (m)		15.6	0.40	5.73	15	17
Tarangire	DBH(cm)	5	95.8	14.15	33.02	65	140
	Height (m)		16.2	1.20	16.56	14	20

A comparison method was used purposively to select five plus trees without considering a distance from one plus tree to the other. A tree was considered a plus tree if it was pest and disease free, had straight and circular stem of large diameter, possessed fine horizontal branches, found between other neighbouring trees, and had large quantities of seeds compare to others (Figure 2).

Figure 2: One of the plus trees selected during fruit collection at Ruaha-Iringa provenance, Tanzania.

3.4 Data collection

3.4.1 Fruits collection

Fruits were collected in August 2019 in all the selected *E. bussei* wild provenances from five plus trees, using fruits collection bags. In all of the three study sites from each tree, 20 fruits were collected making 100 fruits per provenance and 300 fruits for the three provenances. The collected fruits were packed and labelled by the (species name, location, and date of collection) according to their respective provenances and transported to Directorate of Tree Seed Production (DTSP) seed laboratory in Morogoro for further assessments.

3.4.2 Assessment of fruits traits

At the DTSP, fruits from each *E. bussei* provenance were tagged with numbers from 1 to 100. Each numbered fruit was subjected to measurements of length and width using an electronic digital calliper (with a precision of 0.01 mm) and fruit fresh weight using digital weighing balance. Fruits from each provenance were then left to dry under the house shade for 14 days to allow natural opening of the capsules. The morphology of fruits for the three provenances were stored to a greyish-brown coloured woody capsule with many breathing pores on the outside and rounded at the tip. On drying, they split from the tip towards the base and released seeds with a wing attached to the central column (Figure 3).

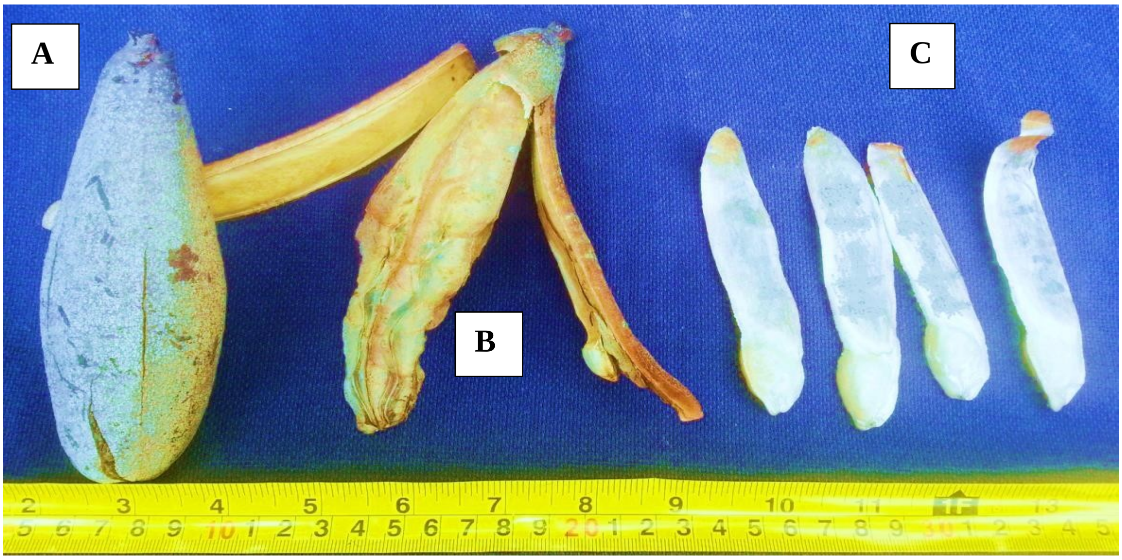

Figure 3: Fruit of *Entandrophragma bussei* with closed capsules (A), Fruit with opened capsules (B) and seeds with flat wings (C)

After the fruit capsules had opened, the seeds were extracted by shaking the capsules using hands. The extracted seeds from each fruit were counted and recorded. The seeds were then grouped according to their respective provenance and cleaned by hand sorting method to remove all the debris.

3.4.3 Assessment of seed traits

3.4.3.1 Seed processing

From each *E. bussei* provenance, a sample of 400 clean seeds were randomly selected using a soil divider and marked with numbers (1 to 400). That made a total of 1200 sampled seeds for Tarangire, Ruaha and kigwe provenances respectively. Seeds of *E. bussei* are characterized with flat wings and thus all the sampled seeds were subjected to measurements without the removal of their wings. Such measurements included, seed length with wings which was measured using electronic digital calliper and weight of the seeds which was measured using a calibrated digital weighing balance.

3.4.3.2 Determination of seed moisture content

Seed moisture content was determined using the oven drying at 14°C and expressed as a percentage fresh weight (% fresh mass basis) of the original sample as prescribed in the International Seed Testing Association rules (ISTA, 2013). The moisture content (%) was determined immediately after the seeds were extracted from the fruits. During handling and weighing, all efforts were made to minimize the exposure time of seed sample to the laboratory atmosphere.

The oven-drying method was used for determination of moisture content (Reeb, 1999). This involved weighing the seed samples, the container, and its cover before and after filling; and placing the container rapidly in an oven maintained at a temperature of 103° ± 2°C for 17 ± 1 hours. The drying period was counted from the time when the oven reached the required temperature. At the end of the prescribed drying period, the container was covered and placed into a desiccator for 45 minutes to cool. After cooling, the container with its cover and contents was weighed again. The weighing was done in grams to three decimal places.

Seed moisture content, expressed as a percentage by weight was calculated by the **following formula:**

Moisture content (%) $=\left(\frac{M2-M3}{M2-M1}\right)\times 100$

Where M1 = weight in grams of the container and its cover,

M2 = weight in grams of the container, its cover and seeds before drying, and seeds before drying and

M3 = weight in grams of the container, its cover and seeds after drying.

The percentage of seed moisture content was thus expressed based on fresh weight. The arithmetic mean of the duplicate moisture content was expressed as a percentage by weight to the nearest 0.1 percentage.

3.4.3 Assessment of seed germination

Seed germination experiment was conducted from January 2020 to February 2020 at the Directorate of Tree Seed Production (DTSP) seed germination laboratory in Morogoro. Temperature in the laboratory ranged from 10^0C to 25^0C during the study period. The experiment was laid out in a Complete Randomized Block Design (CRBD) with the three provenances replicated four times. During the experiment, twelve rectangular germination containers of average volume of 4826.6 cm^3 that contained sand (that had been washed to remove silt and organic matter) as a substrate were used for each provenance. In each container, 25 cleaned seeds were sown (after the removal of the wings) to a uniform depth of 10 mm to make 300 seeds per provenance and 900 seeds per experiment.

The sand was water-irrigated manually twice per day (in the morning from 08:00-08:15 hours and in the evening 15:00-15:15 hours) to keep the sand continuously wet without becoming waterlogged. Germination behaviour was assessed similarly for all the three provenances. *Entandrophragma bussei* seeds have an epigeal type of germination. The spongy layer of the seed absorbed water, and then the radical emerged first from the seed base and develops into a taproot, followed by the short, stout hypocotyl, which carries the seed coat together with the two thick cotyledons above the germination medium. The cotyledons expanded slightly, split, and later changed colour from white to green (Figure 4).

Figure 4: Laboratory germination tests for *Entandrophragma bussei* seeds

Germinated seeds were counted first on the twelfth (12th) day after seeds were sown and the emergence of a visible protrusion of cotyledons above the substrate surface. The seedlings count was done until no more germination was observed. In total, the entire lasted 34 days. During the counting germinated seeds were stored and recorded either as normal (for those found with one or more leaves), abnormal (for those found with no leaves) or dead (for those found without a leaves protrusion until the end of the experiment. After a physical examination of the condition of embryos (Asiedu *et al.*, 2012) and the following germination parameters were calculated:

3.4.3.1 Germination period

Germination period (GP) was determined as number of days from first observed germination (FOG) to where no more germination was observed (NMG) (Asiedu *et al*., 2012).

Formula:

GP = NMG – FOG

3.4.3.2 Germination percentage

Germination percentage (GC) was determined as the ratio of the total germinated seeds (TGS), to the total of the seeds sown (TSS).

Formula:

GC = (Total germinated seeds/ Total seeds sown) x 100

3.4.3.3 Germination value

Germination value (GV) is a composite value, which combines both germination speed and the total germination and provides an objective means of evaluating the results of germination tests (Djavanshir and Pourbeik, 1976; Msanga, 1998). The value was calculated using the formula,

$$GV = \sum\left(\frac{DGs}{N}\right)GP/10$$

Where

GV = Germination value.

GP = Germination percentage at the end of the test.

DGs = Daily germination speed, obtained by dividing the cumulative germination percentage by the number of days since sowing.

N = the number of daily counts, starting from the date of first germination.

10 = Constant.

3.4.3.4 Mean germination rate

Mean germination rate (MGR) is the ratio of sum of number of seeds germinated until no more germination to the sum of product of number of seed germinated and number of days taken for such amount of seeds to germinate.

Formula:

MGR = $\frac{\sum F}{\sum FX}$

Where

F = Number of germinated seeds on a particular day

X = Number of days taken for seeds to germinate

3.4.3.5 Final germination

Final germination (FG) is the ratio of number of seeds germinated when there is no more germination to the total number of days taken on for particular seeds to germinate.

Formula: FG = $\frac{GS}{Dt}$

Where

GS = Number of seeds germinated when there is no more germination

Dt = Total number of days taken for particular seeds to germinate

3.4.3.6 Germination index

Germination index (GI) is an estimate of the time (in days) it takes for a certain germination to occur. The seed lot having greater germination index is considered to be more vigorous.

Formula:

$$GI = \sum \frac{¿}{Dt}$$

Where

Gt = is the number of germinated seeds on day t

Dt = is the time corresponding to Gt in days

3.4.4 Assessment of seedling traits

The assessment of seedling traits (*i.e*. shoot height, root colour diameter and number of leaves) was conducted at the DTSP nursery from April to July 2020. The experiment was laid out in a Completely Randomized Block Design (CRBD) with three provenances replicated three times (as adopted from Mwase *et al.* (2010)). Individual seeds were sown in black polythene tubes of 6 cm diameter, width and 12 cm depth, filled with woodland soil mixed with sawdust in 3:1 ratio.

Watering was done using watering can two times a day (morning 08:00-08:15 and evening 15:00-15:15) to maintain the ideal soil moisture condition. The assessment of the seedling traits was conducted on 30^{th}, 45^{th}, 60^{th}, 90^{th}, and 105^{th} days after sowing the seeds. During the assessment, shoot height and root collar diameter were measured using a standard ruler and micro-calliper, respectively. During the assessment, the number of leaves per each seedling was also counted and recorded.

