Chapter

Germination and Seedling Growth of *Entandrophragma bussei* Harms ex Engl. from Wild Populations

Samora M. Andrew, Siwa A. Kombo and Shabani A.O. Chamshama

Abstract

Entandrophragma bussei Harms ex Engl. (wooden banana) is an important indigenous multipurpose tree species endemic to Tanzania. The species has a long history of human use but recent increased utilization pressure, deforestation and high mortality rate of seedlings threaten the survival of natural populations in the wilderness. Therefore, to facilitate domestication, two experimental studies were conducted to evaluate variations in seed germination and seedling growth of three wild populations at the Directorate of Tree Seed Production Laboratories in Morogoro, Tanzania. Germination percentage, mean germination rate, final germination rate and germination index varied significantly among the populations. In terms of seedling growth there was a significant difference in number of leaves among the populations at 3 months of age. The number of course roots and seedling shoot fresh weight varied significantly among the studied populations at 10 months of age. Ruaha population had the highest survival (56%) followed by Kigwe (41%) and Tarangire being the last (36%). The two experiments have clearly demonstrated the existence of considerable variation in germination and seedling growth traits in *E. bussei*. These traits may prove to be important tools for selection of suitable seed sources for domestication and tree improvement programmes.

Keywords: Height, root collar diameter, seed, germination traits, seedling traits, Tanzania

1. Introduction

Although often not pronounced, arid and semi-arid areas are critical areas for biodiversity conservation and as sources of livelihoods to many communities. Of the total area of Tanzania, arid and semi-arid cover more than 74% of total land equivalent to 88.6 million hectares comprising about 74% of plant species found in East Africa [1]. *Entandrophragma bussei* Harms ex Engl. (wooden banana) is a high value multipurpose tree species found in arid and semi-arid areas of Tanzania. It occurs as an emergent species from deciduous *Commiphora* thicket, often associated with *Cordyla densiflora* and *Adansonia digitata* but can also occur in deciduous woodland and bushland, at an elevation range of 785–1220 m [2, 3]. Nearly all parts of the tree are used for certain purposes and the species contributes to rural and urban incomes. The species is found in the Meliaceae family and shares many of the characteristics with genuine mahogany and thus can be used as an alternative. The tree produces heavy timber with good finish and reddish-brown colour and therefore used as source of construction and handicrafts materials [4]. The tree is also used locally as a source of dye and tannin in Tanzania [5]. Research has shown that extracts of the tree parts (roots, leaves and barks) contain secondary metabolites and other lead compounds used as source of medicine to cure diarrhoea, anaemia, worms, hypertension, asthma, urinary infection, trypanosomiasis, chest and abdominal problems, and general ailments [6–10]. Most importantly, the species has been prioritized to be among the top 10 multipurpose tree species to be domesticated by the World Agroforestry Centre in Tanzania [11].

Despite the importance, *E. bussei* is increasingly threatened from over exploitation and deforestation [5]. Next to over exploitation and deforestation, high mortality rate of seedlings due to fire poses another threat to the survival of *E. bussei* populations in the wilderness. Under natural conditions, seeds of *Entandrophragma* germinate abundantly but seedling growth requires light shade environment at initial stages but after sometime they should be exposed gradually to lighter environment [2]. Germination and seedling growth information is available for other *Entandrophragma* species [12, 13], but there is inadequate information for *E. bussei*.

To design effective domestication and tree improvement programmes for high value important species with wide distribution range like *E. bussei*, knowledge on silviculture is necessary. This knowledge will not only help researchers and planners in designing the programmes but other stakeholders including plantation managers and forest and extension officers would use the knowledge to encourage the wide use of the species in afforestation/reforestation projects. This study was therefore designed with the overall objective to evaluate variation in germination and seedling growth from seeds collected in three different agroecological zones of Tanzania. It is hoped that this study will facilitate development of efficient conservation and tree improvement strategies both within and outside the natural habitats of the species. A previous study done by Andrew et al. (*in press*) was the first work to report diversity in fruit and seed morphology of *E. bussei* in Tanzania. The present study supplements the previous one by focusing on variation in seed germination and seedling growth traits of three populations of *E. bussei* found in Tanzania. Differences in germination characteristics depending on climatic zone are commonly observed for widely distributed plant species [14].

2. Materials and methods

2.1 Study area

This study was carried out between February 2020 and January 2021 at the Directorate of Tree Seed Production (DTSP) Laboratories in Morogoro, Tanzania. The DTSP is one of the Directorates of Tanzania Forest Services Agency (TFS) with the mandate to produce, procure and market high quality tree seeds and other propagating materials in Tanzania.

Morogoro region is located at 6.8278° S and 37.6591° E and experience sub-humid climate with average annual temperature of 25°C, annual rainfall of about 935 mm, relative humidity of about 75% and altitude of around 550 m.a.s.l. Seeds of *E. bussei* used in the germination and seedling growth studies were obtained from three sites (**Figure 1**) found in three agroecological zones i.e. arid, semi-arid and southern highlands, respectively (**Table 1**).

