EFFECTS OF SEED SIZE ON SEEDLING VIGOUR IN IDIGBO (*TERMINALIA IVORENSIS*)

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ONI, O. & BADA, S.O. 1992. **Effects of seed size on seedling vigour in idigbo (*Terminalia ivorensis*).** The effects of seed size on seedling vigour of *Terminalia ivorensis* were investigated. Seeds were collected from plantations of the species located at the Forestry Research Institute of Nigeria, Ibadan, Oyo State, Ore Forest Reserve, Ondo State and Awi Forest Reserve in Cross River State of Nigeria. Seed sizes were determined by displacement method and two small and large size classes were recognised and used for the study. Seedlings were raised from the two size classes and grown in a completely randomised design under the green house for nine months. Growth analyses of the seedlings were carried out at two-month intervals for the duration of the experiment. Seed size significantly affected all the growth parameters considered on the seedlings. Seedlings from large seeds showed better growth in height, diameter, leaf production, leaf area and biomass production. Also, seedlings from large seeds had a higher relative growth rate (RGR) than those from small seeds. However, seedlings from small seeds had higher values for net assimilation rate (NAR) than those from large seeds.

Key Words: Idigbo - *Terminalia ivorensis* - Seed size - seedling vigour - plantation forestry

Introduction

In plantation forestry, the performance of a tree species on the field depends on the initial vigour of the seedlings used in the plantation establishment. Heydecker (1969) defined "vigour" as the "overall ability of seeds to perform well when sown in the field". For the successful improvement and plantation establishment of indigenous hardwoods species in Nigeria therefore, there is an urgent need to develop proper selection methods that will ensure seeds with adequate seedling vigour. At present, seed collections for plantation establishment of most West African hardwoods are obtained from naturally occurring trees of the species. Thus, the seeds are half-sibs with wide variability. There is therefore the need for evaluation of the superiority of growth of different seedlots.

Such exercise according to Allan *et al.* (1965) is not always possible under field conditions. This is because weather conditions may fluctuate drastically during the course of a field test and lessen the value of the results obtained. Considering the long gestation periods of the tree species in forestry, such exercise is both labour and capital intensive that the merits may not justify the investments. In view of the problems associated with field screening of seedlings, the development of reproducible green-house techniques that measure seedling vigour would be of great benefit. Venator (1974) pointed out that the nursery stage offers an excellent opportunity for the measurement of genetic differences between provenances since the seedlings are exposed to approximately uniform conditions.

Different authors have used different traits to quantify seedling vigour. In cashew (*Anacardium occidentale*), Rao *et al.* (1957), Turner (1956), Ibikunle and Komolafe (1973) and Komolafe (1975) showed nut size as an important factor influencing the germination of cashew nuts. Voight and Brown (1969) using the number and height of seedlings as indicators in oats (*Avena sativa*) observed a positive correlation between grain yield and seedling vigour. Allen and Donnely (1965) used emergence percent (E%) as an indicator for seedling vigour. Many workers have used growth analysis (Redford 1967) or crop growth from planting to maturity (Brinkman & Frey 1977, Gibson & Schertz 1977, Helsel & Frey 1978, Fakorede & Mock 1980) to express seedling vigour.

Little information is available about seedling vigour of tropical forest trees and the techniques for early selection of superior genotypes of the hardwood species. In this study, the effects of seed size on seedling vigour in *Terminalia ivorensis* were investigated.

Materials and methods

Study sites

Mature seeds of *T. ivorensis* were collected from plantations at the Forestry Research Institute of Nigeria, Ibadan, Ore and Awi sites in 1987. The Forestry Research Institute of Nigeria, Ibadan, is in Oyo State of Nigeria (lat. 7°20'N, longtd. 3°56'E), altitude of 150 *m* with an average annual rainfall of 1,232 *mm*. The soil is ferruginous tropical soil. Ibadan is in the dry high forest zone.

Ore is in Ondo State of Nigeria (lat. 6°44'E, longtd. 4°52'E), altitude 91 *m*, has a mean annual rainfall of 2,149 *mm* and lies on red farralitic soil on loose sand sediment. Ore Forest Reserve belongs to the moist high forest zone.

Awi is in Cross River State of Nigeria. It is located at latitude 8°21'N and longitude 4°58'E at an altitude of 63 *m*. The mean annual rainfall is 2,500 *mm* and the soil is typical forest alfisols formed from volcanic ash deposit. Awi is in the wet high forest zone.