3.5 Data analysis

Data on fruit traits and seed traits were explored by adopting the protocol proposed by Zuur *et al*. (2010), whereby Shapiro-Wilk Test was used to test the normality of the studied traits. The traits were fruit traits (length, width, weight, and the number of seeds per fruit), seed traits (length, width, and weight), germination traits (germination period, germination percentage, germination value, mean germination rate, final germination rate and germination index), and seedling traits (shoot height, collar diameter and number of leaves). During the test, fruits and seeds’ length and width, number of seeds per fruits, germination period, germination percentage, mean germination rate and final germination rate were not normally distributed at P = 0.05. Therefore, fruits and seeds’ length and width, number of seeds per fruits, and germination period, mean germination rate and final germination rate were log transformed while germination percentage was arcsine transformed.

Variations on fruits, seeds, germinations, and seedlings traits among the three *E. bussei* provenances were subjected to the Analysis of Variance (ANOVA). Least significance difference test (LSD) was used to compare means of fruits’ length, width, and weight against the number of seeds per fruits from the three studied provenances. The Pearson’s correlation was used to explore linear relationship among variables, to test the association. All the analysis were done using SAS version 9.12 (SAS Institute, Cary, North Carolina, USA).

CHAPTER FOUR

4.0 RESULTS

4.1 Fruit traits

Overall, the measured fruit traits varied significantly among *Entandrophragma bussei* provenances in this study. Higher figures for most of the traits were recorded in Ruaha and Tarangire provenances and the least were in Kigwe provenance. The fruit size (length and width) were significantly different among the three provenances ($F_{2,\ 97,}$ = 10.3, p = 0.0019) (Figure 5). Ruaha-Iringa provenance had the longest and widest fruit size (19.31 ± 0.10 cm and 7.71 ± 0.12 cm respectively) compared to Tarangire-Manyara provenance (16.84 ± 0.10 cm and 5.40 ± 0.12 cm) and Kigwe-Dodoma provenance (15.65 ± 0.15 cm and 4.86 ± 0.17 cm). Furthermore, the fruit weight among provenance were significantly different ($F_{2,\ 97}$ =5.97, p = 0.0029) (Figure 5).

Ruaha provenance had the highest fruit weight (62.46 ± 1.34 g) compared to Tarangire provenance (60.71 ± 1.12g) and Dodoma provenance (56.53 ± 1.28 g). Ruaha provenance had highest number of seeds per fruit (22 ± 0.48) followed by tarangire provenance (20 ± 0.37) while Kigwe provenance had the least (20 ± 0.37). The variation in number of seeds per fruit among provenance was statistically significant (F2, 97= 5.26, p = 0.0057) (Figure 5).

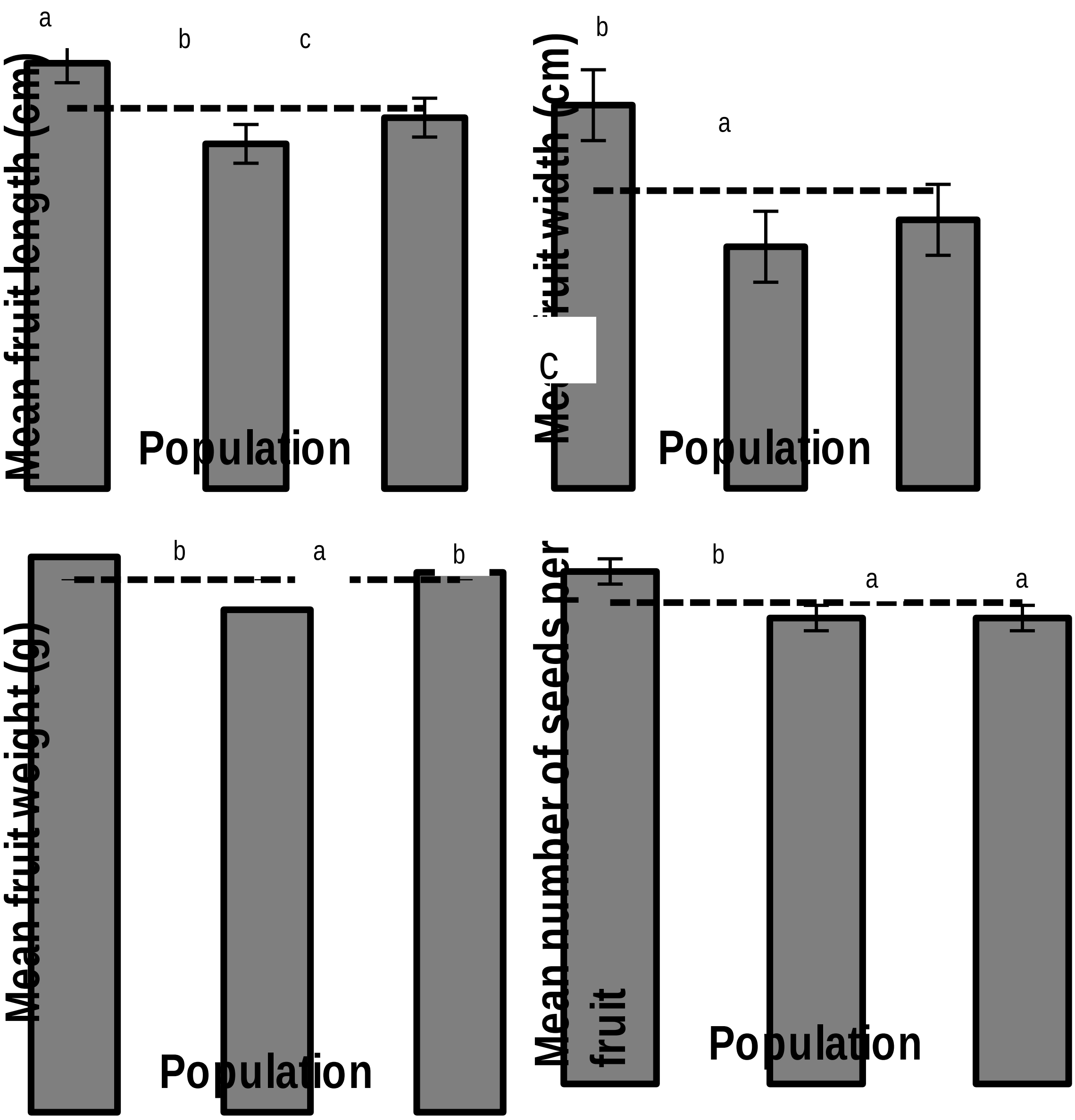

Figure 5: **Mean (±SE) fruit characteristics for each of the provenances. Bars marked with different letters are significantly different (Least Significance Difference, *P* < 0.05). Overall mean is indicated by a dotted line.**

There was a positive and significant correlation between several measured fruits traits (Table 3). Fruits length was positively correlated with fruit width (r = 0.89, p < 0.0001), fruit weight (r = 0.50, p < 0.0001), and the number of seeds per fruit (r = 0.79, p < 0.0001). Fruit width was positively and significantly correlated with fruit weight (r = -0.61, p < 0.0001), and the number of seeds per fruit (r = 0.70, p = < 0.0001) while fruit weight was positively and significantly correlated with the number of seeds per fruit ($r = 0.54$, $p < 0.0001$).

Table 3: **Pearson correlation coefficients of fruit and seed traits of *Entandrophragma bussei* in Tanzania**

Trait (Unit)	**Fruit length**	**Fruit width**	**Fruit weight**	**No. of seeds per fruit**	**Seed length**	**Seed width**
Fruit width (cm)	**0.89**					
Fruit weight (g)	**0.50**	**0.61**				
No. of seeds per fruit	**0.79**	**0.70**	**0.54**			
Seed length (cm)	**0.23**	**0.15**	0.02	**-0.25**		
Seed width (cm)	0.07	0.02	**0.23**	0.004	-0.06	
Seed weight (g)	**-0.16**	**0.17**	**0.27**	**-0.20**	**0.28**	**0.34**

Statistically significant correlations ($P < 0.001$) are indicated with bold numbers.

4.2 Seed traits

Seed length varied significantly ($F_{2, 97} = 163.69$, $p < 0.0001$) among the provenances (Figure 6), with the longest seeds (9.60 ± 0.06 cm) were observed in Tarangire provenance while Kigwe provenance had the shortest seed length (8.48 ± 0.05 cm). However, seed length for Ruaha and Kigwe provenances were not statistically different. Seed width varied significantly ($F_{2, 97} = 56.91$, $p < 0.0001$) among the provenances (Figure 6). The thickest seeds (1.80 ± 0.01 cm) were from Dodoma provenance followed by Ruaha (1.75 ± 0.01 cm) and Tarangire (1.65 ± 0.01 cm) provenances.

Seed weight was significantly ($F_{2, 97} = 33.49$, $p < 0.0001$) different among the provenances (Figure 6). Dodoma provenance had the heaviest seed weights (0.83 ± 0.01 g) followed by Tarangire (0.77 ± 0.01 g) and lastly Ruaha provenance, which had the lightest seed weight (0.75 ± 0.01 g). Seed weights for Tarangire provenance were not different from that of Ruaha provenances despite being superior to it.

