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Research Paper

EFFECT OF SEED SIZE AND ACID SCARIFICATION ON GERMINATION AND EARLY GROWTH OF *Prosopis africana*

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Abstract

Seed size variation has implications for the success of seedling establishment, but the underlying mechanisms are not yet fully explored in many species, including *Prosopis africana*. Moreover, seed size is measured in different ways (for example, mass or length), but the extent to which these different ways of measurement differ in predicting seedling growth parameters is unknown. This study evaluated the effect of seed size and scarification with sulphuric acid on seed germination of *P.africana.* at the Forestry Nursery of the Federal University of Agriculture, Makurdi on the basis of length, breadth, width and weight. Seeds were collected from three locations in Benue State from Zones A, B and C. The treatments were replicated using the randomized block design. Seeds were segregated into three size categories and assigned size class numbers: 1, 2 and 3 for big, medium and small size classes, respectively. All seed size classes were also acid scarified while the control was not scarified. Data was analyzed using means, percentages, correlation and single factor analyses of variance (ANOVA). The big seeds ranged in size from 10.23±0.2mm to 10.57±0.2mm in their mean length, 6.20±0.1mm to 6.61±0.2mm in their mean breadth, 4.63±0.1mm to 4.71±0.2mm in their thickness and 0.22033±0.0007g to 0.2300±0.01g in their mean weight. The medium sized seeds had values of 9.33± 0.2mm in their mean length 5.95 ± 0.26.21±0.1 in mean breadth, 4.32±0.2-4.6±0.1 mean thickness and from 0.1674± 0.01-0.1911±0.01 in mean breadth, 4.32±0.2-4.6±0.1 mean thickness and from 0.1674±0.01g to 0.1911±0.01g in their mean weight. Also the small seeds ranged from 7.85± 0.3-8.72± 0.2 in their mean length, 5.1±0.4-5.61± 0.1 in their thickness and from 0.10064± 0.009-0.13584± 0.007g in their weight. A comparison of seed germination based on seed size showed that the small sized seeds gave the highest germination percentage while the big sized seeds gave the least germination percentage even for scarified seeds and the control. After scarification with H_2SO_4, all the seed size categories

germinated earlier and at a faster rate with the small seeds germinating earlier even for the unscarified seeds., The small seeds gave the highest germination percentages of 92%, 93%, 83% for seeds from seed size categories A_3, B_3 and C_3 respectively, followed by the medium-sized seeds with germination percentages of 89%, 82% and 62% respectively for seed size categories A_2, B_2 and C_2, respectively and The big seeds gave the least germination percentages of 81%, 80% and 27% for A_1, B_1 and C_1 respectively. Small seeds germinated earlier and at a faster rate and acid scarification made smaller seeds to germinate faster than other seed categories. Acid scarifification (with H_2SO_4) and use of small-sized seeds (Seed size category 3) of *P. africana* from zone C should be used in raising seedlings in the nurseries for plantation establishment.
Key words: Seed size, scarification, germination, growth.

INTRODUCTION

The term 'seed' in the strict botanical sense ts defined as the ovule developed after fertilization that contains an embryo (embryonic axis and cotyledons) and reserve tissue (sometimes absent), both being protected by a seed coat (integument) [1, 2]. The structure, size, colour and shape of seeds may vary from one woody plant to another. Seed size polymorphism refers to size variations in seeds produced by a species [3]. Documented studies exist on this phenomenon [4]. Seed size variations may emanate from both genetic variability and differences in site resources and/or conditions; individuals of the same species could vary greatly in sizes of seeds produced [5, 6]

Seed germination refers to the resumption of active growth of the embryo that result in the rapture of the seed coat and the emergence of the young plants. Seed biologists consider germination as the physiological events occurring in imbibed seeds, which are completed by the emergence of the embryo, usually a radicle (embryonic root) first, however, to agronomists, the emergence of seedlings from soil is sometimes called germination.[7] Some seeds can germinate soon after fertilization and long before their normal harvesting time. Other seeds may be dormant and require an extended rest period or additional development before germination can occur. For germination to take place, the seeds must be viable (alive and capable of germinating); they have to be subjected to appropriate environmental conditions (availability of water, appropriate temperature, oxygen and light in some cases). Other forms of embryo dormancy include: immaturity of the embryo, metabolic blocks within the embryo, chemical germination inhibitors, or a combination of two or more of these factors.