Five hundred seeds were collected from each of the three sites described above and mixed together and used for the study.

Selection of samples for growth analysis

Sizes of the sample seeds were determined by displacement method. Seeds were classified as small or large depending on their volume. Seeds with average seed volume of 0.01 ± 0.008 *ml* were classified as small while those with mean seed volume of 0.03 ± 0.01 *ml* were classified as large seeds (Figure 1).

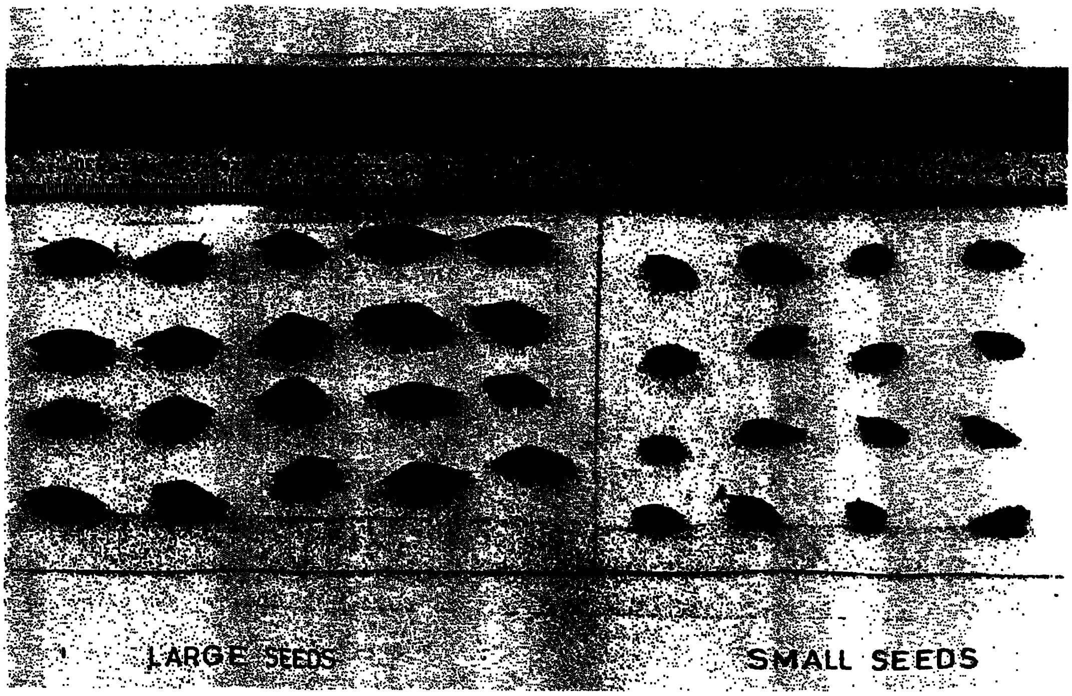

Figure 1. Seeds of *Terminalia ivorensis* from two size classes - large and small seed sizes

Four hundred (400) seeds were afterwards selected from each size class and sown in sterilised river sand under a high humidity (80%) propagator. Watering was done once daily in the morning. At the four leaves stage (two months from the date of sowing), 90 equal-sized seedlings from each size class were transplanted into large polypots (22 X 13.5 *cm*) containing the standard potting mixture of the West African Hardwoods Improvement Project at FRIN, Ibadan. The potting mixture consists of: five headpans of forest top soil, two headpans of horse manure, one headpan of gravel and 35 *g* of N.P.K. (15:15:15) fertilizer. The 180 seedlings were later transferred into the green house where the mean minimum temperature was 24°*C* and the mean maximum temperature 28.5°*C*. The seedlings were arranged on benches in three replicates using the completely randomised design with each replicate containing 60 seedlings. The seedlings were allowed a period of 40 days to establish before assessment commenced. At the start of the experiment, the seedlings were paired and samples were taken and used for the determination of initial dry weights of plants and leaf areas.

Three harvests were made at two-month intervals. At each harvest, ten seedlings were harvested from each seed size class. The following parameters were also measured from each of the harvested seedlings, *viz* seedling height, stem diameter at the colar and number of leaves.

