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EFFECT OF SOWING DEPTHS ON THE GERMINATION AND EARLY GROWTH OF DIFFERENT SEED-SIZE CLASSES OF *Artocarpus heterophyllus* Lam.

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Abstract
Information on the effect of sowing depth on the germination and early growth of different seed sizes of A. heterophyllus has not been documented. Therefore, this study examined the effect of sowing depths on the germination and early growth of different seed sizes of A. heterophyllus. It specifically evaluated the effect of differents owing depths on the emergence, duration of emergence, germination percentage, total height, number of leaves, collar diameter, seedling biomass and moisture content of three seed size classes of A. heterophyllus. Viable seeds of A. heterophyllus were obtained from a single mother tree and separated into three seed size classes using their diameters. The diameter classes are small (0.90-1.26 cm), medium (1.30-1.55 cm) and large (1.60 -1.80 cm). The seed diameter varied significantly (p ≤ 0.05) among the three size classes. The experiment was laid out in a Completely Randomized Design (CRD). Seeds from each seed-size class were sown at three depths (2, 4 and 6 cm) with ten replicates for each of the sowing depths. The results of the study showed that emergence started from 2cm depth for all the seed diameter classes; 13 days after sowing (DAS) for the small and medium size classes and 14 DAS for the large seed-size class. Increase in sowing depth slightly delayed emergence for one day (4cm depth) and two days (6cm depth), for all the seed sizes. Germination was 100% for the small and medium seed sizes at all the sowing depths and 100%, 90% and 80% for the large diameter seed class at the 2cm, 4cm and 6cm depths, respectively. Germination duration was shortest at the 2cm sowing depth except for the small seed size. At twelve weeks after sowing (WAS) seedlings from the large seed-size class performed better in the evaluated growth variables despite the generally slight delay in emergence. Biomass and fresh weight were higher in large and small seed sizes sown at 2cm with the exception of the medium size where biomass was highest at 6 cm depth. This study revealed that sowing A. heterophyllus seeds at a depth of 2 cm is most appropriate for better germination and growth.

Keywords: *Artocarpus heterophyllus, sowing depths, seed sizes, germination, early seedling growth*

Introduction
Artocarpus heterophyllus, a tree species commonly called Jack fruit, belongs to the family moraceae. Its origin is traced to the Western Ghats of India and Malaysia (Zielenski, 1955; Barrau, 1976; Haq, 2006) but it is now found in central and eastern Africa, south-eastern Asia, the Caribbean, Florida, Brazil, Australia, Puerto Rico, as well as in many pacific Islands (Nair, 1987; Falacao and Clement, 2001). It is a large evergreen tree, 10-15m in height, indigenous to the evergreen forest at altitude 450-1200 mm and cultivated throughout the hotter parts of the world (Prakash *et al*., 2009).It requires a soil which is well drained but moist, with pH of 4.3 to 8.0 and with medium soil fertility. The optimum temperature is 19 to 29°C, altitude of approximately 1600 meters above sea level and the annual rainfall between 1000 and 2400mm.

Jackfruit (*Artocarpus heterophyllus*) perhaps the most widely distributed tree species in the genus Artocarpus, enjoys a dominant place in tropical agroforestry primarily on account of its multiple uses and amenability to integrate with other crop forms (Nair, 1989; Hossain and Haq, 2006). It produces heavier fruit than any other tree species, and bears the largest known edible fruit (up to 35kg). The uses of jackfruit are quite enormous. The flakes of its ripe fruits are nutritious. According to Rashid *et al*., (19870) and Haq(2003), its very nutritious seeds are boiled or roasted and eaten as chestnuts; while the tree which age to an orange or reddish brown color is known for its durable timber and anti-termite properties (Orwa*et al*., 2009). The leaves and fruit waste provide valuable fodder for cattle, pigs and goats. Jackfruit wood chips yield a dye, which is used to give famous orange-red color. In addition, many parts of the plants, including the bark, roots, leaves and fruits have medicinal properties (Prakash *et al*., 2009).

The importance of seed germination as a process in plant development and means of obtaining an optimal number of seedlings that result in higher yield have been reported by Ojo (2000), Adebisi (2004) and Adebisi*et al*. (2011). Seed size is an attribute of seed that can affect the performance of crop, and is a widely accepted measure of seed quality (Jerlin and Vadivelu, 2004).In recognition of the important role seed size plays in crop production and yield, Akinyosoye*et al*., (2014), noted that it is one of the most important characteristics of seeds that can affect seed development. The effects of seed size on seed germination, emergence, and related agronomical aspects,have been reported for many crop species (Kaydan and Yagmur, 2008). It has also been reported that seeds of different plant species need to be sown at different depths in line with their sizes for the roots of the germinated seedlings to grow very well and for better anchorage.