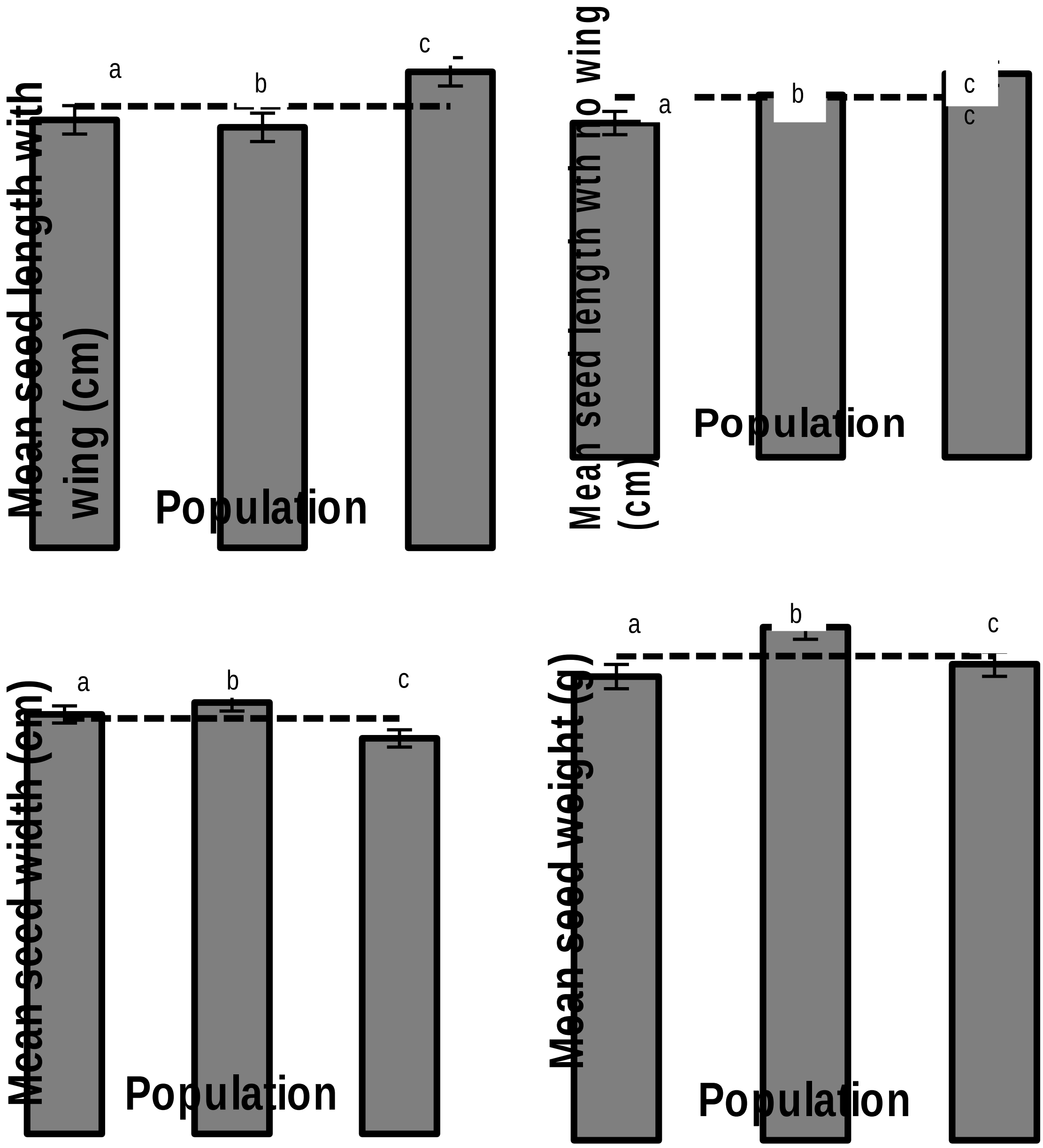

Figure 6: **Mean (±SE) seed characteristics for each of the provenances. Bars marked with different letters are significantly different (Least Significance Difference, *P*<0.05). Overall mean is indicated by a dotted line.**

The relationship between seed traits and fruit traits demonstrated a significant correlation (Table 3). Seed weight was significantly and positively correlated with seed length ($r = 0.28$, $p < 0.0001$), seed width ($r = 0.34$, $p < 0.0001$), fruit weight ($r = 0.27$, $p < 0.0001$), fruit width ($r = 0.17$, $p < 0.0001$), but negatively correlated with fruit length ($r = -0.16$, $p < 0.0001$), and the number of seeds per fruit ($r = -0.20$, $p < 0.0001$). Seed width was positively and significantly correlated with fruit weight ($r = -0.20$, $p < 0.0001$) while seed length was positively and significantly correlated with fruit length ($r = 0.23$, $p < 0.0001$) and fruit width ($r = 0.15$, $p < 0.0001$) but negatively correlated with the number of seeds per fruit ($r = -0.25$, $p < 0.0001$).

4.3 Germination traits

Gradual increase in seed germination was experienced until day 30 (85%) for Kigwe provenance, day 30 (80%) for Tarangire provenance and day 34 (68%) for Ruaha provenance (Figure 7).

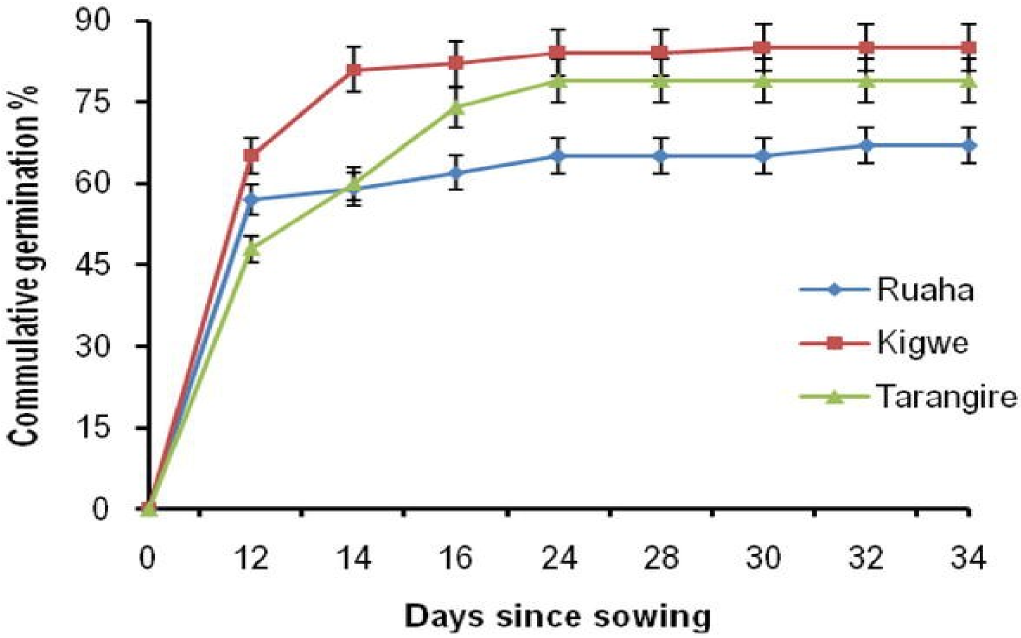

Figure 7: Germination of seeds of three wild populations of *Entandrophragma bussei* in Tanzania. Vertical bars are Standard Errors

No new seedling emerged after the 34^{th} day. The examination of seed after 34 days of germination period revealed that all the un-germinated seeds were rotten. There were significant differences ($F_{2, 93}$ = 15.14, p > 0.001) between provenances in germination percentages of *E. bussei* amongst the three provenances. Germination period ranged from 10 to 12 days and was not statistically different ($F_{2, 93}$ = 1.21, p = 0.3035) among the three provenances. However Ruaha provenance had the highest germination period of (12 ± 1.02 days) followed by Kigwe provenance (11 ± 1.03 days) and the least was Tarangire provenance with (10 ± 0.62 days).

Dodoma and Manyara provenances had highest germination percentage (81.38 ± 1.83 and 72.13 ± 2.82 respectively) as than Iringa provenance (63.38 ± 2.16) (Table 4). However there was no significant difference in germination value among the three provenances ($F_{2, 93}$ = 0.21, p = 0.8112). However, the germination values in Iringa, Manyara, and Dodoma were very similar (1.03 ± 0.04, 1.03 ± 0.03 and 1.01 ± 0.02, respectively). Mean germination rate, germination index and in final germination rate for the three provenances varied significantly ($F_{2, 93}$ = 3.12, p = 0.05; $F_{2, 93}$ = 3.96, p = 0.02 and $F_{2, 93}$ = 0.79, p = 0.45 respectively) (Table 4).

Dodoma and Manyara provenances had higher and significantly different mean germination rate (20.34±2.60 and 18.03±4.00 respectively), germination index (0.96±0.34 and 0.83±0.26 respectively) and in final germination rate (0.13±0.37 and 0.12±0.32 respectively) as compared to Iringa provenance (Table 4).

Table 4: Variations of *Entandrophragma bussei* seed germination traits among the three provenances

Provenance	Germination percentage	Germination period	Germination value	Mean germination rate	Final germination rate	Germination index
Kigwe	81.38±1.83a	11±1.03a	1.01±0.02a	20.34±2.60a	0.13±0.37a	0.96±0.34a
Ruaha	63.38±2.16b	12±1.02a	1.03±0.04a	15.84±3.06b	0.06±0.20b	0.75±0.31b
Tarangire	72.13±2.82c	10±0.62a	1.03±0.03a	18.03±4.00c	0.12±0.32a	0.83±0.26a

Values bearing letters are means ± standard deviation, Values in columns with the same letter (s) do not vary significantly (P = 0.05); LSD Test

There were significant correlations among some of the germination traits (germination period, germination percentage, germination value, mean germination rate, final germination rate and germination index) (Table 5). Germination value was negatively correlated with germination index (r = -0.41, p <0.0001), mean germination rate (r = -0.73, p < 0.0001), and germination percentage (r = -0.73, p < 0.0001). A negative and significant correlation was observed also between germination index and germination value (r = -0.41, p < 0.0001). Mean germination rate had a positive significant relationship with final germination rate (r = 0.22, p = 0.0339). There was a positive and significant difference between final germination rate and germination percentage (r = 0.22, p = 0.0339).

Table 5: **Pearson correlation coefficients for the seed germination traits**

Germination trait	GP	GV	GI	MGR	FGR
Germination value	-0.16				
Germination index	0.02	**-0.41**			
Mean germination rate	0.03	**-0.73**	0.16		
Final Germination Rate	-0.05	-0.14	0.17	**0.22**	
Germination period	0.03	**-0.73**	0.16	1	**0.22**

GP Germination period, GV=Germination value, GI=Germination index, MGR=Mean germination rate, FGR=Final germination rate, GP=Germination period. Statistically significant correlations ($P < 0.001$) are indicated with bold numbers.

4.4 Effect of provenances on seedling traits

Seedling shoot height, root collar diameter, and the number of leaves were significantly ($F_{2, 97} = 10.31$, $p = 0.000132$) different among the provenances. Ruaha-Iringa provenance (63.90 ± 6.21 mm) had the longest shoot height followed by Tarangire-Manyara provenance (43.70 ± 6.26 mm) and Kigwe-Dodoma provenance was recorded the least (39.50 ± 6.23 mm). Iringa recorded the highest root collar diameter (8.05 ± 0.77 mm), while Manyara and Dodoma provenances had (5.57 ± 0.78 mm and 5.00 ± 0.78 mm respectively).

Iringa provenance had the highest number of leaves (3 ± 0.34) followed by Manyara provenance (2 ± 0.34). On the other hand Dodoma provenance recorded the least mean number of leaves (2 ± 0.34). However, Dodoma and Manyara provenances were not statistically different in terms of seedling shoot height, root collar diameter, and the number of leaves (Table 6).