2.2 Fruits collection and processing

Fruits were collected from a total of 15 parent plus trees (5 from each site) in the three regions in August 2019 and stored under room temperature at the DTSP

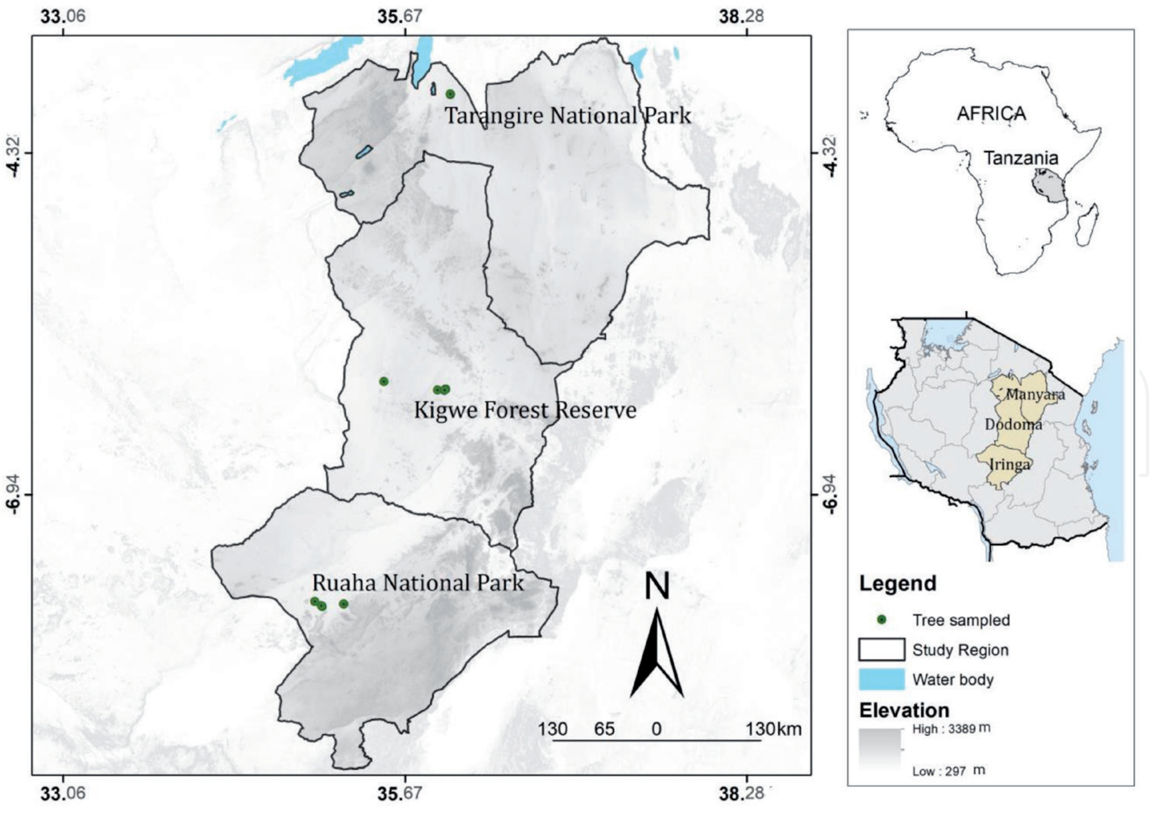

Figure 1.
Map of Tanzania showing location of Entandrophragma bussei *natural populations used in the study.*

Population	Administrative Region	Agroecological zone	Location	Elevation (m)	Rainfall (mm)
Ruaha	Iringa	Southern Highlands	7°75'S, 34°98'E	945	1100
Kigwe	Dodoma	Semi-arid	6°08'S, 35°51'E	1039	650
Tarangire	Manyara	Arid	3°87'S, 36°01'E	1195	550

Table 1.
Site data for the three wild populations of Entandrophragma bussei *used in germination and seedling growth studies in Tanzania.*

until February 2020. The parent trees had heights and diameter at breast heights (DBH) ranging from 15 to 20 m and 54–104 cm, respectively. From each plus tree, 20 ripe fruits without any damage or malformation were collected making 100 fruits per population and 300 fruits for the three populations. The collected fruits were packed and labelled appropriately and transported to DTSP for further processing. Fruits were left to dry under the house shade for 14 days to allow natural opening of the capsules. Seeds were extracted by shaking the capsules using hands and cleaned by hands to remove debris. The extracted seeds were finally stored under shade until time of use for seed germination and seedling growth experiments.

2.3 Germination experiment

Seed germination study was conducted in the germination laboratory at DTSP where temperature ranged from 10–25°C. The experiment was laid out in a randomized arrangement with three populations replicated four times. During the experiment, twelve rectangular germination trays (24 x 18 x 11 cm) that contained sand (that had been washed to remove silt and organic matter) were used for each population. In each tray, 25 cleaned seeds were sown (after the removal of the wings) to a uniform depth of 1 cm making a total of 300 seeds per population and 900 seeds per experiment. The sand was water-irrigated manually twice per day (in the morning and in the evening) to keep the sand continuously moist without becoming waterlogged. Germinated seeds were counted first on the 12th day after seeds were sown and the emergence of a visible protrusion of cotyledons above the substrate surface. During the experiment, the number of dead seeds was also recorded on the 34th day. The seeds count was done for 34 days after which no more germination was observed. At the end of the 34-day observation period, ungerminated seeds were removed and condition of the embryos was physically inspected.