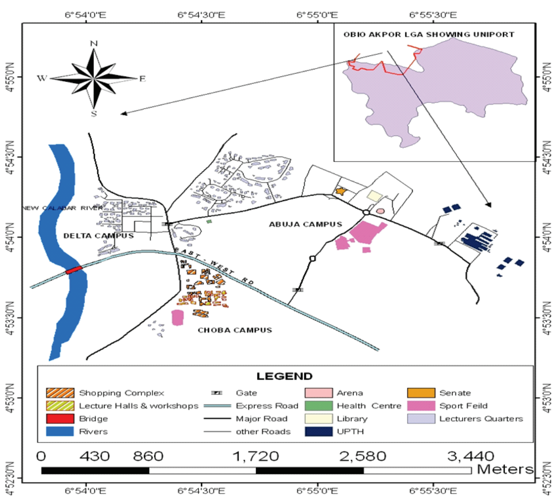
The knowledge of silviculture is of paramount importance in the propagation and cultivation of tree crops. Due to pressure on the available lands as a result of competing claims, there has been a serious advocacy for the adoption of agroforestry which combines the growing of arable crops with tree crop and/or livestock, on the same land, for increased productivity. However the successful adoption of certain tree species for inclusion in agroforestry by farmers will not only depend on the economic importance of such species, but also on the availability of research-based silvicultural knowledge that will enhance their cultivation, management and productivity.

Several authors (Nair, 1989; Haq, 2003, 2006; Orwa*et al,* 2009; Swami *et al.,* 2012) have documented the importance of *A. heterophyllus*in terms of its nutritive and preservative values, and multipurpose uses. Despite the listing of the species in the agroforestry database, its cultivation in the Niger Delta Region and most other parts of Nigeria is rare. As was observed by Willenborg, *et al*., (2005), there are several studies on the relationship between seed size and early growth but none exists for *A. heterophyllus.*This study therefore was conducted to determine the bestsowing depth for different seed-size classes of *A. heterophyllus*for optimum germination and seedling development.

Materials and Methods

Study Area

This research was carried out at the plant nursery within the arboretum of the Department of Forestry and Wildlife Management, located at the University Park (Abuja Campus) of the University of Port Harcourt, Rivers State, Nigeria. The University of Port Harcourt is located on a land area of about 400 hectares in Obio/Akpor Local Government Area of Rivers State (latitude 4.90794 and 4.90809N and longitude 6.92413 and 6.92432E). The area has two seasons, the dry and wet seasons with a nearly all year round rainfall distribution (Aiyeloja*et al*., 2015. The arboretum covers a total land area of about 4226.2581m², and contains several tree species which include *Gmelinaarborea, Tectonagrandis, Naucleadiderrichii, Khayagrandifoliola and Irvingiagabonensis.* These tree species are of great importance in wood production, paper making, food production, among several other uses (Chima*et al*., 2016). Figure 1 is the map of the University of Port Harcourt showing its campuses.



Source: Department of Geography and Environmental Management, University of Port Harcourt, Port Harcourt, Nigeria

Seed Collection, Processing and Viability Test

Artocarpusheterophyllus fruits were collected from one healthy tree with good growth characteristics. The fruits were processed manually by depulping. Viability test was done using floatation method. The seeds were placed inside a bucket of water and allowed to stay for a period of thirty minutes. The ones that sank were classified as viable seeds, while those that floated were classified as non-viable and discarded.

Experimental Design

The experiment was laid out in a completely randomized design (CRD) with ten replicates for each sowing depth of a seed size. The diameter of the seeds were used to classify seeds into three size classes namely; small (0.90 to 1.26 mm), medium (1.30 to 1.55 mm) and large (1.60 to 1.80 mm). A venier caliper was used to measure the diameter of the seeds. A total number of 90 seeds were used for the experiment at 30 seeds per seed size (i.e. 10 seeds per sowing depth). The seeds were sown at 2, 4 and 6cm depths, for each seed size. Watering was done twice daily in the early morning and late evening with 62 ml volume of water per seedling. Topsoil was collected from 0-20cm depth at the University of Port Harcourt Arboretum. Leaf litters on the forest floor were removed before the collection of the topsoil. The collected soil was properly bulked to enhance its homogeneity and sterilized to eliminate pathogenic soil organisms that may have detrimental effect on the growth of the seedlings. Each polypot was taken as an experimental unit anda replicate of its own.