Table 6: Variations in seedling traits of *Entandrophragma bussei* among three provenances

Provenance	Shoot height (mm)	Root collar diameter (mm)	Number of leaves
Kigwe	39.50±6.23a	5.00±0.78a	2±0.34a
Ruaha	63.90±6.21b	8.05±0.77b	3±0.34b
Tarangire	43.70±6.26a	5.57±0.78a	2±0.34a

Values bearing letters are means ± standard deviation, Values in columns with the same letter (s) along the same column do not vary significantly ($P = 0.05$); LSD Test

Positive and significant correlation was observed between seedling-measured traits (Table 7). Result revealed a positive and significant correlation between seedling shoot height and root collar diameter (r = 0.9589 9, p < 0.0001) as well as the number of leaves (r = 0.95531, p < 0.0001). Similarly, the number of leaves was strongly correlated with seedling collar diameter (r = 0.93236, p < 0.0001).

Table 7: Pearson correlation coefficients for seedling growth/development traits

Trait (Units)	Seed height	Number of leaves	Collar diameter
Seed height			
Number of leaves	**0.96**		
Collar diameter	**0.96**	**0.93**	

Statistically significant correlations (*P* < 0.001) are indicated with bold numbers.

Measurements of seedling traits were not significantly ($F_{2, 97}$ = 0.38, p = 0.8262) different between the periods (days) after seeds were sown (Table 8). Mean shoot height for the whole time of the experiment, ranged from 45.2 mm to 52.7 mm, mean root collar diameter ranged from 5.06 mm to 7.08 mm and mean number of leaves ranged from 2 ± 0.42 mm to 3 ± 0.44 mm for the period of 105 days.

Table 8: Variations of *Entandrophragma bussei* seed germination traits among three provenances

Time	Shoot height	Root collar diameter	Number of leaves
Day 30	45.20±8.05a	5.06±1.01a	2±0.42a
Day 45	46.79±8.13a	5.84±1.00a	3±0.44a
Day 60	48.19±8.04a	6.30±1.00a	3±0.43a
Day 90	52.31±8.05a	6.74±1.01a	3±0.43a
Day 105	52.70±8.04a	7.08±1.01a	3 ±0.44a

Values bearing letters are means ± standard deviation, Values in columns with the same letter (s) do not vary significantly (*P* = 0.05); LSD Test

CHAPTER FIVE

5.0 DISCUSSION

5.1 Variation in fruit size, weight and number of seeds per fruit

It is possible that, the observed variations on fruits traits is a results of variation in environmental factors (altitudes, annual rainfall patterns and temperature) and genetic variations from the selected trees within the selected provenances (Ngulube *et al.*, 1997). Collection of fruits in the field for the purpose of improvin0g *E. bussei* traits during domestication process requires consideration of provenance source that provides best traits (Ngulube *et al.,* 1997).

A positive and significant relationship noted between fruit size, fruit weight, and number of seeds per fruit, indicates that fruit size and weight can both be used as predictors of the number of seeds per fruits in the field. During fruits collection, selection quantity of seeds could be based on directly measurable traits (fruit length, width, and weight) provided that the results are based on a genetic inheritance (Dicko *et al*., 2019). Similar results were observed for *Strychnos cocculoides* (Mkonda *et al*., 2003) and for *Adansonia digitata* (Munthali *et al*., 2012).

Heavier fruits are a good predictor of seed traits (table 3). Considering the importance of high weight in germination and seedling growth and development, Ruaha population stands as the best source for fruits with high weight followed by Tarangire and Kigwe populations in this study.

5.2 Variation in seed size and weight

The variation in seed size and weights could have contributed by seed genetic differences (Abasse *et al*., 2010), environmental factors (Ngulube *et al.*, 1997), altitudinal difference, and climatic conditions in particular provenances (Fredrick *et al*., 2015). Provenance selection during seed collection is therefore important with the consideration of strong seed traits such as seed weight. Healthier and heavier seeds are important because the heavier the seed, the higher the food nutrients reserved in it and the higher the chance in supporting seed germination and early seedling growth and development (Mwase *et al*., 2006; Mkwezalamba *et al.*, 2015).

Collection of heavier seeds in the fields from these provenances can rely on seed size (seed length and seed width) as these are positively correlated. Ruaha and Trangire provenances had higher fruits weight compared to Dodoma provenance, making them stand a chance of being prioritized in seed collection. The higher seed weight displayed by Kigwe could be influenced by amount of rainfall, considering the rainfall patterns among the provenances (Table 1), the results indicate that, possibly high water stress in Kigwe and Tarangire provenances have influenced reservation of much substrate in seeds so as to enhance the survival of seedlings in such environment as compared to Iringa provenance.

Similar observation is reported by Loha *et al*. (2006) on *Cordia africana*. With consideration of geographical and climatic variations in the country, seed collection exercise for domestication process should consider species-site matching and thus each of the studied provenances need to be matched to appropriate climate, altitude and soils during domestication process

5.3 Variation in germination traits

Germination is an important factor in assessing the quality of any seed. In this study, seed cumulative germination percentage ranged from 63% to 81% indicating that the three provenances possess quality seeds that can be used during the domestication process. The observed variation in germination percentage among the provenances might not be attributed to differences in altitudes, environmental factors (day length, temperature, light quality, water availability and altitude), and climatic conditions of particular provenances. The result indicates that, maternal factors associated with individual seeds from each provenance could explain the observations (Freigoun *et al*., 2017).

In order to support establishments of a nursery for *E. bussei* domestication, genotypes with superior germination traits are favoured (Mkwezalamba *et al*., 2015). The results could be attributed by the Dodoma source having seeds with heavier weight than the other two sources as supported by Mwase *et al.* (2006) on *Uapaca kirkiana*. The seeds from Dodoma and Manyara provenances have high nutrient reserves which contributed to high germination of (72%-81%) within 16 days (Figure 7). The selection of seeds from these provenances would be appropriate during nursery development in tree domestication process.

5.4 Variation in seedling traits

Seedling traits (shoot height, diameter, and number of leaves) variations are important determinants for seedlings to be planted in the field. This experiment was set at DTSP nursery in Morogoro for all the three provenances. It is obvious that the observed results have been influenced by seed genetic makeup (which were not tested in this study) from each individual provenance rather than variation of environmental factors between the provenances as reported by Freigoun *et al*. (2017) on *Balanite aegyptiaca*.

Between the period of three months and a half, seedling growth traits were not significantly different but showed a positive and strong correlation among them (Table 7). Despite such insignificant observation during the period of measurements, it is important to consider raising the seedlings in the nursery for at least six months to allow seedling maturation and biomass increase. The highest percentage of seedlings in Iringa contradicts the results shown by Assogbadjo *et al*. (2010) who reported that, positive seedling growth was influenced by large seed sizes. This may be influenced by other factors than the size of seed alone.

Meanwhile the number of leaves for *E. bussei* obtained in this study did not differ significantly among the provenances but was close to what reported on *E. angolense* while the rest of the seedlings traits were significantly higher (Ambebe and Achangkeng, 2019).

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Significant variations in fruits, seeds and seedling traits for the three provenances have been demonstrated. The observed variations could be due to environmental differences among the provenances and maternal genetic variations of the collected trees. Given the level of variations reported in this study, the selection for improving any traits of the species would be effective at provenance level. Despite the observed variations, provenance-site matching is a key to ensure success in domestication. Among the provenances, Kigwe presents better traits followed by Tarangire. The two provenances can be considered as potential seed sources and thus they can be considered during the domestication process for collection of seeds with best traits.

Domestication of this tree from the wild, should consider collection of seeds that are heavier, healthier and possess swift germination under managed nurseries. In this study, Kigwe and Tarangire had the best seeds traits that had high germination percentage and value during the laboratory experiment. However, a different trend was observed during the nursery experiment where Ruaha provenance the best. The difference observed for the two experiments could have resulted from variations in environmental factors between the two experiments sets. In fact, the nursery used in this study does not represent climate as well as elevation of all the three provenances (Kigwe, Ruaha and Tarangire) which makes it difficult to interpret the results with a reasonable confidence.

6.2 Recommendations

Successive establishment of *E. bussei* from the wild to these new ecosystems, require more research. Availability of reliable and current information will guide identification of candidate plus trees in specific wild provenances for obtaining quality seed traits that perform well in the field. To attain that, more research studies should address the followings;

- Genetic variation of seeds within and between provenances
- Variation of fruits between families within and between provenances
- The effects of other treatments on *E. bussei* germination and seedlings development like collar girth, number of leaves and dry matter contents.
- Performance of *E. bussei* seedlings in different geographical field locations in the country

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APPENDICES

Appendix 1: Final surveyed sites details

Height and Diameter of five selected Best Trees							
Provenance Kigwe -Dodoma							
SN	**Latitude**	**Longitude**	**Altitude (m.a.s.l)**	**Name**	**Timestamp**	**Location**	**Description**
1	-6.14519	35.972867	1054	W4tree 3	8/15/2019 14:53	Kigwe	dbh 120 cm ht 16 m seed 3 branch 8 heathy 4
2	-6.07778	35.512225	979	W5tree bo 4 kigwe	8/15/2019 16:50	Kigwe	dbh150 cm ht17 m seed 4 branch 3 heathy 5
3	-6.1413	35.920107	1098	W1 eneo la kuanzia	8/15/2019 10:44	Kigwe	dbh 100 cm ht 18 m seed 1 branch 3 healthy 2
4	-6.13455	35.983997	1062	W2	8/15/2019 13:57	Kigwe	tree no 1 cm dbh 105 m ht 15 seed prod 2 stms 5
5	-6.14295	35.97662	1056	W3tree no 2	8/15/2019 14:33	Kigwe	tree no 2 cm dbh 110 m ht 15 seed 3 branch 6 heathy 3
Provenance Ruaha -Iringa							
SN	**Latitude**	**Longitude**	**Altitude**	**Name**	**Timestamp**	**Location**	**Description**
1	-7.79528	35.03979	972	W22tree no 21 ruaha	8/24/2019 10:11	Ruaha	dbh 54 cm ht15m seed2 stem 1 healthy 4
2	-7.78904	35.032602	970	W24tree no 23 ruaha	8/24/2019 10:44	Ruaha	dbh 65 cm ht 16 m seed 2 stem 1healthy 3
3	-7.75611	34.982682	915	W25tree no 24 Ruaha	8/24/2019 13:39	Ruaha	dbh 108 cm ht17 m seed 3 stems1 healthy 3
4	-7.77636	35.203237	970	W20tree no 19 ruaha	8/24/2019 8:32	Ruaha	dbh 80 cm ht 15 m seed 4 branch2 healthy 3
5	-7.77619	35.202925	974	W21tree no 20 Ruaha	8/24/2019 8:43	Ruaha	dbh 90 cm ht 15 m seed 4 bra 2 healthy 3
Provenance Tarangire - Babati							
SN	**Latitude**	**Longitude**	**Altitude**	**Name**	**Timestamp**	**Location**	**Description**
1	-3.88034	36.019808	1222	W15tree no 14	8/18/2019 15:15	Tarangire	dbh 104 cm ht 15 m seed2 stems 1 healthy 3
2	-3.87894	36.01853	1220	W17tree no 16	8/18/2019 15:43	Tarangire	dbh 105 cm ht 18 m seed 1 bra 1 healthy 2
3	-3.87825	36.018283	1214	W17tree no 17	8/18/2019 15:46	Tarangire	dbh 140 cm ht 20 m seed 2 bra 1 healthy 4
4	-3.876203°	36.017283°	1181	W18tree no 18	8/18/2019 16:36	Tarangire	dbh145 cm ht 20 m seed 2 bra 1 healthy 3
5	-3.876253°	36.014844°	1167	W118 tree no 18b	8/18/2019 17:16	Tarangire	dbh 130 cm ht 15 m seed 2 bra1 healthy 3