Thereafter, the seedlings were each separated into root, stem and leaves for biomass measurements. Leaf stalks were included in stem biomass. The leaf areas were traced on 1 mm^2 graph sheets and the leaf areas estimated by counting the number of full squares as well as those up to three quarter of a square. Wet weights of the various components (root, stem and leaves) were determined before the samples were oven dried at 80°C for 24 *h*. The dry weights and leaf areas were then used to calculate the relative growth rate (RGR), net assimilation rate (NAR), leaf area index (LAI) and shoot/root ratios according to the formulae of Kvet *et al.* (1971) as follows:

$$\text{NAR } (g\ m^2 wk^1) = \frac{W_2 - W_1}{A_2 - A_1} \times \frac{\text{Ln}A_2 - \text{Ln}A_1}{t_2 - t_1}$$

$$\text{RGR } (g g^1\ wk^1) = \frac{\text{Ln } w_2 - \text{Ln } w_1}{t_2 - t_1}$$

where W_1 and W_2 = biomass at times t_1 and t_2, respectively; A_1 and A_2 = leaf areas at times t_1 and t_2, respectively; Ln A_1 and LnA_2 = natural logrithms of leaf areas at times t_1 and t_2, respectively.

$$\text{Leaf Area Index (LAI)} = \frac{A}{P} \text{ (area: area)}$$

where A = leaf area (cm^2); P = ground area (cm^2)

Results

Height growth

A summary of analysis of variance (ANOVA) for height growth among the seedlings from the two seed sizes is given in Table 1. Seed size showed significant effect on height growth in seedlings of *T. ivorensis* at $P \leq 0.01$. Seedlings from large seeds had a better height growth with a mean of 19.08 *cm*, while seedlings from small seeds had a mean height growth of 14.3 *cm* (LSD = 0.99 Table 2).

Harvest time also had a significant effect ($P \leq 0.1$) on height growth in seedlings from the different seed sizes. The interaction between harvest time and seed size also showed a very high significant effect ($P \leq 0.01$) on height growth of the seedlings.

Table 1. Summary of analysis of variance for seedling height, seedling diameter, leaf production, leaf area, root dry weight, leaf dry weight, stem dry weight and total dry weight of seedlings of *Terminalia ivorensis* from two seed sizes

Variable	df	Seedling height (*cm*) MS	Seedling diameter (*mm*) MS	Number of leaves MS	Leaf area (cm^2) MS	Root dry weight (*g*) MS	Stem dry weight (*g*) MS	Leaf dry weight (*g*) MS	Total dry weight (*g*) MS
Harvest time	2	5327.84**	317.785**	12373.7**	7.5568E+06**	0.0106288**	0.0066084**	0.0249449**	0.121402**
Seed size	1	1024.86**	44.0048**	2471.55**	2.62631E+06**	0.0032021**	0.0020726**	0.0070087**	0.0370288**
Harvest time and seed size	2	58.0391**	0.484607NS	687.622**	220331 NS	0.00108364**	0.0008199**	0.00185002**	0.0124481**
Error	174	11.536	0.576058	82.7581	231463	0.0000782912	0.00004693	0.000142697	0.00081134

* Significant at P ≤ 0.05; ** Significant at P ≤ 0.01; NS Not Significant

Table 2. Summary of mean values for seedling heights, seedling diameter, number of leaves, leaf areas, root dry weights, stem dry weights, leaf dry weights and total dry weights of seedlings of *Terminalia ivorensis* from two seed sizes

Variable	N	Seedling height (*cm*) Mean	Seedling diameter (*mm*) Mean	Number of leaves Mean	Leaf area (cm^2) Mean	Root dry weight (*g*) Mean	Stem dry weight (*g*) Mean	Leaf dry weight (*g*) Mean	Total dry weight (*g*) Mean
Harvest 1 (5 *mth*)	60	6.48	1.04	9.57	434.93	0.0006617	0.00061	0.003805	0.00506167
Harvest 2 (7 *mth*)	60	18.56	4.12	26.15	975.25	0.009555	0.0080467	0.02329	0.040945
Harvest 3 (9 *mth*)	60	25.04	5.54	38.17	1103.7	0.0268367	0.0213267	0.0445717	0.0944483
Small seeds	90	14.31	3.07	21.0	717.17	0.0081333	0.0066011	0.0176489	0.0324756
Large seeds	90	19.08	4.07	28.0	958.76	0.0123511	0.0133878	0.0301289	0.0611611
LSD		0.99	0.22	2.65	140.5	0.0025	0.002	0.0034	0.008

LSD = Least Significant Difference; N = Number of cases

Seedling diameter growth

Table 1 gives the summary of analysis of variance for diameter growth among the seedlings from the two size classes. Diameter growth showed significant difference ($P \leq 0.01$) among the seedlings from the two size classes. At nine months, seedlings from large seeds had a better diameter growth with a mean of 4.1 *mm* while seedling from small seeds had a lower mean diameter growth of 3.1 *mm* (LSD = 0.22, Table 2).