Data Collection

Data were collected on weekly basis for a period of three (3) months on the following:

1 Inception and duration of emergence for each seed size at different sowing depths: this was done by counting the number of days it took the first plumule to emerge from the date of sowing, while duration is the number of days between the first and the last emergence.

2. Germination percentage for each seed size at each sowing depths: this was calculated by dividing the number of seeds that germinated by the total number of seed sown and multiplying by 100.

3. Seedling height, collar diameter and leaf production (number of leaves) for each seed size at different sowing depths: seedling height was measured using a meter rule, vernier caliper was used in measuring the collar diameter, while the number of leaves produced was determined by counting.

4. Seedling biomass for each seed size at different sowing depths was measured by taking the fresh and oven dry weight of the uprooted seedlingsusing analytic weighing balance. Seedling moisture weight was determined thereafter by finding the difference between the fresh and dry weights.

Data Analysis

A one-way analysis of variance (ANOVA) was used to test for significant difference in the measured growth attributes among sowing depths for each seed size class. The analysis of variance was performed using Statistical Package for Social Science (SPSS). The Least Significant Difference Test (LSD) was used for mean separation where significant difference was observed.

Germination percentage was calculated as:

$$GP = (\sum n/N) * 100$$

Where: n is the number of germinated seeds at each sowing depth for each seed size class and N is the number of seeds sown at each depth.

Results

Variation in Seed Sizes

The diameter range and mean of seeds in the different seed size classes is presented in Table 1. The means were significantly different ($P \leq 0.05$).

Table 1: Diameter of different seed sizes

Seed Class	Seed Diameter (cm)	
	Range	Mean (n = 30)
Small Size	0.90 – 1.26	1.21[c]
Medium Size	1.30 – 1.55	1.42[b]
Large Size	1.60 – 1.80	1.68[a]

Means with the same alphabet are not significantly different ($p \leq 0.05$)

Effect of sowing depth on the germination of the various seed sizes

The effect of the various sowing depths on plumule emergence for each of the three seed-size classes is shown in Figure 2. Plumule emergence occurred earliest in 2cm depth, followed by 4cm and 6cm depths, respectively with the exception of the small seed-size where plumule emergence started on the same day for both 2 and 4 cm depths.

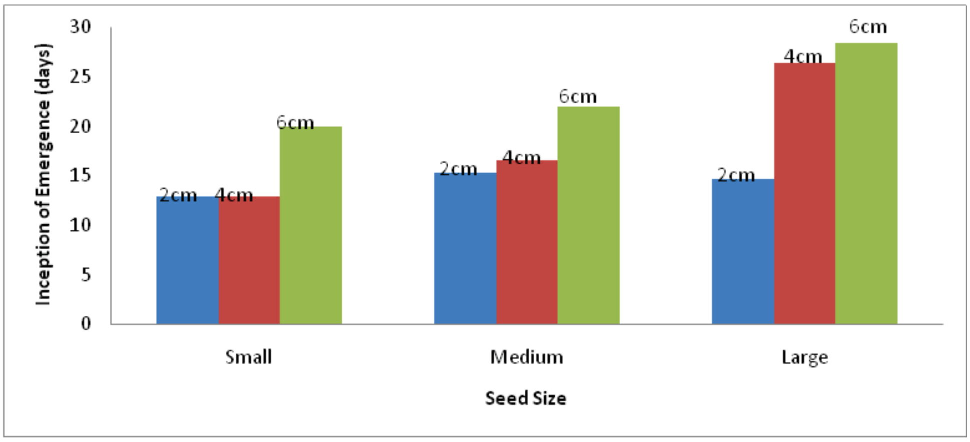


Figure 2: Inception of emergence for the seed-size classes at different depths

The effect of sowing depth on the duration of germination for each of the seed sizes is shown in Figure 3. The duration of germination was longest at the 2cm depth and shortest at 4cm depth for the small seed size. However, the duration of germination was shortest at 2cm depth for both the medium and the large seed sizes.