Major constraints to the germination of seeds of *Propsopis africana* Taub include: (a) inability of the seeds to dehisce to release *Prosopis* seeds through explosive mechanism (b) waxiness and hardness of its seed coat which makes *Prosopis s*eeds to imbibe water slowly due to the slow permeability of the seed coats to water and gases [8, 9]. Thus *Prosopis africana* exhibits physical (seed coat) dormancy. Any method that can soften or scarify the seed coat will induce germination in *Prosopis Africana.* Scarification can be mechanical or acid-induced [10] Mechanical scarification involves the abrasion of the micropyle end of the seeds with fine grade steel file or sand paper for a uniform number of times [11]. Acid scarification involves soaking seeds in concentrated sulphuric acid (H_2SO_4) or dilute hydrochloric acid (for thirty minutes) with frequent stirring and subsequently washing thoroughly under tap water for five (5) minutes [12]. Acid scarification is more satisfactory and more reliable than mechanical scarification as a means of improving seed germination This is because

mechanical scarification may cause accidental damage to the embryo or undue exposure of the seed to microbial attack, thus reducing the germination percentage. The seeds of *Prosopis* germinate within 2-5 days (60 hours) while the unscarified seeds take seven (7) days on the average to germinate [9].

Prosopis africana is endangered in view of the adverse effects of increasing human activity on the wild population and the fact that it is not a cultivated species. *Prosopis s*urvives in the wild strictly by natural regeneration under adverse ecological and physiological forces. Accounts on *Prosopis africana* and its germination [8, 12 13] scarcely included the relationship between seed size and germination of seeds.

Naturally, impervious seed coats are softened through: (i) the action of micro-organisms in the soil during warm periods of the rainy season (ii) passage through the digestive tract of birds and mammals (iii) mechanical abrasion (iv) alternate freezing and thawing (v) effects of fire. To date, there is not much information on the effect of seed size variation on the germination and growth of nursery cultured *Prosopis africana* . The germination difficulties and lack of knowledge about vegetative propagation techniques of *P. africana* are a serious obstacle to the conservation of the species, given the human pressures and climatic hazards. It is thus necessary in this study to assess the effect of seed size and acid scarification on its germiation in Makurdi, Benue State, Nigeria.

MATERIALS AND METHODS

The Study Area

The study was carried out in Benue State of Nigeria. It is one of the middle belt states lying between longitude 6^0-1^0c East and latitude 6^0-8^0c North. Benue State has an estimated land mass (area) of 67,740km^2 and an arable land area of over 31,840km^2 which is spread over different ecological zones (Ministry of Information n.d.). Extrapolations from 2006 National Population Census in 2010 indicate that Benue State has a population of over 2.7 million people, 70% of which are farmers [14]. It is made up of 23 local government areas which are grouped into three (3) geopolitical ones; A, B and C with its headquarter is Makurdi.

Much of Benue lies within the geographical trough which separates the north central highlands from the southeastern scope lands and Cross River plains. The plains of Benue has been lowered greatly by the river Benue and its tributaries and deposited alluvial soil in the Benue trough forms the bulk of agricultural land that is its pride (Ministry of Agriculture, n.d.). The state has a tropical climate with two marked seasons; the rainy season (April-October) and the dry season (November-March) (Ministry of environment, n.d.).

Benue State is covered although tall tress, tall grasses and oil palm trees exists, in the western and southern parts of the State, it is classified, as Guinea Savanna which is found in the eastern and northern part with mixed grasses and trees of average heights. (Ministry of Environment). It has the capacity of growing the wide variety of food crop e.g. Yam, rice, millet, mazie, sorghum, potato, cassava, beniseeds etc. The location in the transition belt between the forest area of south and semi-grassland of north affords a tremendous grazing potentials (Ministry of Agriculture n.d.). This great agricultural potential earns it the name “Food Basket of the Nation”.

Benue was chosen as a study area because of the existence of *prosopis Africana* trees in the state and also due to the importance attached to the state which suggests the possible needs for developing and improving the growth and distribution of the trees in the state.