2.4 Seedling growth experiment

Seedling growth experiment was also established in a randomized arrangement with three populations replicated three times to assess the development of *E. bussei* seedlings under nursery conditions. One seed was sown in open end black polythene tube of 6 cm diameter and 11.5 cm depth, filled with woodland soil mixed with sawdust in 3:1 ratio. In this experiment, 75 seedlings for each population were raised. Watering was done using watering can once a day to maintain the ideal soil moisture condition. Assessment of seedling growth traits (i.e. shoot height, root collar diameter and number of leaves per seedling) were conducted on the 30th, 45th, 60th, 90th and 105th days after sowing between April and July 2020. Seedling shoot height (cm) and root collar diameter (mm) were measured using a standard ruler and micro-calliper, respectively. After the 105th day, seedlings were maintained until when they were 303 days (10 months) old when shoot height, root collar diameter, tap root length, total number of course roots per seedling, fresh and dry weights of all course roots and shoots, were assessed from twelve (12) randomly selected individuals of each population. Seedlings had shed the leaves at the time of final assessment thus the leaves were not evaluated at the age of 303 days. To determine root and shoot parameters, the seedlings were removed from the polythene tubes and soil washed off carefully using water in the trays to avoid losing roots. Drying of shoot/stem samples was done in the oven at 95°C to constant weight. Fresh and dry weights (in grams) were then measured using a digital balance.

2.5 Data analysis

Germination period (GP) was determined as number of days from first observed germination (FOG) to where no more germination was observed (NMG) i.e. GP = NMG – FOG [15]. Germination percentage (GC) was determined as the ratio of the total germinated seeds (TGS) to the total of the seeds sown (TSS) i.e. GC = (TGS/TSS) x 100. Germination value (GV) was computed as GV = ($\sum$DGs/N) 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 and 10 = Constant [2, 16].
Mean germination rate (MGR) was calculated as MGR = $\sum$ F/ $\sum$ FX where F = Number of germinated seeds on a particular day and X = Number of days taken for seeds to germinate. Final germination (FG) was computed as FG = GS/ Dt where

DOI: http://dx.doi.org/10.5772/intechopen.97489

GS = Number of seeds germinated when there is no more germination and Dt = Total number of days taken for particular seeds to germinate. Germination index (GI) was obtained from GI = $\sum$ Gt/Dt where Gt = is the number of germinated seeds on day t and Dt = is the time corresponding to Gt in days. We examined assumptions of parametric test for germination and growth traits using standard diagnostic plots in package ggplot2 and Shapiro–Wilk's Test. Growth variables that did not meet the assumptions were log transformed and germination percentage was arcsine transformed to reduce skewness in frequency distribution and to improve homoscedasticity. Comparison in germination and growth traits between populations was done using One-way ANOVA and means were compared by using Tukey's Honestly Significant Difference (Tukey's HSD) post hoc test. Pearson Product Moment Correlation (*r*) was used to evaluate the relationship between different germination and seedling growth traits. Standard diagnostic plots were used to check appropriateness of the models to our data sets. All data analyses were done in R free software version 4.0.3 [17].

3. Results

3.1 Seed germination

Germination in the laboratory started within 12 days for all the populations (**Figure 2**). Gradual increase in seed germination was experienced until day 24 for both Kigwe and Tarangire populations after which germination levelled off (**Figure 2**). However, Ruaha population had the gradual increase in germination up to day 32 after which the germination fell off (**Figure 2**). There was no new seedling that emerged after day 34. Physical examination of the seeds at the end of 34 days germination period revealed that all the un-germinated seeds were rotten. Germination period ranged from 10 to 12 days but was not statistically different

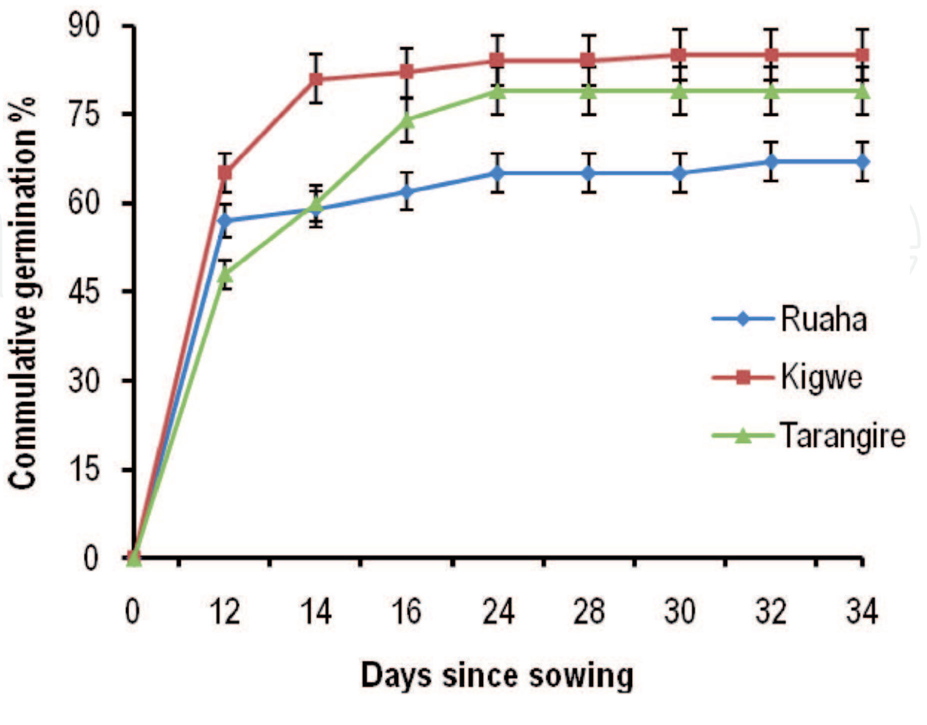

Figure 2.
Germination of seeds of three wild populations of Entandrophragma bussei *in Tanzania. Vertical bars are Standard Errors.*

($P > 0.05$) among the three populations. Ruaha population had the germination period of 12 days followed by Kigwe (11 days) and the least was Tarangire population (10 days).

