Effect of Seed Size on Seed Germination Rate of Adansonia Digitata from Five Natural Populations in Malawi

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ABSTRACT
In Malawi, deforestation has largely eroded much of the indigenous fruit tree germplasm, one such fruit trees is *Adansonia digitata* L. (baobab). There is need to comprehend the variation that occurs between and within populations of *A. digitata* if sustainable use is to be achieved. A study was carried out to assess seed size effect on germination rate of *Adansonia. digitata* from five natural populations in Malawi, namely Mwanza, Salima, Karonga, Chikwawa and Likoma. 2500 seeds were collected and seed traits (weight, width and length) were measured using Vernier calliper and digital balance TR-2101, germination parameters were analysed in the green house at Mzuzu University. There were significant variations ($P<0.001$) in mean seed weight, width, length between populations. Differences were found in mean seed weight 0.37g to 0.58g, mean seed width from 8.87mm to 10.10mm and seed length from 10.87mm to 12.48mm. Differences were also found in seed weight between families. In Chikwawa families ranged from 0.4777g to 0.7439g, Mwanza from 0.3958g to 0.6112g, Likoma from 0.2995g to 0.4674g, Salima from 0.3799g to 0.5875g and Karonga from 0.4151g to 0.6115g. There were also significant variation ($P<0.001$) in the interaction between pre-treatment and provenances but no significant variation for interaction between pre-treatments ($P=0.599$). From these results, it is concluded that there is substantial variation in seed weight, seed width and seed length in *A. digitata* from five populations. It can be further concluded that variations observed are strongly genetically controlled. Future research should strive to partition genetic variation and environmental variation.

Keywords: variation, population, interaction, effect

CHAPTER 1: INTRODUCTION

1.1 Background information

Arid and Semi- arid Africa is blessed with various trees which provide medicinal and non –medicinal values. Among these plants is the baobab (*Adansonia digitata*) which is a fruit- producing tree belonging to the family Bombacaceae (Rashford, 1994). *Adansonia digitata* is important to the livelihood of the people of Africa. It provides food, shelter, clothing and medicine as well as material for hunting and fishing (Benker, 1983). Thus the baobab can be said to be one of the most precious natural resources in the African continent (Venter and Venter, 1996).

1.2 Problem statement

The increasing demand for some major parts of the plant has led to its over-exploitation. As a result existing trees sometimes fail to form fruits or disperse seeds leading to scarcity of its wildlings. Unfortunately there is insufficient information pertaining to its domestication particularly on how seed size may influence seed germination rate of the species. It is against this background that this study was undertaken.

1.3 Objectives of the study

1.4.1 General objective

- The main objective of this study is to investigate the influence of seed size on germination rate of *A. digitata* seed.

1.4.2 Specific objectives

- To determine how seed size affect seed germination of *A. digitata*
- To determine how provenance variation affects seed size of *A. digitata*
- To determine how families affect seed size of *A. digitata*
- To determine how pre-sowing treatments affect seed germination rate of *A. digitata*

1.4 Hypotheses

- There is significant effect of seed size on seed germination rate of *Adansonia digitata*.
- Pre-sowing treatments have significant effect on seed germination rate of *Adansonia digitata*.

1.5 Significance of the study

Once the appropriate seed size is known, it will be easy to promote it on the seed germination of *Adansonia digitata* and one will be able to know how families and provenances affect seed size on seed germination rate of *A. digitata.*

CHAPTER 2: LITERATURE REVIEW

2.1 Botanical description

Adansonia digitata L. is a delicious, massive and majestic tree up to 25m high, which may live for hundreds of years. It has thick, angular wide spreading branches and a short, stout trunk which attains 10-14m or more in girth and often becomes deeply fluted (Sidibe and Williams, 2002). The baobabs are comprised of eight species with large, spectacular, nocturnal flowers (Baum, 1995). The baobab is pollinated by bats (Galago crassicaudatus) and insects but is also adapted for wind pollination.