Data Collection

All the data used here were collected from primary source, which includes, direct measurement of the seeds and observing their germination rate.

Materials Used

The materials used for this study were; metallic caliper, electrical weighing balance, germination trays (plastic), tissue paper, concentrated tetraoxosulphate (vi) acid (concsulphuric acid), and water and, *prosopis Africana seeds*.

Seed Collection and Evaluation

Seeds were collected from the three zones in Benue State, A, B, and C. Seeds were collected from farmers since it was not the fruiting season for *Prosopis africana*. Seed were separated into three different size groups; labeled 1, 2, and 3 in each case by measuring their weights, other size parameters evaluated were, length, breath and thickness, balance (g), the weight of each seed was determined.

The weight of the seed were determined using electrical weighing balance graduated in grammes. Ten (10) seeds were weighed at a time and their mean weight was taken and recorded in grammes as weight of one seed. This was repeated until all the 100 seeds in each case (100 x 9) were weighed. Seeds with heavy weight were classified as big seeds and labeled 1. Those with medium weight labeled as 2 and those with small weight labeled 3. This applied to seeds from each of the zones. This was repeated until all the seeds were weighted. 111 seeds were obtained for each of the three groups in the three zones. A total of 900 seeds were used.

Measurement of Length, Breadth and Thickness

(a) By using a metal caliper calibrated in millimeter (mm) the see length, breadth and thickness were also determined. The length of representative seed were obtained by taking the average after every ten measurements. This applies also to breadth and thickness. A total of 100 seeds were measured in each case. A total of 900 seeds were measured in all.

Seed Viability Test:

Viable seeds were separated from non viable seeds lot by floatation method. A glass beaker was half filled with water, the seeds were put inside the water. Those that floated on the water were regarded as not viable and removed. This was repeated in each case until all the seeds were tested. The number of each case was reduced to 90 after the test.

Seed Pretreatment

The pretreatment method used was acid scarification method; seeds were soaked in acid (conc. H_2s0_4) for 30 minutes with frequent stirring and subsequently washed thoroughly under running water (tap) for 5 minutes.

Sowing

After the pre-treatment, nine replicate samples each containing 90 seeds which had been acid scarified were sown on water, saturated tissue paper at room temperature (25-31^{0}c) and constantly kept moist, (0.05 liter of water). Another 100 seeds in each case were measured out, tested for viability and without any pre-treatment sown as control. The experiment was monitored carefully every morning to note the emergence of the radical, which was used as the germination criteria.

Data Analysis

Descriptive statistical analysis (means, percentages), correlation analysis and single factor analysis of variance (ANOVA), were used for data analysis

RESULT AND DISCUSSIONS

The result provided information on seed length, seed breadth, seed thickness weight and germination of the various size classes in each zones A, B and C in Benue State..

Seed Length

The result shows that the seed length of A_1, A_2 and A_3 ranges from 10.18-10.66, 9.18-9.99, 7.38-8.40 with their mean seed as 10.40, 9.52 and 7.85 respectively. For B_1, B_2 and B_3 their seed length ranges from 10.26-10.88, 9.18-9.52, 7.77-8.50 with mean seed length as 10.57, 9.33 and 8.23 respectively. Also the seed length of C_1, C_2 and C_3 ranges from 10.02 – 10.73, 9.17-9.98, 8.48-8.98 with their mean seed length as 10.23, 9.49 and 8.72 respectively. These results are shown in Table 1.

Seed Breadth

The result of the seed breadth are shown in **Table 2 b**elow.The seed breadth for A_1, A_2 and A_3 ranged from 6.15mm to 6.70mm, 5.60mm to 6.19mm, 4.76mm to 5.0mm with their mean seed breadth as 6.45mm, 5.95mm and 5.09mm respectively. The seed breadth of B_1, B_2 and B_3 range from 6.08mm to 6.37mm, 5.84mm to 6.10mm, 5.29mm to 5.88mm with mean seed breadth as 6.20mm, 6.0mm and 5.61mm respectively. The seed breadth ranged from 6.34mm to 6.98mm, 6.00mm to 645mm, 5.41mmto 5.75mm for C_1, C_2 and C_3 with mean seed breadth as 6.61mm, 6.2mm and 5.58mm for C_1, C_2 and C_3 respectively.