There were significant differences ($P < 0.001$) in germination percentages amongst the three *E. bussei* populations with Kigwe and Tarangire populations having higher germination percentages than Ruaha (**Table 2**). There were no significant differences (in all cases $P > 0.05$) in germination period and germination value among the three study populations. The mean germination rate differed significantly ($P < 0.05$) among the three populations, with Kigwe population having the highest value followed by Tarangire and Ruaha being the last (**Table 2**). Kigwe and Tarangire populations had significantly higher ($P < 0.05$) final germination rate than Ruaha population (**Table 2**). There was a significant difference in germination index among populations ($P < 0.05$), with Kigwe having higher value than Ruaha and Tarangire (**Table 2**).

There were significant correlations among some of the germination traits (**Table 3**). Germination value had a negative significant correlation with germination index ($r = -0.41$, $P < 0.05$), mean germination rate ($r = -0.73$, $P < 0.001$) and germination percentage ($r = -0.73$, $P < 0.001$) (**Table 3**).

3.2 Seedling growth

The first measurement of seedling height, root collar diameter and number of leaves was taken at the 30th day since germination. Seedlings from Kigwe and Tarangire populations exhibited more or less the same trend of gradual increase in shoot height (**Figure 3A**). Seedlings of all the three populations had similar trend of gradual increase in root collar diameter over time (**Figure 3B**). There was a similar steady increase in number of leaves bore by seedlings from Tarangire and Ruaha populations (**Figure 3C**).

Regardless of the population, there were significant differences ($P < 0.001$) in seedling growth traits among assessment age groups i.e. 30, 45, 60, 90 and 105 days (**Table 4**). There were significant differences ($P < 0.001$) in shoot height between 30 and 90 days, and between 30 and 105 days ($P < 0.001$). The shoot height was also significant different ($P < 0.05$) between 45 and 105 days, and between 60 and 105 days ($P < 0.05$). Further comparison revealed that the remaining relationships in shoot height at different ages were not significant (**Table 4**). Root collar diameter differed significantly ($P < 0.001$) among the age groups in the seedling growth experiment (**Table 4**). There were no significant differences in root collar diameter between 45 and 60 days and between 60 and 90 days (in all cases $P > 0.05$). The rest of the relationships in root collar diameter between different age groups were significant (**Table 4**). The number of leaves differed significantly ($P < 0.01$) among assessment ages (**Table 4**). There were significant differences in number of leaves between 30 and 105 days ($P < 0.01$), and between 30 and 90 days ($P < 0.05$). The rest of the relationships in number of leaves between different age groups were not significant at $P < 0.05$ (**Table 4**).

There was no significant difference in shoot height between the three studied populations ($P > 0.05$) at 105 days (**Table 5**). Similarly, the root collar diameter did not differ significantly ($P > 0.05$) among the three populations at 105 days. However, the number of leaves possessed by seedlings differed significantly ($P < 0.01$) among the three populations at the same age, with Kigwe and Tarangire populations having higher number of leaves than Ruaha population (**Table 5**) as also attested by **Figure 3C**.

Positive and significant correlations were observed among the evaluated seedling traits at the age of 303 days (**Table 6**). The lowest significant correlation was

DOI: http://dx.doi.org/10.5772/intechopen.97489

Population	Germination percentage (means ± SD)	Germination period (means ± SD)	Germination value (means ± SD)	Mean germination rate (means ± SD)	Final germination rate (means ± SD)	Germination index (means ± SD)
Ruaha	63.4 ± 1.3b	12 ± 1.02a	1.03 ± 0.04a	15.8 ± 3.06b	0.06 ± 0.20b	0.75 ± 0.31a
Kigwe	81.4 ± 2.4a	11 ± 1.03a	1.01 ± 0.02a	20.3 ± 2.60a	0.13 ± 0.37a	0.96 ± 0.34b
Tarangire	72.1 ± 4.2c	10 ± 0.62a	1.03 ± 0.03a	18.0 ± 4.00c	0.12 ± 0.32a	0.83 ± 0.26a

Means followed by a common letter(s) in the same column are not significantly different at $P < 0.05$, Tukey's HSD Test; Means are followed by the Standard Deviation (SD) of the mean.

Table 2.
Variation in seed germination traits of three wild populations of Entandrophragma bussei *in Tanzania.*

Germination trait	Germination period	Germination value	Germination index	Mean Germination Rate	Final Germination Rate
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 percent	0.03	−0.73***	0.16	0.25	0.22

*Significant at 0.05 probability level.
***Significant at 0.001 probability level.