2.2 Distribution and ecology

Adansonia digitata is widespread throughout the hot, drier regions of tropical Africa. *Adansonia digitata* specifically does well where the annual rainfall is in the range of 150mm to 1500mm at elevation ranging from sea-level up to 1250m (Wickens, 1982; Wilson, 1988; Carlowitz, 1991; Fenner, 1980). As stipulated by Sidibe and Williams (2002) the baobab has an extensive root system and high water holding capacity. It characteristically occurs on free-draining sandy-textured soils but not on deep sand. In terms of temperature baobab can tolerate very high temperature (mean maximum 40-42°C in West Africa) and for minimum temperatures, can survive as long as there is no frost (Simpson, 1995).

2.3 Seed variation and germination

According to a study by Igboeli *et al*., (1997) heavier seeds have low germination rate but give rise to seedlings of greater mass as compared to lighter seeds. According to Addy and Esteshola (1984) seed size of A. digitata could differ between different species of plants. Baobabs are quite easily grown from seed although they are seldom available in nurseries. Sidibe and Williams (2000) argues that direct seeding into the field has not been successful; hence seedlings are mainly raised and transplanted into the field at 10m×10m spacing. The hole size is 60×60×60cm.

CHAPTER 3: MATERIALS AND METHODS

3.1 Experimental site

The experiment was conducted at Mzuzu University within Mzuzu City. Temperature for the area ranges from 13.5 - 20.9ºC and receives rainfall of up to 1150mm per year (Atlas of Malawi, 1983).

3.2 Experimental materials

The seeds of *A. digitata* were collected from Mwanza, Salima, Karonga, Chikwawa and Likoma populations in Malawi. After collecting the seeds, the pulp was removed by washing away the dry powdery coating. As Donahue (1995) recommends, five seeds from each fruit were randomly selected; mass (g) was weighed using analytical balance and length (mm) and width (mm) measured using a Vernier calliper.

3.3 Laboratory methods

The collected fruits were taken to the laboratory at Mzuzu University where seed weight, width and length were measured. Seed weight was determined using the digital balance TR-2101 graduated to 2100g. Seed width and length was measured at the middle of each seed and from end to end respectively using vernier calliper (MDL 005) graduated to 0.02mm.

3.4 Experimental Design and seed germination

The experiment was a 3 × 5 factorial design arranged in a Complete Randomized Design (CRD). The two factors were pre-sowing treatments and provenances. The three pre-treatments were; seeds soaked in hot water over night, seeds nicked with a secateur and seeds not pre-treated (control). The experiment comprised of fifteen treatments. Each treatment was replicated four times with twenty five seeds in each replicate (4 × 25) making 100 seeds per replicate. Thus, 2500 seeds were used for the experiment. Seeds were sown in tubes and watering was done twice a day (morning and evening) for 50 days until the seeds stopped germinating.

3.5 Data collection

Germination counts were made daily and recorded on a seed germination assessment sheet until there was no more seed germination. A seed was considered germinated when the plumule had emerged above the soil surface. The data collected was transformed to get lead of the zeros which were present, Peterson (1991).

3.6 Data analysis

Data was subjected to analysis of variance (ANOVA), using Genstat Statistical Package (3rd Edition), so that the variations in fruit characteristics could be tested. The data was analysed as an unbalanced randomised complete design. The statistical model used was as follows;

$Y_{ijk} = \mu + A_i + B_j + AB_{ij} + \varepsilon_{ijk}$

$_i = 1, 2, 3, 4$

$_j = 1, 2. . . 15$; Where,

μ is the overall mean

A_i^{th} effect of factor A

B_j^{th} effect of factor B

AB_{ij} ij^{th} interaction effect

ε_{ijk} is the random error for observation

Fischer's Least Significant Difference (LSD) was used for pair comparison. Using Genstat Statistical Package (3rd Edition), Coefficient of variation (CV) was calculated for each parameter to determine the precision with which the treatments are compared. Mean seed germination percentages were firstly transformed into arc sine values in order to normalise the data before the analysis of variance was performed to determine significance between treatments.