Name of recorder: John Mtika

Date: 8/15/2019 Signature:…………………………

Appendix 2: Nursery seedling traits

Provenance: Ruaha- Iringa															
Seedling Number	**Day 30**			**Day 45**			**Day 60**			**Day 90**			**Day 105**		
	Shoot Length in (mm)	**Number of Leaves**	**Coller Diameter in (mm)**	**Shoot Length in (mm)**	**Number of Leaves**	**Coller Diameter in (mm)**	**Shoot Length in (mm)**	**Number of Leaves**	**Coller Diameter in (mm)**	**Shoot Length in (mm)**	**Number of Leaves**	**Coller Diameter in (mm)**	**Shoot Length in (mm)**	**Number of Leaves**	**Coller Diameter in (mm)**
1	99.39	5	12.98	105	5	14.52	108	5	17.14	107	5	16.85	109	5	18.09
2	120.18	6	9.11	122.67	6	9.26	123.97	6	9.54	125	6	6.28	0	0	0
3	114.31	5	13.01	115.06	5	14.79	116.76	5	15.25	124	5	17.8	126	5	18.01
4	149.07	10	15.2	152.86	11	17.37	155.78	11	19.07	157	12	21.54	164	12	23.07
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	100.75	4	12.23	101	5	15.19	103	5	16.03	105	5	17.62	106	5	18.53
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	26.14	1	11.03	28.17	1	11.88	30.34	1	12.53	31.2	1	9.78	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	54.88	3	4.23	58.83	4	4.8	63.42	4	5.22	66	4	9.17	69	5	10.17
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	132.55	6	12.4	134.06	7	15.53	135.98	7	16.27	143	7	18.84	145	7	20.5
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	87.73	5	10.56	88.77	5	13.24	90.24	5	15.57	95	5	16.4	99	5	17.18
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	134.87	5	12.61	141.21	7	13.52	147.53	7	16.11	154	7	16.33	155	7	17.33
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	147.45	5	12.31	151.11	5	15.17	153.2	6	17.41	161.2	6	18.07	164	6	18.49
27	72.75	6	9.79	82.53	6	11.63	83.56	6	14.92	84	6	13.16	96	6	14.29
28	67.24	5	7.9	72.95	5	8.47	77.63	5	9.07	92	5	9.3	92	6	9.7
29	146.82	7	11.97	147.81	7	15.88	150.08	7	17.94	159.1	7	20.12	162	7	20.83
30	128.3	7	11.42	130.18	7	14.62	133.65	7	17.18	136	7	17.21	140	7	17.26
31	100.47	6	16.31	101.21	6	16.34	103.1	6	16.48	110	6	16.91	113	6	20.75
32	114.42	4	12.61	116.94	4	13.31	118.54	4	14.08	119	4	16.7	119	5	17.6
33	99.95	5	11.97	100.1	5	12.93	100.8	5	13.21	106	5	13.6	124	5	13.58
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	74.12	4	13.42	75.05	4	13.62	76.67	4	14.28	82	4	16.2	86	4	16.46
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Provenance: Ruaha- Iringa															
Seedling Number	Day 30			Day 45			Day 60			Day 90			Day 105		
	Shoot Length in (mm)	Number of Leaves	Coller Diameter in (mm)	Shoot Length in (mm)	Number of Leaves	Coller Diameter in (mm)	Shoot Length in (mm)	Number of Leaves	Coller Diameter in (mm)	Shoot Length in (mm)	Number of Leaves	Coller Diameter in (mm)	Shoot Length in (mm)	Number of Leaves	Coller Diameter in (mm)
38	124.25	7	13.87	127.93	7	14.06	129.21	7	15.85	129	7	17.22	137	7	18.16
39	143.49	5	16.21	153.4	5	16.64	160.2	5	17.32	181	5	17.52	186	6	18.54
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41	120.71	7	11.23	125.32	7	16.37	127.23	7	19.44	144	7	19.5	144	7	20.17
42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45	142.45	8	10.67	153.29	9	15.54	157.54	9	16.45	161	9	17.97	167	9	18.07
46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
48	73.32	5	5.64	74.59	5	6.57	78.23	5	7.14	80	5	10.69	104	6	8.41
49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50	90.26	3	10.47	93.84	3	14.52	95.32	3	17.89	98	3	16.53	103	3	16.67
51	146.34	8	10.34	150.1	9	11.92	153.39	9	12.56	173	9	14.1	177	9	15.85
52	113.46	5	11.76	115.26	5	12.54	116.34	5	13.86	117	5	14.7	129	6	15.84

53	149.49	7	10.27	151.4	7	12.88	154.54	7	14.58	191	9	15.09	93	9	15.9
54	126.76	6	14.37	137.54	6	16.18	139.34	6	17.31	150.3	6	19.1	153	6	19.2
55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56	96.39	6	14.1	98.89	6	15.6	101.23	6	16.3	115	6	17	118	6	18.04
57	110.41	6	12.14	115.7	6	14.63	116.46	6	15.93	120	6	16.09	124	6	16.77
58	113.32	6	10.21	114.26	6	15.86	118.97	6	19.36	124	6	17.1	127	6	18.42
59	121.36	6	11.79	128.42	7	13.04	133.44	8	15.73	151	9	16.39	153	9	16.81
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61	110.42	5	10.04	112.37	5	15.83	115.34	5	19.88	126	5	18.78	126	5	19.1
62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
63	110.38	4	11.92	112.98	6	13.37	114.65	6	15.64	136	6	17.31	138	6	17.79
64	134.63	5	14.09	137.71	5	14.51	139.45	5	15.45	143	5	15.78	145	5	17.75
65	55.04	0	8.9	63.43	0	9.51	77.54	0	10.21	80	0	11.08	89	0	20.35
66	50.27	5	7.93	51.31	5	8.63	54.37	5	9.32	92	5	9.96	85	5	10.92
67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
71	65.34	6	6.47	68.54	6	8.26	72.34	6	8.98	83	7	12.68	91	7	16.02

72	120.01	6	13.77	125.75	6	15.48	127.58	6	16.87	130	6	18.36	136	6	18.74
73	95.39	6	16.21	104.67	6	18.66	109.3	6	18.76	136	6	20.27	136	6	21.27
74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75	56.67	6	10.9	58.1	6	11.28	59.91	6	12.43	120	6	13.54	123	6	15.98

Provenance: Tarangire - Manyara

Seedling Number	Day 30			Day 45			Day 60			Day 90			Day 105		
	Shoot Length in (mm)	Number of Leaves	Coller Diameter in (mm)	Shoot Length in (mm)	Number of Leaves	Coller Diameter in (mm)	Shoot Length in (mm)	Number of Leaves	Coller Diameter in (mm)	Shoot Length in (mm)	Number of Leaves	Coller Diameter in (mm)	Shoot Length in (mm)	Number of Leaves	Coller Diameter in (mm)
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	148.06	7	14.54	149.05	9	17.08	153.36	11	18.25	160	11	20.14	168	11	21.56
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	142.12	6	10.15	142.5	7	15.24	147.77	7	16.82	161	7	20.36	161	7	22.71
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	130.45	8	12.2	132.17	8	14.98	140.24	8	17.05	149	9	17.32	156	9	17.09
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	124.3	7	17.2	126.83	7	18.69	133.15	7	19.83	136	7	21.26	137	7	21.96
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	114.56	6	11.82	115.98	6	13.7	116.91	6	14.32	122	6	15.6	126	6	17.41
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	89.32	5	12.07	92.8	5	13.21	93.53	6	14.68	95	6	15.16	103	6	21.93
27	113.91	9	11.2	115.07	9	15.36	120.99	9	16.04	127	9	17.45	127	9	18.11
28	75.51	3	12.3	80.15	3	12.82	86.01	3	13.6	91	3	13.93	93	3	15.29
29	101.05	6	13.27	107.05	7	15.05	117.01	9	15.69	124	9	16.87	124	9	15.73
30	130.31	6	9.89	131.26	6	10.81	132.85	6	11.33	126.2	6	12.3	145	6	12.49
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

