THE EFFECT OF SEED SIZE ON GERMINATION AND SEEDLING GROWTH OF THREE TROPICAL TREE SPECIES

D.A. Agboola

Department of Biological Sciences, University of Agriculture, P.M.B. 2240, Abeokuta, Nigeria

Received January 1995

AGBOOLA, D.A. 1996. The effect of seed size on germination and seedling growth of three tropical tree species. The germination and seedling growth as affected by seed size in three tropical tree species were investigated. These were *Terminalia superba*, *T. ivorensis* and *Gmelina arborea*. Seed size had no significant effect (p = 0.05) on the germination of *T. superba* and *T. ivorensis* seeds. Rate of germination was faster in small-sized seed of *G. arborea*. There was no significant effect of seed size on the growth of 1- to 3-month-old seedlings of *T. superba* and *T. ivorensis*. Total dry weights of seedlings of *G. arborea* raised from large-sized seeds was 2-3 times more than those from small-sized seeds. The relative growth rate of seedlings of *G. arborea* raised from small-sized seeds was more than those from large-sized seeds. Seedlings of the three tree species had comparatively higher mean leaf area ratio (LAR) and mean relative growth rate (RGR).

Keywords: Seed size - germination - seedling growth - *Terminalia superba* - *Terminalia ivorensis* - *Gmelina arborea*

AGBOOLA, D.A. 1996. Kesan saiz biji benih ke atas percambahan dan pertumbuhan anak benih tiga spesies pokok tropika. Kajian terhadap percambahan dan pertumbuhan anak benih tiga spesies pokok tropika berdasarkan saiz biji benih telah dijalankan. Spesies yang dikaji ialah *Terminalia superba*, *T. ivorensis* dan *Gmelina arborea*. Saiz biji benih tidak mempunyai kesan yang ketara (p = 0.05) ke atas percambahan biji benih *T. superba* dan *T. ivorensis*. Biji benih *G. arborea* yang bersaiz kecil mempunyai kadar percambahan yang lebih cepat. Saiz biji benih juga tidak mempunyai kesan yang ketara (p = 0.05) ke atas pertumbuhan anak benih *T. superba* dan *T. ivorensis* yang berumur diantara 1 hingga 3 bulan. Jumlah berat kering anak benih *G. arborea* yang dicambah daripada biji benih besar adalah 2 - 3 kali ganda berbanding dengan anak benih yang dicambah daripada biji benih kecil. Kadar pertumbuhan relatif anak benih *G. arborea* yang dicambah daripada biji benih bersaiz kecil lebih tinggi jika dibandingkan dengan anak benih yang dicambah daripada biji benih besar. Secara perbandingan ketiga-tiga spesies ini mempunyai nisbah luas daun dan purata kadar pertumbuhan relatif yang lebih tinggi.

Introduction

There is increasing evidence that the distribution and abundance of adults in a plant community are often mediated by events that occur during seedling establishments. The seed and seedling characteristics are likely to be important determinants of both types of microsites within a community where seedling can establish. Large seed size is generally assumed to provide individuals with a competitive advantage (Gross & Werner 1982). However, seed size may affect initial seedling growth, but not final seed yield (Gross & Soule 1981). Furthermore the effect of seed size may be apparent only under competitive conditions, and earlier germination of small seeds may compensate for initial differences in seed size (Gross 1984).

A number of studies on the effect of seed size on seedling success have been made but indepth knowledge of this relationship in tropical tree species remains incomplete. Many factors may complicate the relationship between seed size and seedling fitness. The most important effect of seed size may be on seedling quality, seedling size and adaptability in habitat (Capinera 1979).

Therefore, this study focuses on the effect of seed size variation among three different tropical tree species relating to rate of germination and seedling growth monitored via net assimilation rate (NAR), leaf area ratio (LAR) and relative growth rate (RGR).

Seeds and seedlings of the tropical tree species *Terminalia superba*, *T. ivorensis* (Combretaceae), and *Gmelina arborea* (Verbenaceae) were used for this study. *Gmelina arborea* is an exotic tropical tree species introduced into the West coast of Africa (Lamb 1968). The fruit of *G. arborea* is a drupe with seeds enclosed in small chambers housed in a stony endocarp surrounded by succulent mesocarp which is covered by leathery shinning epicarp. Fruit drop starts in October - November in the southern parts of Nigeria (5° 34' N, 7° 37' E) (Okoro 1979). These areas lie within the tropical rain belt. This species is not used as sawn timber in Nigeria, but is nevertheless a general utility timber tree for light construction and packaging, fire wood, paper pulp and splint.