CHAPTER 4: RESULTS

4.1 Variation of fruit parameters between provenances

4.1.1 Seed weight

Figure 1 shows variation in mean seed weight (g) between five populations of *A. digitata.* The results showed significant differences in the seed weight between provenances (F=570.45, P<0.001) (Appendix 1). The heaviest seeds (0.58g) came from the Chikwawa population whereas Likoma population exhibited the lightest seeds (0.37g) (Figure 1). However LSD (Appendix 10) indicated that mean seed weights for Chikwawa, Mwanza, Salima and Karonga were similar.

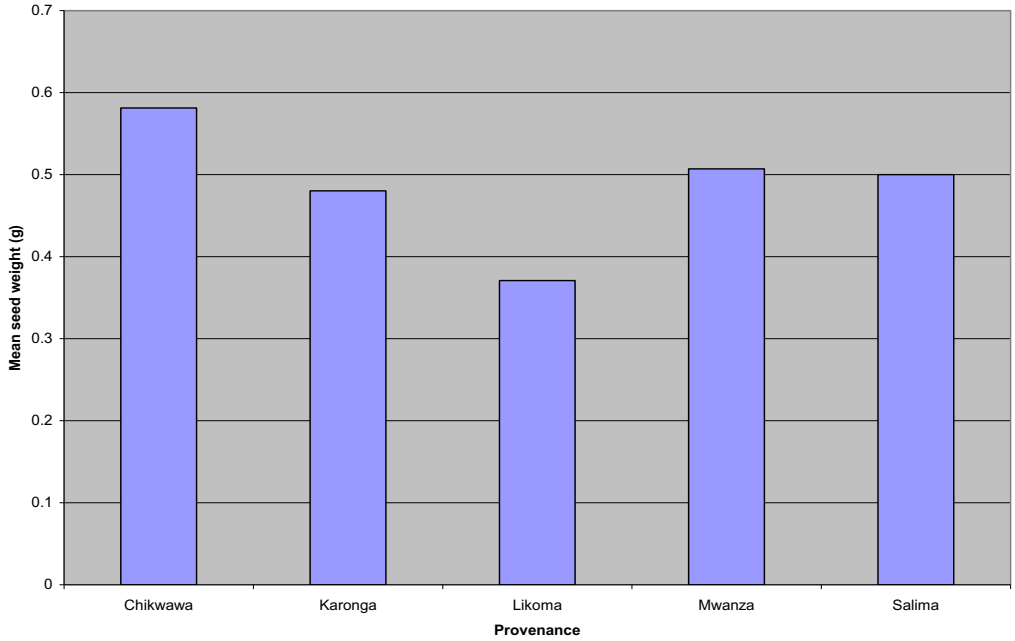

Figure 1: Variation of *Adansonia digitata* in mean seed weight between five populations

4.1.2 Seed width

Figure 2 shows variation in mean seed width between populations of *A. digitata.* Results show that there were significant differences in seed width between provenances (F=177.84, P<0.001) (Appendix 2). The population with highest seed width was Chikwawa with a mean width of 10.10mm and the minimum value was 8.87mm, observed from Likoma population (Figure 2). The LSD (Appendix 10) shows that mean seed widths for Chikwawa, Mwanza, Salima and Karonga were similar except Likoma.