Table 3.
Pearson correlation coefficients for seed germination traits of three wild populations of Entandrophragma bussei *in Tanzania.*

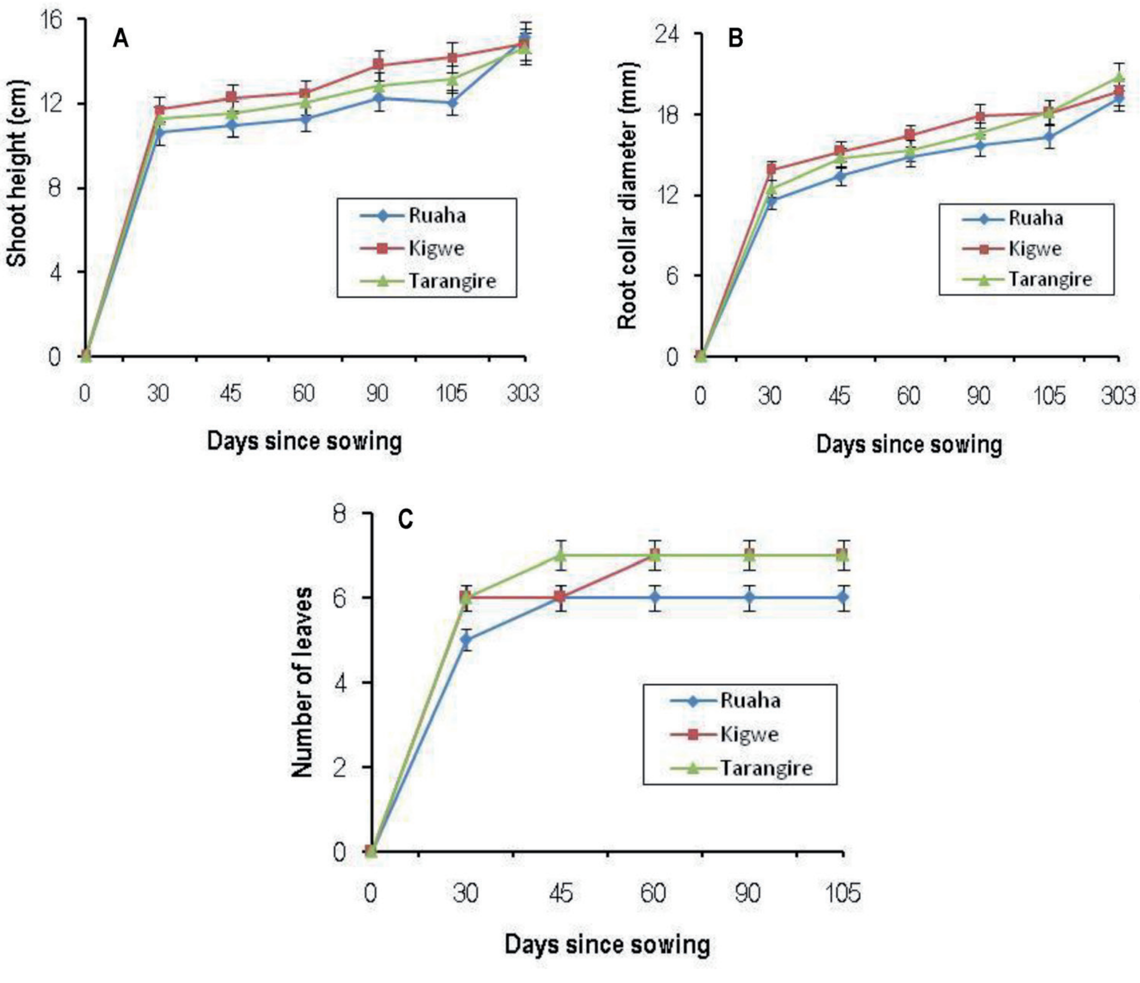

Figure 3.
Nursery growth trends of three wild populations of Entandrophragma bussei *in Tanzania. Vertical bars are Standard Errors.*

observed between shoot dry weight and root collar diameter (r = 0.35, $P < 0.05$) while the highest was between root fresh weight and root dry weight (r = 97, $P < 0.001$) (**Table 6**).

Time period	Shoot height (cm) (means ± SD)	Root collar diameter (mm) (means ± SD)	Number of leaves (means ± SD)
Day 30	11.1 ± 2.8a	12.4 ± 2.4b	5.8 ± 1.6abd
Day 45	11.4 ± 2.8ab	14.3 ± 2.7a	6.3 ± 1.8bef
Day 60	11.8 ± 2.8ab	15.4 ± 2.8a	6.5 ± 1.9bdeg
Day 90	12.8 ± 3.0c	16.5 ± 3.0 ac	6.5 ± 1.9cfg
Day 105	13.2 ± 2.9c	17.7 ± 2.9d	6.6 ± 2.1bc

Means followed by a common letter(s) in the same column are not significantly different at P < 0.05, Tukey's HSD Test; Means are followed by the Standard Deviation (SD) of the mean.

Table 4.
Evolution of seedling growth traits of three wild populations of Entandrophragma bussei *in Tanzania.*

Population	Shoot height (cm) (means ± SD)	Root collar diameter (mm) (means ± SD)	Number of leaves (means ± SD)
Ruaha	12.03 ± 3.0a	16.35 ± 3.5a	5.8 ± 1.7b
Kigwe	14.20 ± 3.2a	18.13 ± 2.8a	7.2 ± 1.4a
Tarangire	13.13 ± 2.4a	18.17 ± 2.6a	7.3 ± 1.8a

Means followed by a common letter(s) in the same column are not significantly different at P < 0.05, Tukey's HSD Test; Means are followed by the Standard Deviation (SD) of the mean.