Harvest time also had a significant effect on diameter growth in seedlings from the two size classes ($P \leq 0.01$). The interaction between harvest time and seed size, however, was not significant.

Leaf production

Seed size significantly affects leaf production ($P \leq 0.01$) in seedlings of *T. ivorensis* (Table 1). Seedlings from large seeds at nine months produced more leaves with an overall mean of 28.0 leaves than seedlings from small seeds which had an overall mean of 21.0 leaves (LSD = 2.7, Table 2).

Harvest time also showed a very high significant effect ($P \leq 0.01$) on leaf production in seedlings of the species. The interaction between harvest time and seed size was also very significant ($P \leq 0.01$).

Leaf area

Harvest time showed a very high significant effect on leaf area at ($P \leq 0.01$) in seedlings of *T. ivorensis* (Table 1). Seed size also had a highly significant effect on leaf area development among the seedlings. At nine months, seedlings from large seeds had a greater mean leaf area of 958.8 cm^2 than seedlings from small seeds with a leaf area of 717.2 cm^2 (LSD = 140.5, Table 2). The interaction between seed size and harvest time was not significant.

Root dry weight

Both seed size and harvest time had significant effect on root biomass accumulation (Table 1). At nine months, seedlings from large seed size accumulated more root biomass with a mean of 0.018 *g* than seedlings from small seeds (0.008 *g*) (LSD = 0.0025, Table 2).

Stem dry weight

A summary of the analysis of variance for stem dry weight is given in Table 1. Both seed size and harvest time showed very highly significant effect ($P \leq 0.01$) on stem dry weight in seedlings of *T. ivorensis*. At the final harvest (9 months) seedlings from large seeds had a greater stem biomass of 0.013 *g* than seedlings from small seeds which had a mean of 0.07 *g* (LSD = 0.002, Table 2). The interaction between seed size and harvest time also produced a significant effect on stem biomass accumulation in seedlings of *T. ivorensis.*

Leaf dry weight

Seed size and harvest time significantly affect leaf dry weight in seedlings of *T. ivorensis* (Table 1). Seedlings from large seeds at nine months had a higher mean leaf biomass (0.38 *g*) than seedlings from small seeds (0.18 *g*) (LSD = 0.003, Table 2).

The interaction between seed size and harvest time also showed a very high significant effect ($P \leq 0.01$) on leaf biomass accummulation in seedlings from both seed sizes.

Shoot: root ratios

A summary of the shoot/root ratios of the seedlings from the two seed sizes is given in Table 3. Seedlings from both size classes showed high shoot/root ratios at the first harvest (5 months old). However, seedlings from small seed size had a greater shoot/root ratio (8:1) than seedlings from large seed size which had a ratio of 5:1. Also at the second harvest, (7 months old), seedlings from small seed size gave a greater shoot/root ratio of 4:1 than seedlings from large seed size which had a ratio of 2:1. At the final harvest (9 months old) seedlings from both size classes gave equal ratios of 2:1 each.

Total dry weight

Table 1 gives the summary of analysis of variance for total biomass accummulation in seedlings of *T. ivorensis.* Seedlings from large seeds had a greater biomass (0.061 *g*) than seedlings from small seeds (0.032 *g*) (LSD = 0.008, Table 2).

The interaction between harvest time and seed size also significantly affected total biomass production in seedlings of *T. ivorensis* from both seed sizes.

Net assimilation rate (NAR)

Net assimilation rate, varied between the two seed sizes and harvest time (Table 3). Seedlings from small seed size had a higher net assimilation rate of 0.2934 ± 0.336 $g\ m^2\ wk^1$ at 9 months than those seedlings from large seed size which had a mean value of 0.1752 ± 0.122 $g\ m^2\ wk^1$.

Relative growth rate

A summary of the relative growth rate of the seedlings from the two seed sizes is shown in Table 3. Relative growth rate varied between the two seed sizes and harvest time. At nine months seedlings from small seed size had a higher relative growth rate of 0.271 ± 0.215 $g g^{-1} wk^{-1}$ than the seedlings from large seed size which had a value of 0.263 ± 0.155 $g g^{-1} wk^{-1}$.