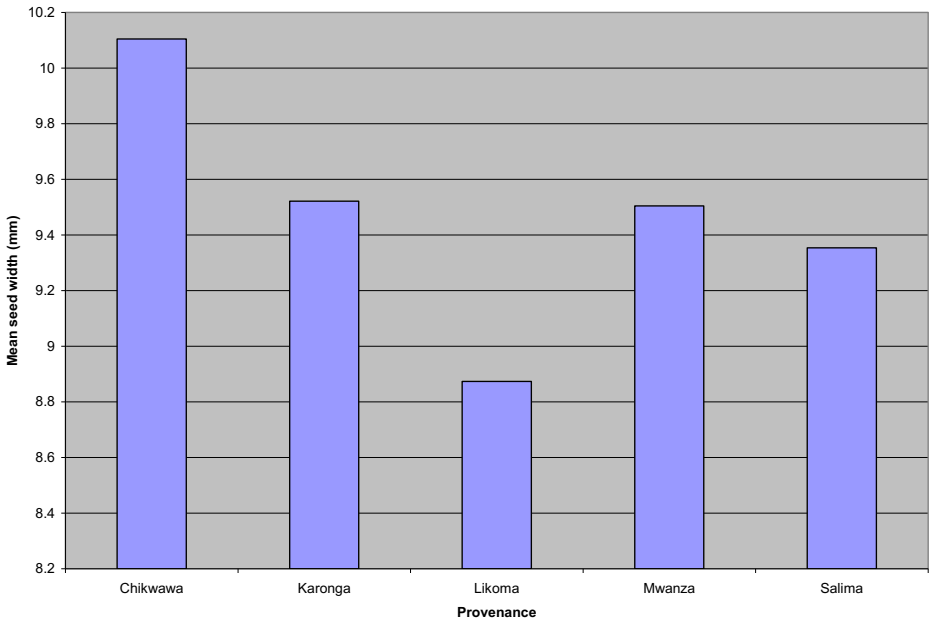

Figure 2: Variation of *Adansonia digitata* in mean seed width between five populations

4.1.3 Seed length

Figure 3 shows the variation in seed length between five populations. There were significant differences in seed length between the five populations ($F=233.79$, $P<0.001$) (Appendix 3). The results showed 12.48mm (from Chikwawa) as the maximum seed length and 10.87mm (from Likoma) as being the minimum mean seed length. The LSD (Appendix 10) shows that there were no significant differences between Chikwawa, Mwanza, Karonga and Salima except Likoma.

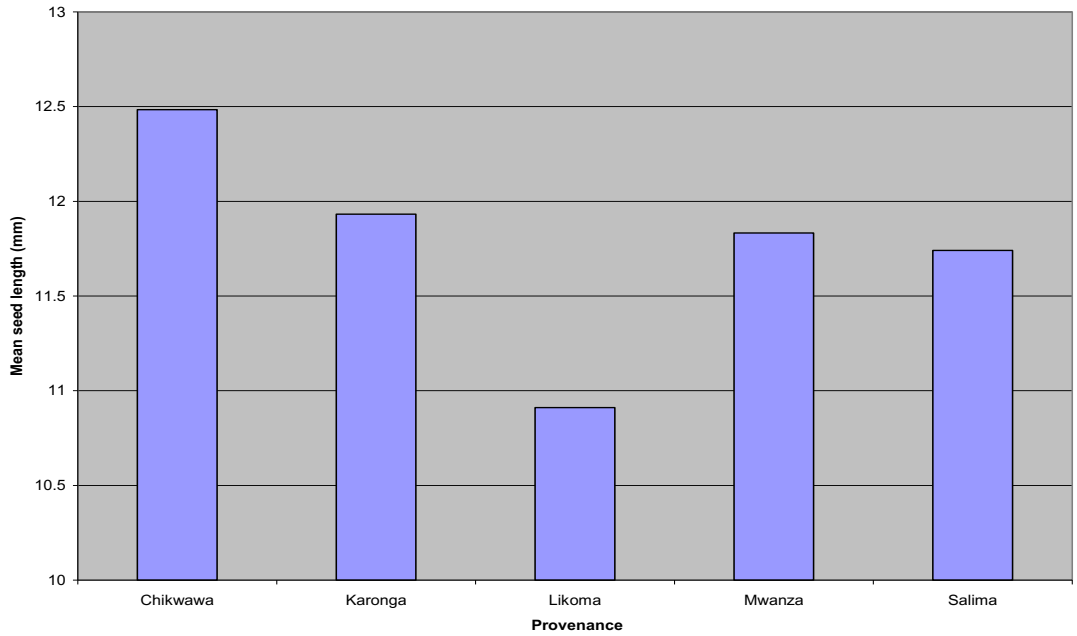

Figure 3: Variation of *Adansonia digitata* in mean seed length between five populations

4.2 Variation of seed weight within population

4.2.1 Variation of seed weight within Karonga population

Appendix 11 shows variation in mean seed weight within Karonga population. The results disclosed significant differences in mean seed weight between trees ($F=29.53$, $P<0.001$) (Appendix 4). The heaviest seed had a weight of 0.6115g. This seed was from tree number 3. On the other hand, the lightest seed (0.4151g) was observed from tree number 5 (Appendix 11). The average weight of seeds was 0.4779g.