Table 5.
Variations in seedling growth traits of three wild populations of Entandrophragma bussei *at 105 days in Tanzania.*

Trait (Unit)	Shoot height	Root collar diameter	Number of course roots	Tap root length	Shoot fresh weight	Shoot dry weight	Root fresh weight	Root dry weight
Shoot height (cm)								
Root collar diameter (mm)	0.23							
Number of course roots	0.29	0.16						
Tap root length (cm)	0.06	0.23	0.02					
Shoot fresh weight (g)	0.27	0.52**	0.52**	0.29				
Shoot dry weight (g)	0.38*	0.35*	0.31	0.28	0.68***			
Root fresh weight (g)	0.32	0.55**	0.30	0.54**	0.63***	0.59***		
Root dry weight (g)	0.30	0.49**	0.24	0.50**	0.53**	0.57***	0.97***	
Root to shoot ratio	0.15	0.17	−0.16	0.27	0.19	−0.12	0.53**	0.58***

*Significant at 0.05 probability level.
**Significant at 0.01 probability level.
***Significant at 0.001 probability level.

Table 6.
Pearson correlation coefficients for the seedling growth traits of three wild populations of Entandrophragma bussei *at 303 days in Tanzania.*

Growth traits	Ruaha (means ± SD)	Kigwe (means ± SD)	Tarangire (means ± SD)
Shoot height (cm)	15.1 ± 2.2a	14.8 ± 1.9a	14.6 ± 1.7a
Root collar diameter (mm)	19.2 ± 3.0a	19.7 ± 3.8a	20.9 ± 3.5a
Number of course roots	12 ± 3.4b	10 ± 4.1a	13 ± 6.2b
Tap root length (cm)	13.6 ± 3a	13 ± 3.6a	12.3 ± 3.4a
Shoot fresh weight (g)	26.9 ± 6.6b	22.9 ± 9.7a	28.8 ± 5.4b
Shoot dry weight (g)	3.5 ± 1.0a	3.5 ± 2.2a	3.6 ± 1.1a
Root fresh weight (g)	16.4 ± 8.2a	16.8 ± 7.2a	15.4 ± 8.8a
Root dry weight (g)	1.7 ± 1.2a	1.8 ± 1.0a	1.5 ± 1.2a
Root to shoot ratio	0.44 ± 0.2a	0.6 ± 0.3a	0.38 ± 0.2a

Means followed by a common letter(s) in the same column are not significantly different at P < 0.05, Tukey's HSD Test; Means are followed by the Standard Deviation (SD) of the mean.

Table 7.
Variation in seedling growth traits of three wild populations of Entandrophragma bussei *at 303 days in Tanzania.*

Most of the evaluated seedling growth traits did not differ significantly ($P > 0.05$) between the three populations on harvesting at 303 days (**Table 7**). However, the number of course roots differed significantly ($P < 0.05$) between the three populations with Tarangire (13) and Ruaha (12) having the higher number of roots per seedling than Kigwe (10). Similarly, Tarangire (28.8 g) and Ruaha (26.9 g) populations had significantly ($P < 0.05$) higher shoot fresh weight than Kigwe (22.9 g) (**Table 4**). In terms of survival in the nursery, Ruaha had the highest seedling survival (56%) followed by Kigwe (41%) and Tarangire (36%) being the last.

4. Discussion

4.1 Variation in germination

This study has demonstrated the differences in germination traits in three populations of *E. bussei* found in three agroecological zones of Tanzania. Germination of less than 100% may indicate dormancy or non-viability of the un-germinated seeds. The rapid germination observed in this species may indicate that this species establishes itself in the environment as quickly as possible to take advantage of the favourable conditions and to give it competitive advantage. All of the three populations germinated well within 34 days which is ideal for nursery production.

The study species *E. bussei* is a native species which is recommended for restoration and conservation strategies since it is adapted to local habitat conditions. So germination studies facilitate better understanding of optimal conditions for germination and influence of seed populations. The observed variation in germination among populations emphasizes the need for proper seed source selection to minimize waiting time and cost of nursery operations [18]. Commercial nurseries are often established to produce large number of high quality planting stocks in the possible shortest time. This study has shown that all the *E. bussei* populations can be produced under nursery conditions to supply strong materials for planting out in agroforestry and plantation forestry. Our study has shown that *E. bussei* can germinate well within reasonable time of five weeks.

Germination is an important factor in assessing the quality of any seed and determines early seedling performance and end products standard. In this study, seed cumulative germination percentage ranged from 63.4% to 81.4% indicating that the three populations possess quality seeds that can be used during domestication and tree improvement processes. The observed variation in germination percentage among the provenances is not attributed to differences in altitudes, environmental factors (day length, temperature, light quality, water availability and altitude), and climatic conditions of particular population, since this study was undertaken in one geographic location [19]. The results overall indicate that, maternal factors associated with individual seeds from each population could explain the observed variations [20]. It has been reported that position of seed in the fruit or tree and the age of the mother plant influence seed germination ability [21]. However in this study, such effects were not studied.