Thickness

Table 3 shows the thickness of the seed ranges from 4.81-5.02, 4.18-4.51, 3.52-4.32 for A_1, A_2 and A_3 with the mean seed thickness as 4.88, 4.32 and 3.94 respectively. For B_1, B_2 and B_3 the range of thickness are 4.36-4.82, 3.99-4.73, 3.61-4.02 with the mean thickness as 4.63, 4.4 and 3.77 respectively, C_1, C_2 and C_3 thickness ranges from 4.48-499, 4.99, 4.39-4.83, 3.72-4.14 with their means as 4.71, 4.60 and 3.99 respectively.

Seed Weight

From Table 4, weight of B_1, B_2 and B_3 ranged from 0.2168-0.2370g, 0.1699-0.1924g; 0.1091-0.1253g with their mean weight as 0.2300g, 0.184g, and 0.1186g respectively, that of A_1, A_2 and A_3 ranges from 0.2141-0.2358g, 0.1511-0.1805g, 0.0954-0.1241g with their mean weight as 0.2203g, 0.1674g and 0.1064g respectively. For C_1, C_2 and C_3 their weight ranged from 0.2214-0.2342g, 0.1753-0.2179g, 0.1258-0.1474g with their mean weight as 0.2285g, 0.1910g and 0.1358g respectively.

Germination Result

The information on germination is summarized in Tables 5, 6 and 7. From results of the control (Table 5), seeds from A_1, A_2, A_3, germinated at the rate of 3.2, 4.25, 6 with total germination percentages of 47%, 57% and 80% for A_1, A_2 and A_3, respectively per day, Seeds from B_1, B_2, B_3, germinated at the arte of 4.3, 5.2 and 5.9 per day with their germination percentage as 58, 69 and 79 respectively Seeds from C_1, C_2, C_3 also germinated at the rate of 1.7, 3.5, 3.9 with total germination percentages of 22%, 47% and 57% respectively.

Small sized seeds started germinating in 2 days (Table 6) while big sized seeds started to germinate in 3 days for scarified seeds small seeds while for the control, small seed started germination in 6 days while big seeds started germinating in 7 days. Germination took 6-7 days and 13-14 days to complete in scarified and control seeds respectively. Seeds in the control were fully imbibed in 6-7 days and 13-14 days while acid scarified seed were fully imbibed on 2-3 days.

Table 7 shows the germination rate for seed control. For the scarified seeds (Table 7), the mean number of seeds germination pay day for A_1, A_2, A_3, were 10.4, 11.4 and 11.8 with their germination percentages as 81%, 89% respectively. B_1, B_2 and B_3 had a mean seed germination figures of 9.1, 10.5 and 11.9 with total generation percentage of 80%, 82% and 93% respectively. Seeds from C_1, C_2, and C_3 germinated at the average rate of 3.4, 8, and 10.7 per day with their total germination percentages as 27%, 62% and 83% for C_1, C_2 and C_3 respectively. The seeds germinated at an average rate of 3.4,8, 10.7 per day with their total germination percentages as 27%, 62% and 83% for C_1, C_2 and C_3 respectively.

DISCUSSION

Prosopis africana presents a large variability in size in Benue State. Even seeds from the same tree, within the same pod exhibited variation in size. Three seed groups were isolated, the big seeds, the medium and the small seeds based on their weight, length, width thickness.

Statistical analysis showed that the mean length of seeds from fom the seed class categories A_1, A_2, and A_3 differed highly significantly. B_1, B_2, and B_3 also differed significantly and so did C_1, C_2 and C_3 based on the mean length of the big sized seeds. For the medium seeds, zone A had greatest mean length while zone C had the least mean length. Also for small seeds, seeds in zone C had the greatest mean length while zone A has the least mean length.