Table 3. Summary of net assimilation rate (NAR), relative growth rate (RGR) and leaf area index (LAI) in seedlings of *Terminalia ivorensis* from two seed size classes

	Net Assimilation Rate (NAR) $(g\ m^{2}\ wk^{1})$				Relative Growth Rate (RGR) $(g\ g^{1}\ wk^{1})$			
Seed size	H_1**	H_2	H_3	Mean ± S.E.	H_1	H_2	H_3	Mean ± S.E.
Small seeds	0.6844	0.0822	0.1137	0.2934 ± 0.336	0.4294	0.2098	0.1737	0.271 ± 0.215
Large seeds	0.1545	0.226	0.145	0.1752 ± 0.122	0.3342	0.2650	0.1886	0.263 ± 0.155

	Leaf Area Index (LAI) $(cm^{2}\ cm^{2})$				Shoot/Root ratios		
	H_1	H_2	H_3	Mean ± S.E.	H_1	H_2	H_3
Small seeds	1.1	3.6	3.7	2.8 ± 0.70	8:1	4:1	2:1
Large seeds	2.3	4.0	5.0	3.8 ± 0.675	5:1	2:1	2:1

** H_1 = Harvest after 5 *mth*; H_2 = Harvest after 7 *mth*; H_3 = Harvest after 9 *mth*

Discussion

The importance of the results of this study to practical forestry cannot be overemphasised. This is because the use of seed size as an estimator of seedling vigour may be an efficient tool in facilitating plantation establishment of *T. ivorensis*. It can also afford the forest manager the opportunity of selecting desired traits in seedlings without going through the rigour and expenses of nursery practices and subsequent screening for better seedlings. In forestry biomass production is an important yield component. Thus, for improved wood production, a forest manager may need to select for seed size alone in *T. ivorensis*.

Similar relationships observed in this study have been established by various authors. In *Pinus caribaea*, Venator (1973) reported that seed size can be used as a parameter for predicting seedling growth rates in the nursery and for a brief period following establishment. Stanton (1985) also reported the possibility of estimating seed size from cotyledon width in *Raphanus raphanistrum*.

Seed size as well as harvest time significantly affected all the parameters considered under the growth analysis. In all the parameters observed, seedlings from large seeds have consistantly shown better growth.

The superior growth exhibited by the seedlings from the large seeds could be attributed to larger food reserves in these seeds which might have accounted for the early comparative growth advantage in the seedlings. The above findings agree with the observations of Ibikunle and Komolafe (1973) and Faluyi (1986) who reported better growth in cashew (*Anacardium occidentale*) seedlings from large nuts than in seedlings from small nuts. Cooper (1977) also reported that seedlings from large seeded alfalfa, red clover and alsike clover showed better growth than seedlings obtained from small seeds. Cooper explained his findings by suggesting that the more advanced state of embryology in the large seeds might have accounted for the differences in growth of the seedlings from the two different size classes. The significant interactive effect of harvest time and seed size on some of the traits considered showed that time and energy reserves are essential in the growth of the seedlings of *T. ivorensis.*

The initial high shoot/root ratios observed in seedlings from both size classes may be an adaptation in the species to promote early establishment. Also the higher shoot/root ratios observed in the seedlings from small seed size could connote much dependence on light for higher photosynthetic efficiency to compensate for the small food reserve in the small seeds. This is necessary to enhance the competitive fitness of the seedlings from small seed size with the more vigorous seedlings from large seed size.

The lower net assimilation rate (NAR) and the smaller relative growth rate (RGR) observed in seedlings from large seeds may be a result of the larger food reserves in the large seeds. This agrees with the suggestion of Piper (1986) that seed size may be a function of amount of stored reserves which make seedlings from larger seeds to be less dependent upon photosynthesis for early growth.

The values obtained for net assimilation rate (NAR)and relative growth rate (NGR) are consistent with those reported for this species by Fasehun and Adebagbo (1982) in a fertiliser experiment. Further, Fasehun and Audu (1980) stated that seedling growth and development are dependent on seed size, NAR, respiration rate and leaf development.

Conclusion

The ability of large seeds to produce seedlings of better growth in *T. ivorensis* indicates that better seedling vigour could be selected directly from the seed collection stage. The importance of these findings to practical forestry and tree improvement cannot be overemphasised. In order to obtain better stands of *T. ivorensis*, it is advisable to use large seeds in the production of seedlings for plantation establishment. Also, trees that produce large seeds could be identified, and if they satisfy the conditions for selection as "plus trees", such trees could be used as seed sources for subsequent seed collection and in plantation establishment. However, seed collection should be broad-based to widen the genetic base.

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