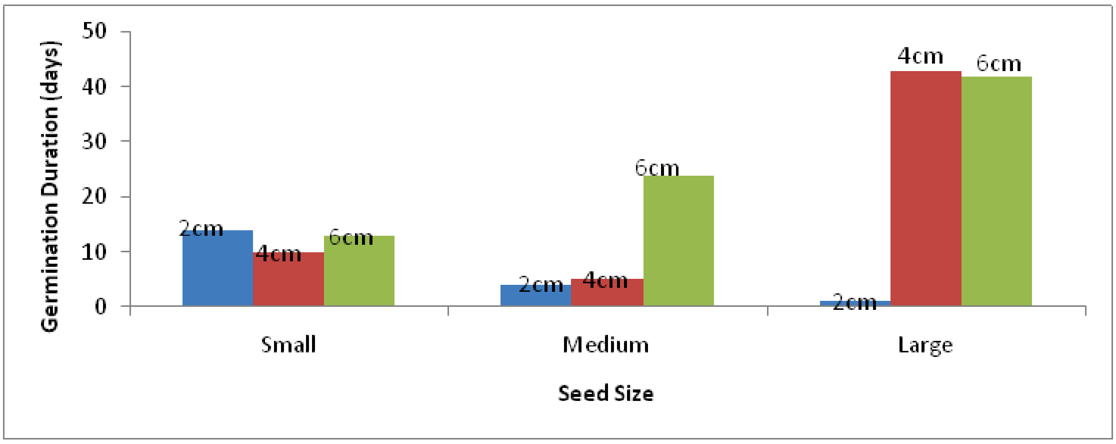


Figure 3: Germination duration for the seed-size classes at different depths

The germination percentages at different sowing depths for the small, medium and large seed sizes, is shown in Figure 4. Germination percentage was 100 at all the sowing depths for the small and medium seed sizes. However, for the large seed size, the germination percentage slightly decreased with increase in sowing depth with the 2, 4 and 6 cm depths having 100, 90 and 80%, respectively.

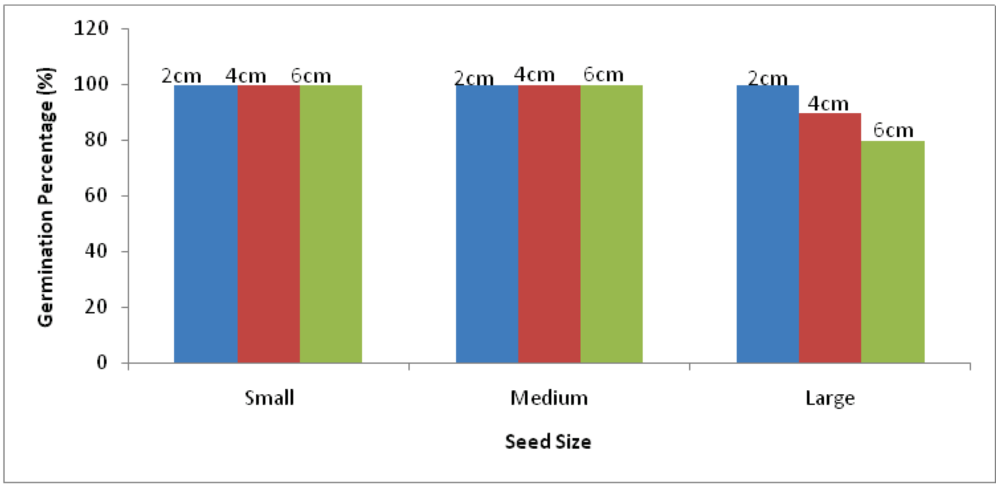


Figure 4: Germination percentage for the seed-size classes at different depths

Effect of sowing depth on seedling growth attributes of different seed sizes of *A. heterophyllus*

The effect of sowing depth on the evaluated seedling growth attributes is shown in Table 2 for the small, medium and large seed sizes. Mean seedling total height reduced with increase in sowing depth for all the seed sizes. However, the reduction was not statistically significant ($p > 0.05$). Mean collar diameter was highest at 6cm depth for the small and medium seed sizes and highest at 2cm depth for the large seed size. There was significant difference ($p \leq 0.05$) in collar diameter between the 2 and 6 cm depths for the small and medium seed sizes while there was no significant difference among the three sowing depths for the large seed size. Mean number of leaves did not vary significantly ($p > 0.05$) among the sowing depths for each of the seed size classes. However, higher mean values were recorded at 2cm depth for the small and large seed sizes and at 4cm depth for the medium seed size.