4.2.2 Variation of seed weight within Chikwawa population

Variation in mean seed weight of A. digitata within Chikwawa population is shown in Appendix 11**.** There were significant differences ($F=31.02$, $P< 0.001$) (Appendix 5) in mean seed weight between the trees in Chikwawa population. *Adansonia digitata* showed heaviest seed of 0.7439g and lightest seed of 0.4777g from tree number 2 and 6 respectively (Appendix 11). The average weight recorded was 0.5751g.

4.2.3 Variation of seed weight within Mwanza population

Appendix 11 shows variation in mean seed weight of A. digitata within Mwanza population**.** The results showed significant differences in mean seed weight between trees ($F=61.87$, $P<0.001$) (Appendix 6). The heaviest seed (0.6112g) came from tree number 12 while the lightest weight (0.3958g) was observed from tree number 1. The average seed weight observed was 0.5159g (Appendix 11).

4.2.4 Variation of seed weight within Likoma population

Appendix 11 shows variation in mean seed weight of A. digitata within Likoma population**.** There were significant differences in mean seed weight within trees ($F=24.53$, $P<0.001$) (Appendix 7). The seed with greatest weight was from tree number 7, with weight of 0.4674g. The minimum value in seed weight was 0.2995g, observed in tree number 4. The average seed weight was 0.3669g.

4.2.5 Variation of seed weight within Salima population

Appendix 11 shows variation in mean seed weight of A. digitata within Salima population. There were significant differences in mean seed weight ($F=96.00$, $P<0.001$) (Appendix 8). The results showed 0.5875g as the minimum seed weight from tree number 10, 0.3799g (tree 15) as being the maximum mean seed weight. The average seed weight was 0.5037g.

4.3 Pearson's correlation matrix of seed characteristics

Table 1 shows the correlation matrix of the seed traits. The results indicated that there is a significant weak correlation among seed length and seed width ($P=0.000$). Pearson's correlation analysis showed that seed length was lowly correlated with seed width ($r=0.265$, $P=0.000$). On the other hand Pearson's correlation analysis showed that there is a linear relationship between seed weight and seed length ($r=-0.005$, $P=0.779$) and seed weight and seed width ($r= -0.005$, $P=0.801$).

Table 1: Pearson's correlation coefficient of seed characteristics of *Adansonia digitata* in five populations

Seed traits	Seed weight	Seed length
Seed length	-0.005 **0.779**	
Seed width	-0.005 **0.801**	0.265 **0.000**

4.4 Seed germination

Table 2 displays days germination started, days germination completed and the final germination percentages of *A. digitata* seed subjected to various pre-treatments, Analysis of variance indicated no significant differences (P=0.599) between all provenances in terms of pre-sowing treatments. However, Salima population recorded slightly higher mean germination percent (49) whereas Mwanza population had the lowest mean germination percentage of 7 (Table 1). Results also showed significant interaction between pre-treatments and provenances (F=7.24, P<0.001) (Appendix 9).

Germination started with seeds soaked in water over night from Karonga population, seeds nicked using secateur from Karonga population and seeds nicked using secateur from Salima population on the ninth day. As germination progressed, seeds soaked in water over night from Karonga population, seeds nicked using secateur from Karonga population and seeds nicked using secateur from Mwanza population were the first to complete germination after 41 days after sowing.