The mean breadths of the big, medium and small seeds were analyses, A_1, A_2, and A_3 differed significantly and so did C_1, C_2 and C_3. The mean breadth of seed from zones A, B, C were also analyzed; the seeds from A_1, B_1, C_1, differed statistically and so did A_2, B_2, C_2, and A_3, B_3, C_3 respectively. For the big seeds, A_1, had the highest mean breadth while C_1, had the lowest mean. Also for medium-sized seeds, C_2, had the highest mean while A_2 had the least mean breath. For the small seeds, the mean breadth of B_3 was the highest while the mean breath of A_3 was the least.

The mean thickness (mm) of seed size categories A_1, A_2, and A_3 differed significantly and so did B_1, B_2, and B_3 and C_1, C_2 and C_3 respectively. Statistical analysis also showed that the mean thickness of A_1, B_1, and C_1 did not differ significantly. A_2, B_2, C_2 did not differ significantly and so did A_3, B_3, C_3. Among the big seeds, A_1 had the highest mean thickness while B_1 had the least mean thickness. C_2 had the highest mean thickness while A_2 had the least mean thickness. Also the mean thickness of C_3 was the highest while that of B_2 was the least. The seed size polymorphism exhibited by seeds from Zones A,B and C agree with the results of Leishman *et al.*and Halper [5, 15] nwho observed that seed size variations may emanate from both genetic variability and differences in site resources and/or conditions; individuals of the same species could vary greatly in sizes of seeds produced.

Analysis showed that seeds from A_1, A_2, A_3 differed significantly in their weight. B_1, B_2, B_3 also differed significantly and so did C_1, C_2, C_3. Statistical analysis also showed that the seed weights from the three locations (zones) were not different statistically. That is: the weights of seeds from A_1, B_1, C_1 were not different statistically, A_2, B_2, C_2 did not

differ significantly and so did A_3, B_3, and C3. Also, B_1 had the highest mean weight while A_1 had the least mean weight for big seeds in mean weight while A_2 had the least mean weight. Among small seeds, C_1 had the highest mean weight while A_3 has the least mean weight. Weight was found to be directly proportional to length.

Seeds germinated earlier and at a faster rate in small sized seeds than in big seeds in agreement with reports by *Eze et at* [16]. This result was at variance with the findings of Padonou *et al* who assessed germination in *Afzelia africana* and reported that larger seeds of *A. .africana* germinated earlier and grew faster than smaller seeds [17]. Germination was also much earlier and faster in scarified than in control seeds. This result is in agreement with that of Abu-Qaoud, as well as that of Ajiboye *et. al.* [12, 13]. Similarly, in their study of *Afzelia quanzensis* Welw Mtambalika *et al* reported that there were significant differences in seedling height and root collar diameter among the different seed sizes, with large seeds having the highest seedlings height and largest root collar diameter [18]. The general germination percentage was highest in larger seeds (A_3, B_3 and C_3) and least in smaller seeds (A_1, B_1 and $C_{1)}$ this means that the smaller the seed size, the greater the germination percentage and germination rates. This was also applicable to seeds in the control, though the later had lower germination percentage when compared to the scarified seeds. This is because the smaller the seeds, the smaller the embryo and the shorter the time taken to reach full water imbibition's. Correlation result showed that there was a significant relationship between seed size and germination. The analysis showed a negative relationship between seed size and germination with the smaller seeds germinating earlier and at a faster rate than larger seeds. This implied that germination, was inversely proportional to seeds size. Acid scarification of *P Africana* seeds resulted in a faster rate of germination. Similar results were obtained for *Dacroodes edulis* using H_2SO_4 for 20 minutes; scarification decreased the time taken for the seeds to germinate and increased seedling viability while untreated seeds took a longer time to germinate [19]. In another study, H_2SO_4 scarification increased the germination percentage but it reduced the viability of the seed in *Canna indica* L. [20]