32	106.88	6	9.82	109.88	8	13.24	118.76	8	13.64	119	8	15.1	120	8	17.58
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	98.15	6	13.82	100.34	6	15.14	110.98	6	14.65	116	6	16.35	117	9	20.35
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Provenance: Tarangire- Manyara															
Seedling Number	**Day 30**			**Day 45**			**Day 60**			**Day 90**			**Day 105**		
	Shoot Length in (mm)	**Number of Leaves**	**Coller Diameter in (mm)**	**Shoot Length in (mm)**	**Number of Leaves**	**Coller Diameter in (mm)**	**Shoot Length in (mm)**	**Number of Leaves**	**Coller Diameter in (mm)**	**Shoot Length in (mm)**	**Number of Leaves**	**Coller Diameter in (mm)**	**Shoot Length in (mm)**	**Number of Leaves**	**Coller Diameter in (mm)**
41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45	118.56	8	14.31	121.26	10	17.84	122.87	10	18.27	125	10	20.1	164	10	20.6
46	117.67	6	12	118.56	6	15.42	120	6	15.03	121	6	16.35	127	6	17.22
47	91.48	7	11.84	94.45	7	11.91	97.01	7	12.82	99.2	7	15.82	110.2	7	15.56
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50	95.42	7	10.93	99.69	7	11.93	106.13	7	13.56	112	7	15.4	113	8	16.32
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
52	113.13	6	11.47	115.4	6	16.75	120.63	8	17	125	8	18.32	133	8	19.3
53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54	115.05	6	12.6	122.63	9	12.76	135.67	9	13.25	147.6	9	14.3	155	9	18.22
55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56	95.12	5	13.63	100.64	5	17.07	104.74	5	17.31	113	5	18.21	114	5	20.16
57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
58	125.84	6	11.9	127.07	7	12.34	136.32	8	13.21	141.3	8	13.7	144	8	17.84
59	123.23	7	14.01	125.2	7	17.81	134.07	7	18.12	139	7	18.9	143	7	21.04
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61	76.07	4	11.35	80.59	4	16.65	83.68	4	17.1	155.6	4	18.5	83	4	18.8
62	133.86	5	14	138.79	7	14.65	146.47	7	14.36	157	7	14.69	155	8	16.69
63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
64	110.6	6	12.69	111.64	7	17.41	115.74	8	16.82	127	8	18.6	129	8	20.27
65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
67	143.92	6	14.58	144.52	6	15.27	146.69	6	15.94	157	6	16.43	157	6	17.55
68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
70	74.05	5	10.3	74.56	5	11.06	75.32	5	11.35	79	5	12.35	84	5	13.7
71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
72	128.07	7	12.81	131.23	7	14.24	132.76	7	14.19	135	7	14.35	156	7	15.16
73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Provenance: Kigwe-Dodoma															
Seedling Number	**Day 30**			**Day 45**			**Day 60**			**Day 90**			**Day 105**		
	Shoot	**Number of**	**Coller**	**Shoot**	**Number of**	**Coller**	**Shoot**	**Number of**	**Coller**	**Shoot**	**Number of**	**Coller**	**Shoot**	**Number of**	**Coller**
	Length in (mm)	**Leaves**	**Diameter in (mm)**	**Length in (mm)**	**Leaves**	**Diameter in (mm)**	**Length in (mm)**	**Leaves**	**Diameter in (mm)**	**Length in (mm)**	**Leaves**	**Diameter in (mm)**	**Length in (mm)**	**Leaves**	**Diameter in (mm)**
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	131.99	6	11.15	133.54	8	15.98	135.43	8	17.34	140	8	18.61	142	8	20.45
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	67.5	2	14.05	68.34	4	15.97	70.61	4	17.02	78	4	14.26	86	4	16.92
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	107.51	7	17.24	110.72	7	18.18	112.65	7	18.98	124	7	22.22	129	7	23.37
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	66.43	7	9.04	90.12	8	10.23	92.73	8	11.23	110	9	17.79	118	9	12.01
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	48.1	6	12.51	57.84	7	14.86	63.43	7	15.21	66	7	18.94	66	7	11.07
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	126.68	6	15.05	128.91	6	16.8	130.2	6	17.08	137	6	18.03	138	6	18.51
34	143.49	8	15.01	153.34	9	16.19	156.21	9	18.21	180	9	18.64	184	9	19.62
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	128.62	4	15.83	128.65	5	17.11	130.01	6	18.37	135	6	18.86	137	7	19.44
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Provenance: Kigwe-Dodoma															
Seedling Number	**Day 30**			**Day 45**			**Day 60**			**Day 90**			**Day 105**		
	Shoot	**Number of**	**Coller**	**Shoot**	**Number of**	**Coller**	**Shoot**	**Number of**	**Coller**	**Shoot**	**Number of**	**Coller**	**Shoot**	**Number of**	**Coller**
	Length in (mm)	**Leaves**	**Diameter in (mm)**	**Length in (mm)**	**Leaves**	**Diameter in (mm)**	**Length in (mm)**	**Leaves**	**Diameter in (mm)**	**Length in (mm)**	**Leaves**	**Diameter in (mm)**	**Length in (mm)**	**Leaves**	**Diameter in (mm)**
38	109.03	6	16.06	120.41	6	17.29	120.56	6	18.64	121	6	18.82	125	6	19.9
39	99.33	7	14.96	99.35	7	15.75	100.71	7	17.15	118	7	17.25	117	7	18.07
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46	136.09	6	13.47	153.33	8	14.16	155.34	9	14.76	170.8	9	16.04	182	9	16.54
47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
53	133.58	9	10.96	135.49	9	11.18	136.94	9	12.85	143	10	14.66	147	10	16.01
54	121.11	7	15.03	121.17	7	15.53	124.24	9	17.09	134	7	21.1	136	7	15.77
55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56	99.86	7	15.45	110.1	7	17.1	113.45	7	18.53	133	7	18.67	131	7	20.11
57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60	132.61	6	14.77	140.27	7	16.09	142.8	7	16.69	144	7	20.99	147	7	21.84
61	153.49	6	15.72	153.57	6	16.34	156.05	6	17.16	185	6	17.81	194	6	20.71
62	102.73	5	14.68	103.92	5	14.98	105.03	5	15.32	111	5	15.51	115	6	16.42

63	153.48	7	12.71	153.5	9	13.58	155.61	9	14.26	179	9	15.75	181	9	17.96
64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
67	113.22	3	16.53	115.22	6	16.67	116.54	6	17.29	133	6	17.59	137	6	17.81
68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
69	143.89	6	12.48	153.7	8	15.08	158.43	8	17.84	183	8	18.99	184	8	19.86
70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
71	146.49	4	11.33	150.13	6	12.01	153.1	6	14.17	155	6	17.03	161	6	17.9
72	111	6	12.31	118.42	9	15.11	119.92	9	15.66	173	9	15.85	177	9	17.35
73	116.24	6	12.03	117.18	6	15.07	117.89	6	16.8	121	6	17.55	126	6	19.3
74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Name of recorder: George Ngatema

Date:17/02/2020 Signature:…………………………

Appendix 3: Measurement of fruit length and width of *Entandophragma bussei*

Provenance: Ruaha-Iringa

No.	Length (cm)				Width (cm)			
	R1	R2	R3	R4	R1	R2	R3	R4
1	8.14	8.13	7.64	8.15	3.6	2.9	2.9	3.7
2	7	8.18	7.3	7.05	3.02	2.8	2.8	3.3
3	8.05	8.2	7.5	8.1	3.8	2.6	2.6	3.8
4	7.35	7.64	7.33	7.66	3.4	2.81	2.81	3.4
5	7.35	7.22	8.1	7.35	2.89	3.2	3.2	2.89
6	7.15	7.1	7.22	7.15	3.9	2.6	2.6	2.86
7	8.13	8.1	7.6	8.15	3.9	2.6	2.6	3.9
8	7.66	7.25	7.3	7.66	2.91	2.6	2.62	2.88
9	7.88	7.45	7.21	7.2	2.98	2.6	2.6	2.95
10	7.1	8.05	8.22	7.15	3.14	3.8	3.8	3.1
11	8.2	7.5	8.14	8.25	3.9	3.2	3.2	3.8
12	8.14	7.53	7.5	8.16	3.4	2.65	2.65	3.4
13	7.83	8.1	8	7.5	2.67	3.4	3.4	2.65
14	8	7.22	7.52	7.18	3.4	2.61	2.61	2.91
15	7.53	7.53	8.05	7.61	2.61	3.7	3.7	3.4
16	8.05	7,16	7.38	7.25	3.7	2.82	2.82	2.63
17	7.4	7.18	7.2	8.26	2.88	2.7	2.7	3.7
18	7.2	7.03	7.64	8.2	2.77	3.5	3.5	3.8
19	7.62	7.15	7.35	7.35	3.6	2.82	2.82	2.86
20	7.38	8.1	7.16	7.38	2.84	2.6	2.6	2.64
21	7.15	8	7.48	7.6	2.8	2.2	2.2	2.92
22	7.48	7.2	8.15	8.1	2.24	3.9	3.9	3.1
23	7.21	7	7.1	8.16	2.61	3	3	3.8
24	7.36	8.16	7.55	7.44	2.66	2.69	2.69	2.2
25	7.61	7.25	7.66	7.37	2.62	2.64	2.64	2.81
Average	7.5988	7.59458	7.572	7.6572	3.7	2.9176	2.9184	3.176

Name of recorder: Mwamtoro Said
Date:18/10/2019 Signature:…………………………

Provenance: Kigwe -Dodoma

No.	Length (cm)				Width (cm)			
	R1	R2	R3	R4	R1	R2	R3	R4
1	6.8	7.1	6.5	6.1	2.11	3.8	1.8	1.5
2	5.11	5.9	6.5	6.2	1.9	1.6	1.7	1.7
3	7	7	6.5	5.6	3.7	3.3	1.8	1.8
4	6.3	6.6	6.6	5.5	1.9	1.7	1.7	1.6
5	7.2	6.6	6.6	6.3	3.9	1.7	1.7	1.5
6	5.8	6.4	6.5	7.4	1.6	1.8	1.7	3.9
7	5.9	5.7	7	6.6	1.7	1.5	3.8	1.6
8	5.8	5.8	7.04	5.8	1.5	1.3	3.3	1.5
9	7.01	6.2	7.3	5.18	3.5	1.4	2.7	1.7
10	7	7.1	6.4	5.8	3.6	2.6	1.6	1.8
11	6.3	7.1	5.8	5.8	1.7	2.5	1.6	1.5
12	6.5	7.1	5.7	1.7	1.8	2.6	1.5	1.6
13	6.6	5.7	5.4	5.7	1.7	1.5	1.6	1.7
14	7.2	5.7	5.6	6.2	2.9	1.5	1.5	1.8
15	5.7	5.8	6.2	6.7	1.5	1.3	1.6	2.12
16	5.8	5.8	5.7	5.8	1.5	1.5	1.5	1.6
17	5.8	5.8	5.8	5.15	1.3	1.7	1.5	1.9
18	5.8	6.5	5.7	5.7	1.7	1.8	1.5	1.5
19	5.14	6.5	7	5.8	1.7	1.7	3.5	1.5
20	5.8	5.4	5.8	5.8	1.6	1.6	1.5	1.6
21	6.2	5.8	5.7	6.4	1.5	1.5	1.5	1.6
22	7.1	7	6.3	6.2	2.6	3.7	1.7	1.6
23	5.4	6.4	6.2	5.8	1.7	1.5	1.5	1.8
24	6.3	6.2	5.8	5.7	6.3	1.6	1.6	1.5
25	6.1	5.1	5.9	5.8	6.5	1.6	1.7	1.6
Average	6.2264	6.252	6.2216	5.7892	2.4564	1.932	1.884	1.7408