Table 2: Seedling growth attributes of small, medium and large seed sizes at different depths

Seed Size	Growth Attribute	Sowing Depth 2cm	4 cm	6 cm
Small	Total Height (cm)	26.63 ± 1.72^{a}	25.57 ± 3.05^{a}	24.07 ± 2.22^{a}
	Collar Diameter (mm)	3.21 ± 0.25^{a}	3.48 ± 0.22^{ab}	3.88 ± 0.13^{b}
	No. of Leaves	4.50 ± 0.34^{a}	4.00 ± 0.56^{a}	4.30 ± 0.63^{a}
Medium	Total Height (cm)	29.67 ± 1.15^{a}	28.49 ± 0.83^{a}	28.00 ± 6.09^{a}
	Collar Diameter (mm)	3.42 ± 0.14^{a}	3.44 ± 0.13^{a}	3.83 ± 0.06^{b}
	No. of Leaves	4.00 ± 0.30^{a}	5.00 ± 0.50^{a}	4.70 ± 0.30^{a}
Large	Total Height (cm)	29.89 ± 1.07^{a}	24.11 ± 2.83^{a}	22.19 ± 3.91^{a}
	Collar Diameter (mm)	3.86 ± 0.03^{a}	3.32 ± 0.42^{a}	2.92 ± 0.52^{a}
	No. of Leaves	4.50 ± 0.52^{a}	3.80 ± 0.66^{a}	3.80 ± 0.80^{a}

Means with the same alphabet on the same row for each seed size are not significantly different ($p > 0.05$)

Effect of sowing depth on seedling biomass and moisture content of different seed sizes of *A. heterophyllus*

The effect of sowing depth on seedling biomass and moisture content for different seed sizes of *A. heterophyllus* is presented in Table 3. There was no significant different in the biomass and moisture content of seedlings of each of the seed sizes among the sowing depths. However, mean fresh and dry weights were higher at 2cm depth for the small and large seed sizes while they were higher at 6cm depth for the medium seed size. Moisture content followed a similar trend with fresh and dry weights at the 2, 4 and 6 cm depths for the small, medium and large seed sizes. The large seed size also had more biomass and moisture content than the other seed sizes.

Table 3: Biomass and moisture content of small, medium and large seed sizes at different depths

Seed Size	Biomass/Moisture Weight	Sowing Depth 2cm	4 cm	6 cm
Small	Fresh Weight (g)	4.50 ± 0.27^{a}	3.58 ± 0.43^{a}	4.02 ± 0.17^{a}
	Dry Weight (g)	1.08 ± 0.12^{a}	0.94 ± 0.09^{a}	1.00 ± 0.03^{a}
	Moisture weight	3.42 ± 0.19^{a}	2.64 ± 0.34^{b}	3.02 ± 0.14^{ab}
Medium	Fresh Weight (g)	4.53 ± 0.20^{a}	5.16 ± 0.31^{a}	5.21 ± 0.23^{a}
	Dry Weight (g)	1.18 ± 0.03^{a}	1.21 ± 0.06^{a}	1.23 ± 0.03^{a}
	Moisture Weight	3.35 ± 0.18^{a}	3.95 ± 0.26^{a}	3.98 ± 0.21^{a}
Large	Fresh Weight (g)	5.18 ± 0.38^{a}	4.80 ± 0.20^{a}	5.11 ± 0.37^{a}
	Dry Weight (g)	1.37 ± 0.07^{a}	1.18 ± 0.06^{a}	1.36 ± 0.06^{a}
	Moisture Weight	3.81 ± 0.36^{a}	3.62 ± 0.17^{a}	3.75 ± 0.32^{a}

Means with the same alphabet on the same row for each seed size are not significantly different ($p > 0.05$)

Discussion

Each species has specific sowing depth requirement based on the type of seed and environmental conditions (Agboola, 1996; McWilliams, *et al.,* 1998; Aldrete and Mexal 2005). Variation in seed size and sowing depth influenced the germination of *A. heterophyllus.* For this study, emergence commenced with the least sowing depth 2cm, followed by 4 and 6cm for all the seed size classes. This is in agreement with Aikins*et al.* (2006), who observed that deep sowing depth significantly reduced crop emergence and yield. Also emergence started with the small seed size. This agrees with the findings of Umeoka and Ogbonnaya (2016) in their study on *Telfairiaoccidentalis*where small seeds germinated before large seeds.