CONCLUSION

In determining the effect of seed size on the germination of *Prosopis africana,* three seed size groups (Big, medium and small) were determined using a metal caliper for measurement. The big seeds ranged in size from 10.23±0.2mm to 10.57±0.2mm in their mean length, 6.20±0.1mm to 6.61±0.2mm in their mean breadth, 4.63±0.1mm to 4.71±0.2mm in their thickness and 0.22033±0.0007g to 0.2300±0.01g in their mean weight. The medium sized seeds had values of 9.33± 0.2mm in their mean length 5.95 ± 0.26.21±0.1 in mean breadth, 4.32±0.2-4.6±0.1 mean thickness and from 0.1674± 0.01-0.1911±0.01 in mean breadth, 4.32±0.2-4.6±0.1 mean thickness and from 0.1674±0.01g to 0.1911±0.01g in their mean weight. Also the small seeds ranged from 7.85± 0.3-8.72± 0.2 in their mean length, 5.1±0.4-5.61± 0.1 in their thickness and from 0.10064± 0.009-0.13584± 0.007g in their weight. A comparison of seed germination based on seed size showed that the small sized seeds gave the highest germination percentage while the big sized seeds gave the least germination percentage even for scarified seeds and the control. After scarification with H_2SO_4, all the seed size categories seed germinated earlier and at a faster rate with the smaller seeds germinating earkier even for the uunscarified seeds., The small seeds (group three) gave the highest germination percentage of 92%, 93%, 83% for seed from A_3, B_3 and C_3 respectively, followed by the medium-sized seeds with germination percentages of 89%, 82% and 62% respectively

for seed size categories A_2, B_2 and $C_{2,\ respectively}$ and The big seeds (group 1) gave the least germination percentages of 81%, 80% and 27% for A_1, B_1 and C_1 respectively.

RECOMMENDATION

1. In terms of germination, group three (small seeds) gave the highest germination percentage of 92%, 93%, 83% for A_3, B_3 and C_3 seed batches respectively and are hereby recommended for use in afforestation programmes to ensure uniformity in germination as well as save the cost of nursery operations.
2. In the alternative seeds from group 2 (medium sized seeds) should be selected for afforestation in preference to big-sized seeds as these medium-sized seeds can germinate better compared to big-sized seeds.

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Table 1: Mean Seed Length for Zones A, B and C (cm)

S/No	Zones								
	Zone A Length of seeds (mm)			Zone B Length of seeds (mm)			Zone C Length of seeds (mm)		
	A1	A2	A3	B1	B2	B3	C1	C2	C3
1	10.66	9.29	7.66	10.88	9.18	8.45	10.73	9.17	8.71
2	10.61	9.66	7.74	10.51	9.20	8.27	10.61	9.62	8.54
3	10.18	9.41	7.92	10.72	9.52	8.08	10.18	9.41	8.70
4	10.58	9.42	7.38	10.63	9.25	8.48	10.17	9.23	8.75
5	10.66	9.81	8.40	10.26	9.51	8.50	10.13	9.49	8.62
6	10.33	9.18	8.16	10.42	9.28	8.12	10.30	9.88	8.48
7	10.31	9.50	7.88	10.61	9.40	8.20	10.04	9.53	8.88
8	10.18	9.51	7.62	10.80	9.28	8.04	10.02	9.86	8.75
9	10.24	9.47	7.62	10.29	9.50	8.42	10.12	9.98	8.98
10	10.28	9.99	8.16	10.55	9.19	7.77	10.07	9.69	8.81
Treatment totals	**104.03**	**95.22**	**78.3**	**105.67**	**93.31**	**82.33**	**102.37**	**94.86**	**87.77**
Treatment means	**10.403± 0.2**	**9.55± 0.2**	**7.850± 0.3**	**10.567± 0.2**	**9.331± 0.2**	**8.233± 0.2**	**10.234± 0.2**	**9.486± 0.3**	**8.722± 0.2**

KEY:
A1, B1 and C1=Big seeds from Zones A, B and C, respectively
A1, B2 and C2= Medium sized seeds from Zones A, B and C, respectively
A3, B3 and C3= Small sized seeds from Zones A, B and C, respectivel

Table 2: Mean Seed Breadth for Zones A, B and C (mm)