Name of recorder: Mwamtoro Saidi

Date:18/10/2019 Signature:……………………………………

Provenance: Tarangire - Manyara

No.	Length (cm)				Width (cm)			
	R1	R2	R3	R4	R1	R2	R3	R4
1	6.6	7	6.7	6.7	2.7	3	2	1.84
2	6.6	5.6	6.6	6.6	2.7	1.6	2	2.4
3	6.9	7.01	7.02	7.02	2.1	3.2	1.7	3
4	6.6	7.7	6.9	6.9	2.5	3.2	2.5	1.8
5	6.7	6.9	6.7	6.7	2.03	1.7	2.5	1.9
6	6.9	6.9	6.7	6.7	1.8	2	1.8	2.01
7	6.9	6.7	6.6	6.6	1.8	2.01	3	2.6
8	7.01	6.6	6.6	6.6	3.2	2.4	1,8	2.6
9	7	6.8	6.9	6.9	3	1.1	2	1.7
10	5.6	6.8	6.7	6.7	1.7	2.02	1.9	2
11	6.7	6.8	6.8	6.8	2	2	2.5	2.1
12	6.7	6.7	6.7	6.7	2	2.1	2.1	1.9
13	5.8	7.04	6.4	6.4	1.9	3	2	1.3
14	5.9	6.7	6.7	6.7	1.7	1.8	2.1	2.5
15	6.6	7.4	6.8	6.8	2.4	1.6	1.7	1.8
16	6.7	6.7	7.1	7.1	2.4	1.7	1.3	3.3
17	6.8	6.7	6.6	6.6	2.01	2.4	1.6	2.5
18	6.7	5.8	6.8	6.8	1.9	1.7	3.3	1.8
19	6.6	6.9	5.9	5.9	2.5	2	2.5	1.8
20	6.6	6.8	5.7	5.7	2.5	1.7	2	2.2
21	6.1	6.7	6.7	6.7	2.1	1.9	1.6	1.9
22	6.8	6.8	5.6	5.6	1.8	2.7	1.8	1.7
23	6.4	6.6	7.1	7.1	1.8	2.7	1.9	3.2
24	6.6	6.9	6.8	6.8	2.5	1.8	1.7	1.8
25	6.7	6.7	5.7	5.7	1.91	2	1.8	1.9
Average	6.5804	6.77	6.5928	6.5928	2.198	2.1332	2.05417	2.142

Name of recorder: Mwamtoro Saidi

Date:18/10/2019 Signature:…………………………………

Appendix 4: Measurement of seed length and width of *Entandophragma bussei*

Provenance: Kigwe - Dodoma

No.	Length (cm)				Width (cm)			
	R1	R2	R3	R4	R1	R2	R3	R4
1	24.67	20.32	21.77	0.28	19.68	13	15.1	0.12
2	21.8	21.72	21.77	20.01	15.19	14.09	15.11	15.1
3	17	21.44	24.4	17.1	10	13.01	19.5	15
4	19	23.11	21.8	21.62	11	18.16	1.16	14.1
5	0.17	21.11	22.48	23.18	0.12	13.13	17.32	19.12
6	20	23.18	20.1	21.8	15.13	19.22	14.1	11.2
7	23.18	21.8	23.18	22.4	19.2	15.19	19.22	19.6
8	24.44	17	21.4	21.72	19.11	10.01	12.04	14.07
9	21.68	17	21.8	21.77	14.11	15	14.2	15.13
10	21.77	0.19	22.61	21.75	15.11	0.11	16.11	15.05
11	21.8	19	22.8	17.15	15.19	11.01	17.6	14.3
12	20.11	0.26	21.68	17.1	15.11	0.17	14.11	15
13	0.22	0.17	21.8	19	0.16	0.11	15.1	11.4
14	0.19	23.66	22.52	20.32	0.11	19.44	17.1	13
15	24.62	22.66	17.15	20.13	19.61	17.4	15.2	15.1
16	21.8	20.14	24.66	24.6	15.11	19.08	19.68	18.6
17	19	21.77	20.14	24.66	11.2	15.11	15.1	19.62
18	22.66	21.8	20.33	23.18	17.4	15.15	13	19.22
19	17.1	24.62	21.72	20.14	15	19.61	14.09	15.1
20	21.44	23.18	23.11	21.4	13.01	18.26	18.14	12.02
21	21.72	20.11	17	22.55	14.16	15.11	11.02	16.3
22	23.11	19	22.6	22.65	18.16	11	16.4	18.17
23	21.11	24.67	19	17.1	13.13	19.66	10	14.7
24	20.32	22.6	21.72	17.15	13	17.4	14.1	15
25	21.8	21.8	21.14	21.72	15.19	18.17	12.14	14.09
Average	18.8284	18.8924	21.5472	20.0192	13.3676	13.904	14.6656	14.8044

Name of recorder: Mwamtoro Said

Date:18/12/2019 Signature:…………………………………

Provenance: Ruaha - Iringa

No.	Length (cm)			Width (cm)				
	R1	R2	R3	R4	R1	R2	R3	R4
1	26.31	23.4	27.1	22.8	19.15	18.23	15.74	16.7

2	26.15	25.55	23.25	26.25	18.68	16.66	14.2	18.2
3	27.18	23.24	23.21	24.25	17.51	16.4	14.24	20.1
4	27.18	27.22	24.67	27.22	16.91	17.3	19.5	16.65
5	23.2	27.12	24.67	23.2	17.18	15.7	19.57	14.4
6	22.9	24.9	24.67	27	16.82	20.1	19.5	18.2
7	26.2	24.86	22.9	27.1	18.29	17.44	17.9	16.8
8	23.27	23.24	26.15	24.8	16.48	17	17.25	16.6
9	24.67	26.1	26.15	24.86	19.57	17.3	17.33	17.2
10	26.2	25.86	22.5	27.2	18.2	17.6	16.65	14.1
11	31.25	30.2	22.57	26.3	14.74	14.7	16.7	16.6
12	25.9	25.86	27.2	26.3	17.95	16.6	17.5	17.7
13	27.13	25.86	27.22	23.2	16.68	17.22	17.6	16.4
14	26.3	27.18	24.66	23.27	18.26	16.9	18.54	16.5
15	25.86	27.18	24.59	25.66	17.22	16.91	18.6	16.6
16	24.96	26.31	25.86	26.2	20.11	19.15	16.2	18.5
17	23.44	22.9	25.86	26.25	18.25	16.8	17.22	18.25
18	23.2	22.91	25.86	22.61	15.17	16.82	17.22	16.8
19	27.22	25.8	23.2	26.15	17.65	17	18.25	18.62
20	26.1	25.85	23.21	24.77	17.33	17.22	14.2	19.51
21	23.21	22.59	26.12	24.67	14.25	16.7	17.3	18.55
22	27.12	24.67	26.1	24.67	15.74	19.56	16.45	19.57
23	25.6	23.2	25.54	23.2	16.85	18.29	15.7	16.17
24	23.24	27.1	24.62	24.6	16.4	15.7	18.6	17.2
25	22.59	24.96	28.1	27.18	16.7	20.1	16.64	17.35
Average	25.4552	25.3624	25.0392	25.1884	17.2836	17.336	17.144	17.3308

Name of recorder: Mwamtoro Said

Date:18/12/2019 Signature:………………………………

Provenance: Tarangire - Manyara

No.	Length (cm)				Width (cm)			
	R1	R2	R3	R4	R1	R2	R3	R4
1	0.17	0.18	0.18	0.17	0.12	0.15	0.14	0.8
2	1.02	0.16	0.16	0.14	0.11	0.11	0.6	0.7

3	0.18	1.04	1.04	0.14	0.13	0.1	0.12	0.5
4	0.14	0.12	0.15	0.17	0.8	0.7	0.7	0.8
5	0.14	0.14	0.14	0.17	0.8	0.7	0.8	0.12
6	0.14	0.17	0.14	0.14	0.6	0.8	0.7	0.6
7	0.8	0.19	0.14	0.18	0.12	0.8	0.6	0.13
8	1.01	0.17	0.14	0.8	0.7	0.7	0.6	0.7
9	0.18	1.02	0.14	0.18	0.8	0.12	0.7	0.8
10	0.18	0.18	1.02	0.19	0.8	0.8	0.12	0.7
11	0.9	0.7	0.18	0.17	0.8	0.7	0.8	0.14
12	0.19	0.17	0.18	0.19	0.7	0.12	0.8	0.8
13	0.18	0.17	0.9	0.17	0.11	0.11	0.8	0.14
14	0.18	0.18	0.9	0.18	0.13	0.12	0.7	0.8
15	0.14	0.17	0.9	1.03	0.7	0.7	0.8	0.12
16	0.14	0.16	0.18	0.9	0.8	0.8	0.1	0.8
17	0.14	0.16	0.18	0.17	0.8	0.7	0.13	0.12
18	0.17	0.18	0.18	0.17	0.14	0.11	0.11	0.14
19	0.14	0.14	0.14	0.19	0.8	0.8	0.7	0.8
20	0.19	1.01	0.14	0.18	0.8	0.8	0.8	0.11
21	0.14	0.17	0.17	0.18	0.8	0.8	0.14	0.13
22	0.17	0.17	0.14	0.14	0.8	0.8	0.7	0.8
23	0.14	0.18	0.14	0.14	0.5	0.1	0.8	0.5
24	0.14	0.17	0.17	0.17	0.8	0.1	0.8	0.8
25	0.17	0.17	0.14	0.18	0.8	0.8	0.1	0.13
Average	0.2836	0.2908	0.3156	0.2576	0.5784	0.5016	0.5344	0.4872

Name of recorder: Mwamtoro Said

Date:18/12/2019 Signature:………………………………………

Appendix 5: Measurements of moisture contents

Ruaha -Iringa
Measurement of Mosture content

Weight of	Weight of	Dried	% Moisture
Empty container (EC)	Container+ 5gms of seeds (EC+S)	(EC+S)	Content
69.7	74.7	74.38	6.4
62.58	67.58	67.3	5.6
70.01	75.01	74.69	6.4
68.09	73.09	72.73	7.2

Tarangire - Manyara			
Measurement of Mosture content			
Weight of	Weight of	Weight of	Moisture
Empty container	Container+ 5gms of seeds	Container+ 5gms of seeds	Content (%)
69.58	74.58	74.3	5.6
69.8	74.8	74.52	5.6
70.35	75.35	75.04	6.2
70.7	75.71	75.41	6.0

Kigwe - Dodoma			
Measurement of Mosture content			
Weight of	Weight of	Weight of	Moisture
Empty container	Container+ 5gms of seeds	Container+ 5gms of seeds	Content (%)
61.92	66.92	66.6	6.4
69.88	74.88	74.56	6.4
69.5	74.5	74.24	5.2
68.49	73.49	73.21	5.6

Formula:

$$\textbf{Percentage Mosture content (\%MC)} = \frac{\mathbf{(M2 - M3) \times 100}}{\mathbf{(M2 - M1)}}$$