The duration of germination varied for the different seed size classes at the various sowing depths. The 2cm depth had the shortest duration, followed by 4 and 6cm respectively for the large and medium seed size classes, while the 4cm depth had the shortest duration followed by 6 and 2cm for the small seed size class.

Kumar and Srivastava (2010) had reported that seed size affected germination percentage of *Ricinuscommunis.* For this study, small and medium seed sizes had 100% germination at all sowing depths while large seed had 100% germination only at the 2cm sowing depth with a slight decrease in germination with increasing depth. According to Souza and Fagundes (2014), small seeds require less time for germination than large seeds, they are more water permeable and germinate faster than large seeds. Dolan (1984) also noted that smaller seeds have thinner coats and higher relative surface which ensures greater permeability in small seeds and less time for germination.The result of this study is in line with the report of Roy *et al.* (1996) who stated that large seed size has slower germination rate than small seed size. This also agrees with Nabi*et al.* (2011); Ali and Idris, (2015) and Chima*et al.,* (2017) who in their studies on cotton (*Gossypiumspp*), faba beans (*Viciafaba L.*) and *Annonamuricata* respectively, reported that germination rate reduced with increase in sowing depth.The deeper the seed is sown the more strength it needs to push its shoots above the soil surface (Ali and Idris, 2015).

This study revealed that increase in sowing depthsslightly reducedgrowth in height over time in all the three seed size classes. According to Adeogun*etal.,* 2012, depth of sowing can impose encumbering soil pressure during shoot up thrust. Vigil *et al.* (1997) made a similar observation while studying the growth of *Brassica rapa.* In this study, seeds in the same size class generally performed better at 2cm depth. With respect to the different seed size classes, large seed size class performed better than the medium and the small seed size classes in terms of height.The superior growth in height that was observed in large size seeds could be attributed to the larger food reserves in those seeds (Owoh*et al.,* 2011).Ndor*et al.,* 2012 noted that as the seed size increases there is more food reserved in cotyledon of the seed to sustain the seedling growth than the smaller seed sizes whose food reserved could be exhausted thus affecting the seedling growth and vigour. This agrees with Mtambaliki*et al.* (2014) who reported that large seeds produced crops with higher heights than small seeds at the same planting depths in *Afzeliaquanzensis*.Chima*et al.,* (2017) also reported that large seeds had higher mean values in seedling height, collar diameter and number of leaves than both the small and the medium size seed classes. However, this contradicts the findings of Umeoka and Ogbonnaya (2016) who revealed that small seeds attained the highest plant height irrespective of the sowing depth.

Collar diameter was affected by sowing depth. For small and medium seed sizes, collar diameter was highest at 6cm depth and lowest at 2cm depth and also varied significantly between 2cm and 6cm depths. However, in large seed size, 2cm had the highest collar diameter and 6cm the lowest although the difference was not significant between it and the other sowing depths. Gholami*et al.*(2007) in their study on*Pistaciaatlantica*equally observed that growth in collar diameter was not significantly affected by changes in sowing depth. Generally, growth in collar diameter was slightly higher in seedlings of the small seed size class. Umeoka and Ogbonnaya (2016), also observed highest radial growth for seedlings of small seeds, followed by the medium sized seeds, throughout the period of their study.

The number of leaves produced by seedlings from each of the three seed size classes was not significantly different among the different sowing depths. However, the large and small seed size sown at 2cm depth produced more leaves. This agrees with the findings of Sime *et al.*(2016) where the maize cultivated at a shallow sowing depth of 2cm produced more leaves. The variations in seedling moisture weight and biomass followed a similar trend with leaf production with the large and the small seed sizes having higher values at 2 cm sowing depth and medium seed size at 6 cm depth.

Conclusion and Recommendation

From this study it has been revealed that germination (especially plumule emergence) and early seedling growth of *A. heterophyllus*are affected by sowing depths. Different seed sizes sown at 2cm depth performed better than at lower depths. Small and medium seeds exhibited better germination characteristics than the large seeds. However, the large seeds performed better than the other seed sizes (especially the small seeds) in seedling growth attributes like total height and biomass. Therefore, the use of large seeds with diameter range of 1.60 – 1.80 cm sown at 2cm depth is recommended for optimum growth of *A. heterophyllus*, However, the medium seed sizes sown at 2cm depth can be used as an alternative where the large seed sizes are not available.

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