Sr. No.	Zones								
	Zone A			Zone B			Zone C		
	Breadth of seeds (mm)			Breadth of seeds (mm)			Breadth of seeds (mm)		
	A1	A2	A3	B1	B2	B3	C1	C2	C3
1	6.45	6.19	5.22	6.16	6.04	5.62	6.98	6.21	5.73
2	6.42	5.84	5.30	6.24	6.03	5.51	6.97	6.45	5.41
3	6.41	6.07	5.06	6.24	6.00	5.66	6.40	6.20	5.49
4	6.53	6.06	4.96	6.14	6.07	5.20	6.66	6.00	5.59
5	6.69	5.93	4.88	6.27	6.10	5.88	6.44	6.30	5.48
6	6.45	6.16	4.98	6.19	6.01	5.56	6.76	6.21	5.75
7	6.19	5.93	5.00	6.09	6.02	5.63	6.42	6.00	6.64
8	6.52	6.09	5.54	6.08	5.87	5.82	6.75	6.42	5.45
9	6.15	5.60	4.74	6.37	6.12	5.50	6.44	6.08	5.62
10	6.70	5.66	5.22	6.23	5.84	5.62	6.34	6.18	6.66
Treatment totals	**64.53**	**59.53**	**50.92**	**62.01**	**60.00**	**56.09**	**66.12**	**62.05**	**55.82**
Treatment means	**6.45± 0.2**	**5.953± 0.2**	**5.092± 0.4**	**6.201± 0.1**	**6.000± 0.1**	**5.609± 0.1**	**6.612± 0.2**	**6.205± 0.1**	**5.582± 0.1**

KEY:
A1, B1 and C1=Big seeds from Zones A, B and C, respectively
A1, B2 and C2= Medium sized seeds from Zones A, B and C, respectively
A3, B3 and C3= Small sized seeds from Zones A, B and C, respectivel

Table 3: Mean Seed Thickness for Zones A, B and C

S/No	Zone A Thickness of seeds (mm)			Zone B Thickness of seeds (mm)			Zone C Thickness of seeds (mm)		
	A1	A2	A3	B1	B2	B3	C1	C2	C3
1	4.95	4.37	3.94	4.70	3.99	3.77	4.74	4.39	3.95
2	4.93	4.43	3.52	4.70	4.18	3.69	4.78	4.54	3.84
3	4.86	4.18	4.22	4.60	4.25	4.00	4.85	4.71	4.04
4	4.88	4.51	3.96	4.67	4.45	3.86	4.72	4.57	3.72
5	5.02	4.25	4.22	8.82	4.44	4.02	4.65	4.50	4.09
6	4.81	4.30	3.70	4.66	4.57	3.62	4.48	4.62	4.03
7	4.83	4.26	3.82	4.71	4.73	3.61	4.51	4.52	4.11
8	4.84	4.23	3.66	4.54	4.45	3.70	4.61	4.75	3.97
9	4.83	4.37	4.02	4.36	4.54	3.81	4.99	4.83	4.14
10	4.83	4.28	4.34	4.54	4.44	3.65	4.72	4.54	4.07
Treatment totals	**48.78**	**45.18**	**39.40**	**46.30**	**44.04**	**37.73**	**47.05**	**45.97**	**39.94**
Treatmentt means	**4.878±0.1**	**4.518± 0.2**	**3.940± 0.1**	**4.630± 0.1**	**4.404± 0.2**	**3.773± 0.1**	**4.705± 0.1**	**4.597± 0.1**	**3.994± 0.1**

KEY:
A1, B1 and C1=Big seeds from Zones A, B and C, respectively
A1, B2 and C2= Medium sized seeds from Zones A, B and C, respectively
A3, B3 and C3= Small sized seeds from Zones A, B and C, respectively

Table 4: Mean Weight of seeds in Zones A, B and C (mm)