Table 2: Pre-treatments, days germination started, days germination completed and final germination rate

Pre-treatment	Days germination started	Days germination completed	Final germination percentage
T1	15	45	23.5
T2	13	45	8
T3	12	44	22
T4	11	43	24
T5	9	41	18
T6	9	41	37
T7	18	47	28
T8	16	46	21
T9	13	44	17
T10	17	45	15
T11	11	46	31
T12	11	41	7
T13	16	44	16
T14	15	47	38
T15	9	42	49

T 1: Seeds not pre-treated from Chikwawa population
T 2: Seeds soaked in water over night from Chikwawa population
T 3: Seeds nicked using secateur from Chikwawa population
T 4: Seeds not pre-treated from Karonga population
T 5: Seeds soaked in water over night from Karonga population
T 6: Seeds nicked using secateur from Karonga population
T 7: Seeds not pre-treated from Likoma population
T 8: Seeds soaked in water over night from Likoma population
T 9: Seeds nicked using secateur from Likoma population
T 10: Seeds not pre-treated from Mwanza population
T 11: Seeds soaked in water over night from Mwanza population
T 12: Seeds nicked using secateur from Mwanza population
T 13: Seeds not pre-treated from Salima population
T 14: Seeds soaked in water over night from Salima population
T 15: Seeds nicked using secateur from Salima population

CHAPTER 5: DISCUSSION

5.1 Variation in fruit parameters between populations

The significant differences (P<0.001) shown in seed traits between five populations of *A. digitata* (Figures 1, 2, 3 and Appendix 10), may signify that the populations are genetically different. Breitenbach (1985) reported that growth variation of baobabs is the only parameter that is due to genetic origin. On the other hand, Gebauer *et.al*., (2002) and Sidibe and Williams (2002) reported that variation in fruit characteristics of *A. digitata* can either be due to genotypic composition or environment in which the trees are growing. The results agree with the work done in Zambia, which revealed some significant variations in *Strychnos cocculoides* between and within provenances in fruit and seed weight (Mkonda *et.al*., 2003). Hence the variation in the fruit characteristics of *A. digitata* between the five populations could be due to differences in genetic composition.

Results are showing that seed length is more variable (Appendix 10) than seed weight and seed width (Figure 3). This is agreeing with some work done by Ngulube *et. al*., (1997) who reported that variation in fruit traits and seeds collected from natural stands are attributed to genetic control or phenotypic origin or both. Hence, the variation in seed traits of *A. digitata* between the five populations could be due to differences in genetic composition.

5.2 Variation in fruit parameters within populations

Significant differences in seed weight (Appendix 11) observed within the five populations may indicate that individual trees are different genotypes although they may occur under similar environmental conditions. The results are supported by Gebauer *et.al*., (2002); Sidibe and Williams (2002) who found that variation within seed characteristics are due to genotypic differences. The other possible reason for variability within each population could be as a result of mutation (Sniegowski *et.al*, 2000).

Correlation matrix of seed parameters

There are weak correlations between seed length and seed width (Table 1). The weak correlation between the seed length and seed width shows that one cannot conclude by only measuring the seed length to predict the seed width measurements. On the other hand, there was no significant dependency of the seed weight and seed length but also seed weight and seed width (Table 1).

5.3 Germination rate of *Adansonia digitata*

The results from (Appendix 9) show that there are significant differences in germination rate in populations of *Adansonia digitata*. Figure 1 show that in some population germination rate was faster than in other populations. It is expected that the variations in germination rate of *A. digitata* are due to genetic effect because seeds were grown in a homogeneous environment (Raven, *et.al*., 1999). The apparent causes of low germination rate in some populations may be attributed to inbreeding that might be occurring in the provenance as evidenced by an albino observed in the Karonga population (Appendix 13). The results also showed that there were no significant differences in pre-sowing treatments (Appendix 9) where P=0.599. This may mean that the variation observed in germination rates was due to genetic composition and not pre-sowing treatments *per se* (Munthali, 1999).

It is observed that, Mwanza had a slow germination rate, while Chikwawa, Karonga, Likoma and Salima had a faster germination rate (Figure 4). Igboeli *et al*., (1997) suggest that the germination rate is not only influenced by the provenance from where the seed was collected, but also the weight of the seed. Large or heavy seeds are an indication of abundant food reserves from the mother tree. But also one needs to use heavy seeds because they store a lot of vitamins (Diop *et al*., (2005).