In this experiment no treatment was undertaken for germination of *E. bussei* but the overall germinations for all populations were good as opposed to other species in the genus *Entandrophragma*. For example, it has been reported that *E. cylindricum* needs pre-sowing to attain higher germination while *E. angolense* requires certain substrate type for germination in West Africa [22]. In order to support establishment of a nursery for *E. bussei* domestication, genotypes with superior germination traits are favoured [23]. Kigwe provenance had significantly higher values for most of the germination traits (i.e. germination percentage, mean germination rate and germination index) as compared to the other two populations. These observed results could be attributed to by the fact that Kigwe source had heavier seeds than the other two sources (Andrew et al., *in press*). Studying variation in *Uapaca kirkiana*, Mwase et al. [24] pointed out that seeds with heavy weight were producing higher cumulative germination percentages. High nutrients reserved in seeds from Kigwe have a chance of germinating at 81.4% within 16 days (**Figure 3**). The selection of seeds from this population would be appropriate during nursery development in tree domestication, agroforestry and plantation forestry.

4.2 Variation in seedling growth

Seedling traits including shoot height, root collar diameter, number of leaves, tap root length, total number of course roots per seedling, fresh and dry weights of all course roots and shoots variations are important determinants of seedlings to be planted in the field. This study has demonstrated that there are degrees of variation among various seedling growth traits suggesting that selection of any trait for improvement would be effective [18]. Number of leaves differed significantly among the three populations, with Kigwe and Tarangire having higher number of leaves than Ruaha, at 105 days (**Table 5**). Ruaha and Tarangire had higher number of course roots and shoot fresh weight than Kigwe population at 303 days (**Table 7**). Parker et al. [25] and Assogbadjo et al. [26] reported a positive influence of large seed size and seed reserve on the establishment and early growth of seedlings. So, higher seed width, weight and length might have contributed to the observed variation of *E. bussei* populations in this study. It is known that roots support plants growth by absorbing nutrients and water so presence of higher number of course roots contributed to the higher survival of Ruaha population. It has been reported that traits displayed by seedlings in the nursery are influenced by mostly genetic rather than phenotypic origin. This experiment was set at the DTSP nursery in Morogoro for all the three provenances. It is obvious that the observed results have been influenced mostly by seed genetic makeup (which were not tested in this study though) from each individual population rather than variation of environmental factors between the populations as reported by Freigoun et al. [20] on *Balanite aegyptiaca*. During the study period of ten months, some seedling growth traits were not significantly different but showed a positive and strong correlation among them (**Table 6**). Despite such observations, it is important to consider raising the seedlings in the nursery until plantable size when seedlings are at least 25–30 cm high and with root collar diameter of 3–4 mm to allow seedling maturation and biomass increase [27].

5. Conclusion

E. bussei is threatened by recent intensified utilization pressure, deforestation and high mortality rate of seedlings and hence in situ and ex situ conservation measures are urgently needed to restore and preserve genetic diversity. On site measures can include wide planting, extension services and enforcement of laws governing forestry-agriculture interphase. Domestication of *E. bussei* from the wild should consider collection of seeds that possess swift germination and seedling growth under managed nurseries. Establishment and/or incorporation of the tree into farms or agroforestry systems would help to reduce the pressure on the remaining natural populations. In this study, Kigwe had the best germination traits with high germination percentage, mean germination rate and germination index. However, a different trend was observed during the nursery experiment where Tarangire and Ruaha performed well in number of course roots and shoot fresh weight. Ruaha had the highest survival rate at the age of 10 months. The difference observed for the two experiments could have resulted from variations in genetic factors. Results of this study pave a way for further studies to confirm the best performing population(s) for in situ and ex situ conservation and tree improvement. It is therefore recommended that seedlings in the nursery are monitored until when they reach plantable size (i.e. height of 25–30 cm and root collar diameter of 3–4 mm).

Acknowledgements

G. Ngatena, M. Said, R. Khalfani, P. Mmanda and J. Mtika assisted during fieldwork. Tanzania Forest Services Agency (TFS) supported data collection.

Conflict of interest

None.

Author details

Samora M. Andrew[1*], Siwa A. Kombo[1,2] and Shabani A.O. Chamshama[1]

1 Department of Ecosystems and Conservation, Sokoine University of Agriculture, Morogoro, Tanzania

2 Directorate of Tree Seed Production, Tanzania Forest Services Agency, Morogoro, Tanzania

*Address all correspondence to: smacrice@sua.ac.tz

References

[1] Kideghesho J, Rija A.A., Mwamende K.A. and Selemani I.S. (2013). Emerging issues and challenges in conservation of biodiversity in the rangelands of Tanzania. Nature Conservation 6:1-29

[2] Msanga, H. P. (1998). Seed Germination of Indigenous Trees in Tanzania, Including Note on Seed Processing, Storage and Plant Uses. University of British Columbia Press, Vancouver. 292 pp.

[3] Styles, B.T. and White, F. (1991). Meliaceae Flora of Tropical East Africa. Meliaceae, 67 pp.

[4] Hall, J. S. (2008). Seed and seedling survival of African mahogany (*Entandrophragma* spp.) in the Central African Republic: Implications for forest management. Forest Ecology and Management 255: 292-299

[5] Makonda, F.B.S. and Batiho, T.A. (2018). Benchmarking Current Status of *Entandrophragma bussei* an Endemic Species of Tanzania. Final KiLi meeting Moshi, Tanzania 2nd – 4th October 2018, 6 pp.