S/No	Zone A Weight of seeds (mm)			Zone B Weight of seeds (mm)			Zone C Weight of seeds (mm)		
	A1	A2	A3	B1	B2	B3	C1	C2	C3
1	0.21778	0.17917	0.11726	0.2217	0.16988	0.12369	0.23094	0.20105	0.13325
2	0.22517	0.16678	0.11256	0.22873	0.18852	0.10912	0.22350	0.18915	0.14742
3	0.22506	0.14717	0.12409	0.23703	0.18452	0.12427	0.22493	0.18175	0.14182
4	0.21778	0.15105	0.10573	0.21959	0.17642	0.11660	0.23116	0.18800	0.13355
5	0.20984	0.17038	0.09911	0.22509	0.18747	0.11449	0.22858	0.18261	0.113542
6	0.21413	0.17135	0.10028	0.26830	0.19092	0.11929	0.23422	0.18136	0.12961
7	0.23575	0.15804	0.10725	0.22314	0.18287	0.12433	0.22890	0.18407	0.13469
8	0.21910	0.17087	0.10661	0.23376	0.18965	0.11653	0.23241	0.21789	0.14090
9	0.22092	0.17703	0.09542	0.22753	0.17505	0.11730	0.22854	0.17533	0.13690
10	0.21871	0.18051	0.09573	0.21682	0.19247	0.12511	0.22140	0.18859	0.12581
Tmt totals	2.20334	1.67435	1.06404	2.30171	1.82770	1.18616	2.2846	1.9098	1.35837
Tmt means	0.220334± 0.007	0.167425± 0.01	0.106404± 0.09	0.22996± 0.01	0.183777± 0.008	0.118616± 0.006	0.22846± 0.004	0.19098± 0.01	0.135837± 0.007

KEY:
A1, B1 and C1=Big seeds from Zones A, B and C, respectively
A1, B2 and C2= Medium sized seeds from Zones A, B and C, respectively
A3, B3 and C3= Small sized seeds from Zones A, B and C, respectively

Table 5: Germination Table for the Control by Seed Size Category by Zone

Days	Zone A Seeds			Zone B Seeds			Zone C Seeds		
	A_1	A_2	A_3	B_1	B_2	B_3	C_1	C_2	C_3
5	0	0	0	0	0	0	0	0	0
6	0	2	1	0	1	2	0	0	0
7	1	3	2	1	8	7	0	0	1
8	2	5	11	4	9	11	2	3	3
9	8	9	15	9	13	16	5	10	11
10	10	13	13	6	5	8	3	4	8
11	7	3	4	5	3	3	2	6	7
12	4	3	1	3	1	1	1	2	5
13	2	1	1	2	2	1	0	2	3
14	1	0	0	2	1	0	1	1	2
Total	**35**	**39**	**48**	**32**	**43**	**49**	**14**	**28**	**40**

KEY:
A1, B1 and C1=Big seeds from Zones A, B and C, respectively
A1, B2 and C2= Medium sized seeds from Zones A, B and C, respectively
A3, B3 and C3= Small sized seeds from Zones A, B and C, respectively

Table 6: Number of seeds germinated per seed category per day in scarified seeds.

Days taken for seeds to germinate	**Number of seeds germinated by zone and size category**								
	Zone A Seeds			**Zone B Seeds**			**Zone C Seeds**		
	A_1	**A_2**	**A_3**	**B_1**	**B_2**	**B_3**	**C_1**	**C_2**	**C_3**
1	0	0	0	0	0	0	0	0	0
2	0	2	3	0	0	1	0	0	2
3	2	6	10	1	1	2	2	1	8
4	12	13	15	24	20	22	11	34	38
5	45	40	50	30	34	37	8	12	25
6	14	13	5	7	8	10	2	5	2
7	0	6	0	2	11	12	1	4	0
Total	**73**	**80**	**83**	**64**	**74**	**84**	**24**	**56**	**75**

KEY:
A1, B1 and C1=Big seeds from Zones A, B and C, respectively
A1, B2 and C2= Medium sized seeds from Zones A, B and C, respectively
A3, B3 and C3= Small sized seeds from Zones A, B and C, respectively

Table 7 Scarified Seeds (Summary Table)

Zone	Seed Size Category	No of days taken for germination to start	Mean no of seeds that germinated in a day	Total no of germinated seeds	Total germination percentage	Period (days) over which fresh radicle emerged
A	A_1	3	10.4	73	81	4
	A_2	2	11.4	80	89	3
	A_3	2	11.9	83	92	3
B	B_1	3	9.1	64	71	4
	B_2	3	10.6	74	82	4
	B_3	2	12.0	84	93	3
C	C_1	3	3.4	24	27	4
	C_2	3	8.0	56	62	4
	C_3	2	10.7	75	83	3

KEY:
A1, B1 and C1=Big seeds from Zones A, B and C, respectively
A1, B2 and C2= Medium sized seeds from Zones A, B and C, respectively
A3, B3 and C3= Small sized seeds from Zones A, B and C, respectively