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The study has shown that there are significant differences in seed weight, length and width between and within the five populations of *Adansonia digitata* in Malawi, and these variations affect the seed germination rate. Variation in seed characteristics might be strongly attributed to genetic control than environmental factors. The paper has substantiated that pre-sowing treatments does not affect seed germination rate but the interaction between pre-sowing treatments and provenances affects the seed germination rate of *A.digitata*.

6.2 Recommendations

Based on the findings of the study the following recommendations are put forward:

- The information obtained in this study can be packaged into the extension training kits where rural communities should be sensitised on the need to select superior germplasm for planting.
- Further studies should be done on the effect of seed size on seed germination rate of *Adansonia digitata* L. from provenances of different silvicultural zones. To add on this, heritability studies should be done in order to ascertain how much genes can be heritable from the mother trees to the progenies.

DEFINITIONS OF TERMS

Population: Group of organisms of the same species living together within a common area at the same time
Phenotype: The morphological, physiological, behavioural, and other outwardly recognisable forms of an organism that develop through the interaction of genes and environment.
Genotype: The genetic constitution of an organism, acquired from its parents and available for transmission to its offspring.
Variation: Occurrence of difference among individuals of the same species attributed to differences in their genetic composition or the environment in which they are raised.
Inbreeding: The production of offspring by mating related organisms.
Trait: Observable characteristics.

LIST OF ACRONYMS

ANOVA	Analysis of variance
CRD	Complete Randomised Design
CV	Coefficient of variance
FAO	Food and Agriculture Organisation
LSD	Least Square of Differences
No.	Number
s.e	Standard error
SED	Standard Error of Differences
g	Gram
Cm	Centimetres

APPENDICES

Appendix 1: Population seed weight (g)

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F value	P value
Site	4	10.853069	2.713267	570.45	<0.001
Site. Treatment	57	12.469630	0.218765	45.99	<0.001
Residual	2927	13.921830	0.004756		
Total	2988	37.244529			

Appendix 2: Population seed width (mm)

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F value	P value
Site	4	283.0954	70.7739	177.84	<0.001
Site. Treatment	57	685.4756	12.0259	30.22	<0.001
Residual	2927	1164.8189	0.3980		
Total	2988	2133.3899			

Appendix 3: Population seed length (mm)

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F value	P value
Site	4	560.5717	140.1429	233.79	<0.001
Site. Treatment	57	886.8421	15.5586	25.96	<0.001
Residual	2927	1754.5701	0.5994		
Total	2988	3201.9839			

Appendix 4: Variation within Karonga population in terms of seed weight (g)

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F value	P value
Family_Karonga	8	1.617783	0.202223	29.53	<0.001
Residual	416	2.848598	0.006848		
Total	424	4.466381			

Appendix 5: Variation within Chikwawa population in terms of seed weight (g)

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F value	P value
Family_Chikwawa	15	2.570467	0.171364	31.02	<0.001
Residual	693	3.828280	0.005524		
Total	708	6.398747			

Appendix 6: Variation within Mwanza population in terms of seed weight (g)

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F value	P value
Family_Mwanza	13	2.533346	0.194873	61.87	<0.001
Residual	779	2.453732	0.003150		
Total	792	4.987079			

Appendix 7: Variation within Likoma population in terms of seed weight (g)

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F value	P value
Family_Mwanza	13	2.533346	0.194873	61.87	<0.001
Residual	779	2.453732	0.003150		
Total	792	4.987079			

Appendix 8: Variation within Salima population in terms of seed weight (g)

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F value	P value
Family_Salima	14	4.566091	0.326146	96.00	<0.001
Residual	681	2.313505	0.003397		
Total	695	6.879595			

Appendix 9: Germination rate

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F value	P value
Pre-treatment	2	0.9950	0.4975	0.52	0.599
Pre-Treatment. Provenance	12	83.2465	6.9372	7.24	<0.001
Residual	45	43.1402	0.9587		
Total	59	127.3818			

Appendix 10: Table showing fruit variation in fruit parameters within the population of *A. digitata*