Whereby

M1 = Weight of empty container

M2 = Weight of a container plus seeds before drying

M3 = Weight of a container plus seeds after drying

M2 - M3 = Moisture loss

M2 -M1 = Fresh weight of a seed sample

Appendix 6: Seed Germination Test Results

Kigwe -Dodoma															
Replicate 1				**Replicate 2**				**Replicate 3**				**Replicate 4**			
Number of days	**Normal**	**Abnormal**	**Dead**	**Day of days**	**Normal**	**Abnormal**	**Dead**	**Day of days**	**Normal**	**Abnormal**	**Dead**	**Day**	**Normal**	**Abnormal**	**Dead**
12	15	0	0	12	15	0	0	12	18	0	0	12	17	0	0
14	18	0	0	14	20	0	0	14	19	0	0	14	24	0	0
16	18	0	0	16	21	0	0	16	19	0	0	16	24	0	0
24	19	0	0	24	22	0	0	24	19	0	0	24	24	0	0
28	19	0	0	28	22	0	0	28	19	0	0	28	24	0	0
30	19	0	0	30	22	0	0	30	20	0	0	30	24	0	0
32	19	0	0	32	22	0	0	32	20	0	0	32	24	0	0
34	19	0	6	34	22	0	3	34	20	0	5	34	24	0	1
Ruaha -Iringa															
Replicate 1				**Replicate 2**				**Replicate 3**				**Replicate 4**			
Number of days	**Normal**	**Abnormal**	**Dead**	**Day of days**	**Normal**	**Abnormal**	**Dead**	**Day of days**	**Normal**	**Abnormal**	**Dead**	**Day**	**Normal**	**Abnormal**	**Dead**
12	13	0	0	12	17	0	0	12	9	0	0	12	18	0	0
14	14	0	0	14	19	0	0	14	12	0	0	14	14	0	0
16	14	0	0	16	20	0	0	16	13	0	0	16	15	0	0
24	16	0	0	24	20	0	0	24	13	0	0	24	16	0	0
28	16	0	0	28	20	0	0	28	13	0	0	28	16	0	0
30	16	0	0	30	20	0	0	30	13	0	0	30	16	0	0
32	16	0	0	32	22	0	0	32	13	0	0	32	16	0	0
34	16	0	9	34	22	0	3	34	13	0	12	34	16	0	9
Tarangire -Manyara															
Replicate 1				**Replicate 2**				**Replicate 3**				**Replicate 4**			
Number of days	**Normal**	**Abnormal**	**Dead**	**Day of days**	**Normal**	**Abnormal**	**Dead**	**Day of days**	**Normal**	**Abnormal**	**Dead**	**Day**	**Normal**	**Abnormal**	**Dead**
12	14	0	0	12	16	0	0	12	9	0	0	12	9	0	0
14	14	0	0	14	19	0	0	14	13	0	0	14	14	0	0
16	22	0	0	16	20	0	0	16	15	0	0	16	17	0	0
24	24	0	0	24	20	0	0	24	16	0	0	24	19	0	0
28	24	0	0	28	20	0	0	28	16	0	0	28	19	0	0
30	24	0	0	30	20	0	0	30	16	0	0	30	19	0	0
32	24	0	0	32	20	0	0	32	16	0	0	32	19	0	0
34	24	0	1	34	20	0	5	34	16	0	9	34	19	0	6

Name of recorder: Mwamtoro Said

Date:16/1/2020 Signature:……………………………………….

Appendix 7: Measurement of daily room Temperature at TSPC Laboratory

Month: 18/12/2019

Daily Temperature

Day	Maximum $T^{O}C$	Minimum $T^{O}C$
1	39	23
2	39	25
3	40	23
4	40	25
5	41	25
6	38	21
7	38	20
8	40	23
9	40	23
10	40	22
11	40	23
12	40	23
13	40	22
14	40	22
15	40	20
16	38	22
17	40	23
18	40	23
19	40	23
20	40	23
21	40	23
22	40	23
23	40	23
24	40	10
25	48	10
26	48	10
27	48	10
28	48	12
29	48	14
30	48	14
31	48	10
32	47	10
33	47	14
34	47	14
35	47	14
36	47	4
37	37	4
38	37	4
39	37	4
40	37	4
41	37	4
42	37	4
43	37	4
Average	41.46511628	16.20930233

Name of recorder: Mwamtoro Said

Signature:

Date:…………/……/………………………………… ……………………………

Appendix 8: Measurement of seed weight of *Entandophragma bussei*

Provenance: Tarangire - Manyara

No.	Length (cm)				Width (cm)			
	R1	R2	R3	R4	R1	R2	R3	R4
1	17.43	18.01	17.66	19.26	18.52	17.63	19.1	18.44
2	19.5	17.66	18.2	18	18.01	19.04	18.2	18.22
3	18.59	17.79	17.88	17.14	17.88	18.66	19.26	18.08
4	18.57	18.37	18.66	18.39	20.14	18.22	18.72	19.11
5	19.32	18.04	19.08	19.61	20.08	18.33	18.74	18.39
6	19.63	17.51	18	18.03	18.91	18.5	19.16	18.12
7	18.74	18.11	18.01	17.42	20.41	19.01	18.78	18.92
8	20.1	17.96	17.22	18.04	17.59	18.23	19.57	20.01
9	18.91	18.03	18.71	17.94	18.34	18.19	18.42	18.17
10	18.75	18.22	19	18.03	19.08	19.27	19.24	19.52
11	20.07	19.08	18.31	17.52	18.6	18.53	18.53	18.79
12	18.27	18.36	17.34	18.22	18.22	18.29	17.88	18.84
13	18.88	17.66	17.71	19.66	17.58	18.13	18.71	19.66
14	18.9	18.07	18.34	18.2	19.04	19.2	18.93	20.02
15	20.05	18.44	18.04	17.67	20.11	19.47	19.02	18.37
16	20.09	19.11	17.89	18.09	18.71	18.24	18.29	18.59
17	18.66	18.04	18.36	17.76	18.19	18.43	18.66	18.77
18	19.08	18.3	17.82	18	18.2	19.03	19.28	19
19	18.6	17.88	18.53	17.79	19.04	18.06	18.33	18.79
20	19.5	16.99	18.17	18.13	18.3	19.16	19	19.52
21	18	18.23	17.91	18	18.44	18	19.53	18.41
22	17.28	18.01	18.07	17.93	19.01	20.13	18.16	19.22
23	18.11	17.36	17.54	17.88	18.17	19.44	17.98	18.56
24	18.33	16.88	18.11	18.31	18.47	18.39	18.67	18.39
25	17.67	18.06	18.02	17.49	19.04	18.26	18.58	18.62
Average	18.8412	18.0068	18.1032	18.1004	18.7232	18.6336	18.7496	18.8212

Name of recorder: Mwamtoro Said

Signature:

Date:…………/……/………………………………… ……………………………

Provenance: Kigwe - Dodoma

No.	Lenngth (cm)				Width (cm)			
	R1	R2	R3	R4	R1	R2	R3	R4
1	21.02	18.71	20.29	21.14	20.11	19.81	20.22	19.46
2	20.04	19.02	21.18	20.86	19.72	20.48	18.57	20.21
3	17.99	18.87	20.66	21	18.66	21.66	20.42	18.44
4	19.84	17.99	21.17	19.46	18.49	18.47	19.79	19.21
5	18.26	18.06	20	18.18	19.51	19.68	20.4	20.51
6	21.29	19.22	18.82	20.01	18.61	19.4	19.33	21.29
7	19.93	17.89	18.86	21.74	19.22	18.29	20.53	20.34
8	20.14	18.58	19.81	20.66	18.91	20.31	20.08	18.77
9	19.51	18.61	20.67	21.01	19.34	21.54	19.62	19.09
10	19.56	19.74	21.08	19.02	19.14	20.72	19.71	19.36
11	18.71	19.82	20.44	18.21	18.54	20.03	18.72	20.48
12	18.86	20.16	21.19	19.3	18.22	19.17	18.33	19.93
13	19.78	21.72	20.38	18.34	19.09	20.27	19.82	18.79
14	19.89	20.19	21.48	19.5	19.31	19.27	20.22	19.5
15	19.55	21.88	20.66	18.44	18.9	20.42	21.51	18.27
16	18.37	18.66	21.37	19.29	18.34	19.4	20.39	19.44
17	18.66	18.79	20.39	21	19.61	20.14	21.01	18.69
18	18.77	19.17	21.5	18.13	18.57	18.61	19.29	18.61
19	19.2	22.27	20.01	17.96	19.71	18.58	19.72	19.39
20	18.88	20,44	18.63	18.3	18.69	19.62	20.17	19.12
21	19.67	21.41	19.2	17.51	19.07	20.08	20.04	20.66
22	20.13	20.94	20.18	18.06	18.83	19.43	19.13	21.01
23	20.34	21.09	20.14	18.18	19.27	19.22	18.67	19.79
24	21.09	20.78	20.09	17.82	18.11	19.31	19.51	18.67
25	18.77	21.14	19.13	19.6	19.22	19.07	19.65	19.19
Average	19.53	19.7796	20.2932	19.3088	19.0076	19.7192	19.794	19.5288

Name of recorder: Mwamtoro Said

Signature:

Date:…………/……/………………………………… ……………………………

Provenance: Ruaha - Iringa

No.	Lenngth (cm)				Width (cm)			
	R1	R2	R3	R4	R1	R2	R3	R4
1	15.55	17.01	16.57	16.68	15.41	16.38	15.89	16.41
2	17.08	16.43	17.01	16.92	17.16	15.78	15.68	15.84
3	18.26	17.22	16.14	16.88	15.88	16.94	16.4	16.37
4	16.88	18.01	15.88	16.94	16.22	17.11	17.76	17.01
5	17.12	16.38	15.72	17.02	16.88	16.81	17.58	16.83
6	17.3	17.66	16.44	16.96	15.79	16.93	16.89	16.77
7	16.74	17.02	17.04	16.56	16.38	15.89	17.14	15.96
8	15.46	16.5	17.53	17.54	15.44	16.71	16.91	16.51
9	16.57	17.22	16.91	18.31	16.88	17.08	15.79	17.08
10	17.8	16.17	15.08	17.53	15.91	16.44	16.29	16.34
11	16.98	18.01	17.3	16.77	16.34	16.37	16.52	15.93
12	16.88	17.34	16.5	17.14	16.39	17.66	16.44	16.63
13	15.08	15.66	17.29	16.63	17.16	16.29	16.81	16.59
14	17.47	16.13	16.82	17.06	18	15.79	17.34	17.32
15	17.62	17.44	17.12	16.21	15.26	16.5	16.93	16.6
16	17.08	16.01	16.44	17.5	15.4	16.41	17.18	16.7
17	16.08	17.64	17.27	16.61	16.71	17.04	16.71	17.66
18	16.77	16.08	16.17	15.96	15.88	16.76	16.87	18.06
19	17.08	14.99	12.02	17.76	17.01	16.54	19.01	15.87
20	17.11	15.36	16.34	17.62	16.51	15.88	16.53	16.53
21	16.22	17.2	17.14	18.31	18.66	16.69	17.22	17.82
22	16.04	18.11	16.2	16.14	15.29	17.34	16.28	16.77
23	15.61	17.44	17.01	17.23	16.82	16.51	16.48	16.68
24	16.88	16.01	16.88	16.92	17.23	17.09	16.2	17.52
25	17.56	15.29	17.11	19.88	16.99	16.81	17.07	17.69

Average								

Name of recorder: Mwamtoro Said

Date:…………/……/………………………………… Signature:……………………………