[6] Dery, B. B. (1999). Indigenous Knowledge of Medicinal Trees and Setting Priorities for Their Domestication in Shinyanga Region, Tanzania. World Agroforestry Centre, Nairobi, Kenya.

[7] Monela, G. C., Chamshama, S. A. O., Mwaipopo, R. and Gamassa, D. M. (2005). A study on the Social, Economic and Environmental Impacts of Forest Landscape Restoration in Shinyanga Region, Tanzania. Ministry Natural Resource and Tourisms, Dar es Salaam, Tanzania 223pp.

[8] Mouthé-Happi, G., Tchaleu Ngadjui, B., Green, I. R. and Fogué Kouam, S. (2018). Phytochemistry and pharmacology of the genus Entandrophragma over the 50 years from 1967 to 2018: A golden' overview. Journal of Pharmacy and Pharmacology 70(11): 1431 – 1460.

[9] Nibret, E., Ashour, M. L., Rubanza, C. D. and Wink, M. (2010). Screening of some Tanzanian medicinal plants for their trypanocidal and cytotoxic activities. Phytotherapy Research 24(6): 945 – 947.

[10] Rao, M.R., Palada, M.C. and Becker, B.N. (2004). Medicinal and aromatic plants in agroforestry systems. Agroforestry Systems 61:107-122.

[11] Dery, B. B. and Otsyina, R. (2000). The 10 priority medicinal trees of Shinyanga, Tanzania. *Agroforestry Today*12(1):5 – 8.

[12] Adewunmi, A. O., Bolanle–Ojo, O. T. and Oladejo, A. O. (2014). Seedling growth performance of *Entandrophragma angolense* (Welw.) CDC as influenced by different light intensities. *Journal of Agriculture, Forestry and the Social Sciences* 12(2): 197 – 206.

[13] Hall, J. S., Medjibe, V., Berlyn, G. P. and Ashton, P. M. S. (2003). Seedling growth of three co-occurring *Entandrophragma* species (Meliaceae) under simulated light environments: implications for forest management in central Africa. Forest Ecology and Management 179 (3): 135 – 144.

[14] Hamasha HR, Hensen I (2009). Seed germination of four *Jordanian Stipa* spp.: differences in temperature regimes and seed provenances. Plant Species Biology 24:127-132.

[15] Asiedu, J. B. K., Van Der Puije, G. C., Taah, K. J. and Dovlo, V. (2012). Effect of some presowing treatments on germination of *Bauhinia rufescens* seeds.

International Journal of Agricultural Research 7(4): 195 – 204.

[16] Djavanshir, K. and Pourbeik, H. (1976). Germination value: a new formula. Silvae Genetic 25: 79-83.

[17] R Development Core Team (2020). R: a language and environment for statistical computing. R Foundation for 343 Statistical Computing, Vienna.

[18] Ngulube, M. R., Hall, J. B. and Maghembe, J. A. (1997). Fruit, seed and seedling variation in Uapaca kirkiana from natural provenances in Malawi. Forest Ecology and Management 98(3): 209 – 219.

[19] Vazquez-yanes, A. C., Rincón, E., Toledo, J. R. and Barradas, V. L. (1990). Light beneath the litter in a tropical forest: Effect on seed germination. Ecology 71(5):1952 –1958.

[20] Freigoun, S. A., Raddad, E. Y. and Elagib, T. Y. (2019). Provenance variation in seed morphological traits and early seedling growth of *Balanites aegyptiaca* Del. Sudan Journal of Agricultural Research 27(2): 93 – 108.

[21] Gutterman Y (2000). Maternal effects on seeds during development. In: Fenner M (ed) Seeds: the ecology of regeneration in plant communities, 2nd edn. CABI Publishing, Wallingford, pp 59-84.

[22] Ambebe, T. F. and Achankeng, N. (2019). Influence of pre-sowing treatment and substrate on germination and seedling vigour of *Acacia angustissima* (Mill.) Kuntze, *Entandrophragma angolense* (Welw) CDC and *Newtonia camerunensis* Villiers. *Journal of Agriculture and* Forestry Sciences 7(2): 25 – 35.

[23] Mkwezalamba, I., Munthali, C. R. and Missanjo, E. (2015). Phenotypic Variation in Fruit Morphology among Provenances of *Sclerocarya birrea* (A. Rich.) Hochst. International Journal of Forestry Research 2015: 1 – 8.

[24] Mwase, W. F., Bjørnstad, Å., Ntupanyama, Y. M., Kwapata, M. B. and Bokosi, J. M. (2006). Phenotypic variation in fruit, seed and seedling traits of nine *Uapaca kirkiana* provenances found in Malawi. Southern African Forestry Journal 208(1): 15 – 21.

[25] Parker W.C., Noland T.L. and Morneault A.E. (2006). The effects of seed mass on germination, seedling emergence, and early seedling growth of eastern white pine (*Pinus strobus* L.). New Forests 32:33-49

[26] Assogbadjo, A. E., Glèlè Kakaï, R., Edon, S., Kyndt, T., & Sinsin, B. (2010). Natural variation in fruit characteristics, seed germination and seedling growth of *Adansonia digitata L.* in Benin. New Forests 41(1), 113-125.

[27] United Republic of Tanzania (URT) (2021). Technical Order No. 1 of 2021. Forestry and Beekeeping Division, Ministry of Natural Resources and Tourism.