Population	Seed weight (g)	Seed length (mm)	Seed width (mm)
Chikwawa	0.5751a	12.400c	9.932g
Mwanza	0.5159a	11.880cde	9.555g
Karonga	0.5037a	11.804d	9.447g
Salima	0.4779a	11.772e	9.432g
Likoma	0.3669b	10.885f	8.870h
Grand mean	**0.5035**	**11.846**	**9.58**
P-value	**P<0.001**	**P<0.001**	**P<0.001**
LSD	**0.0619**	**0.6949**	**0.5662**

Appendix 11: Table showing seed weight variation within families of A. digitata in (g)

Provenance	Serial number	Family	Mean seed weight(g)
Chikwawa	1	2	0.7439*a*
	2	4	0.6564*b*
	3	12	0.6348*b*
	4	16	0.6214*b*
	5	7	0.5985*b*
	6	1	0.5888*bc*
	7	14	0.5705*bc*
	8	10	0.5652*bc*
	9	15	0.5624*bc*
	10	3	0.5623*bc*
	11	8	0.5604*bc*
	12	11	0.5599*bc*
	13	9	0.5390*bc*
	14	5	0.5332*bc*
	15	13	0.5171*bcd*
	16	6	0.4777*bcd*
Grand mean	**0.5751**		
S.e	**0.07433**		
LSD	**0.06740**		
CV	**12.9%**		
Karonga	2	3	0.6115*a*
	3	2	0.5514*b*
	5	14	0.4919*bc*
	7	11	0.4723*bc*
	8	7	0.4556*bcd*
	11	12	0.4501*bcd*
	12	13	0.4468*bcd*
	13	8	0.4155*bcde*
	14	5	0.4151*bcde*
Grand mean	**0.4779**		
S.e	**0.08275**		
LSD	**0.03451**		
CV	**17.3%**		
Likoma	2	7	0.4674*a*
	3	9	0.4428*a*
	4	3	0.3877*b*
	5	5	0.3839*b*
	6	2	0.3515*c*
	7	6	0.3225*c*
	9	10	0.3108*bcd*
	10	4	0.2995*bcd*
Grand mean	**0.3669**		
S.e	**0.08320**		
LSD	**0.03606**		

CV	**22.7%**		
Salima	1	10	0.5875*a*
	2	9	0.5817*a*
	3	3	0.5800*a*
	4	2	0.5799*a*
	5	5	0.5698*a*
	6	8	0.5613*b*
	7	1	0.5607*b*
	8	12	0.5411*b*
	9	6	0.5214*bc*
	10	14	0.4509*bcd*
	11	4	0.4204*bcde*
	12	13	0.4073*bcde*
	13	7	0.3861*bcdef*
	14	11	0.3841*bcdef*
	15	15	0.3799*bcdef*
Grand mean	**0.5037**		
S.e	**0.05829**		
LSD	**0.02378**		
CV	**11.6%**		
Mwanza	1	12	0.6112*a*
	2	15	0.5545*b*
	3	3	0.5402*b*
	4	14	0.5376*b*
	5	9	0.5342*b*
	6	8	0.5321*bc*
	7	11	0.5319*bc*
	8	2	0.5238*bc*
	9	10	0.5196*bc*
	10	7	0.4790*bcd*
	11	13	0.4684*bcd*
	12	6	0.4520*bcde*
	13	5	0.4170*bcde*
	14	1	0.3958*bcdef*
Grand mean	**0.5159**		
S.e	**0.05612**		
LSD	**0.02047**		
CV	**10.9%**		

Appendix 12: Table showing variation of mean germination rate of A. digitata between provenances

	Provenance					
Pre-treatments	Likoma	Salima	Mwanza	Chikwawa	Karonga	Mean
Control	5.24a	3.98b	3.92d	5.12g	4.90j	4.63
Nicking	4.15a	6.98b	2.47e	4.79g	6.09j	4.90
Hot water	4.59a	6.13c	5.47ef	2.65hi	4.27jk	4.62
Mean	4.66	5.70	3.95	4.19	5.09	**4.72**
LSD	**1.394**					

Appendix 13: Albino in Karonga population

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