Terminalia superba and *T. ivorensis* are timber producing tropical trees usually found in the high forest within the tropical rain forest. The trees could be up to 50 m high and 3 m in girth. The boles are clean and straight. *Terminalia superba* may be recognised by broad plant-like buttress, long straight bole and whorls of thin branches often growing horizontally. *Terminalia ivorensis* is similar in habit but readily distinguished by the dark, often blackish and deeply fissured bark (Keay *et al.* 1964). The winged fruits are very distinctive. In most species the fruit contains one seed (the size of rice grain) in a winged case which does not open (Agboola 1992).

Materials and methods

Seeds were collected from the seed store of the Forestry Research Institute of Nigeria (FRIN), Ibadan. Seeds of two size classes were collected. Size classes were based on observed variation in seed size (length and width) in natural population according to the method of Gross (1984). Seed sizes ranged 5 - 7 mm by 1 - 2 mm in *T. ivorensis*; 7 - 9 mm by 1 - 2 mm in *T. superba* and 8 - 9 mm by 3 - 4 mm in *G. arborea*. Small and large class-sized seeds were designated Ss and Ls respectively. Seeds of these species have been known to exhibit dormancy due to inhibitors within their fruits, hence were pretreated using the methods of Agboola and Etejere (1991). These involve washing or leaching in stagnant and running water for 24 - 72 h. Five replicates, each of 25 seeds, were prepared for germination in 9 cm glass Petri dishes with two layers of Whatman filter paper and moistened with 20 ml distilled water. Dishes were then placed in a germination cabinet set at a constant temperature of 30 ± 1°C with light for 12 h per day. Seeds were considered to have germinated once the radicle emerged up to 2 cm. Germination counts were made at regular intervals for up to a maximum of 30 days in some cases. Germinants were removed from the dishes while extra distilled water were added where necessary.

For the effect of seed size on seedling growth, four seeds per species per size class were planted in sterilised loamy soil in 20 × 18 cm plastic pots. Seedlings were thinned down to one per pot after emergence. Five pots were used for each size class. The seedlings were harvested at 1, 2, 3 months for dry weight measurements and growth analysis. The number of leaves, leaf area, stems and primary root length were also recorded. The components of growth analysis calculated were the relative growth rate (RGR), net assimilation rate (NAR) and leaf area ratio (LAR), according to the methods of Beadle (1982). In this method, RGR is calculated from the measured values of the dry weights (w_2 & w_1) at different times (t_2 & t_1) using the formula

$$RGR = \frac{\log_e w_2 - \log_e w_1}{t_2 - t_1}$$

The NAR or E was also calculated from the measured values of the leaf area (A_2 & A_1), dry weights of plant (w_2 & w_1) and time (t_2 & t_1) applying the formula

$$NAR = \frac{w_2 - w_1}{A_2 - A_1} \cdot \frac{\log_e A_2 - \log_e A_1}{t_2 - t_1}$$

The calculation of LAR or F at instant period was done from the formula

$$LAR = \frac{(LA_1)}{(Lw_1)} + \frac{(LA_2)}{(Lw_2)}$$

using the measured values of the leaf area (LA_1 & LA_2) and dry weights of leaves (Lw_1 & Lw_2). Data were analysed using an analysis of variance and least significant difference test to determine significant differences between the size classes.

Results

Seed size had no significant effect on the germination of *Terminalia superba* and *T. ivorensis* seeds. For example, it was observed that percentage germination was about the same in the small- and large-sized seeds in the two tree species (Figures 1a & b). On the other hand, it was found that the size of the seeds in *G. arborea* had significant effect on germination (Figure 1c). It was observed, however, that both small- and large-sized seeds began germination at the same time, although 100% germination was achieved at different periods. For example, though germination started at the 6th day, it took 12 and 18 days to achieve 100% germination in seeds from large and small-sized seeds respectively in *G. arborea*.

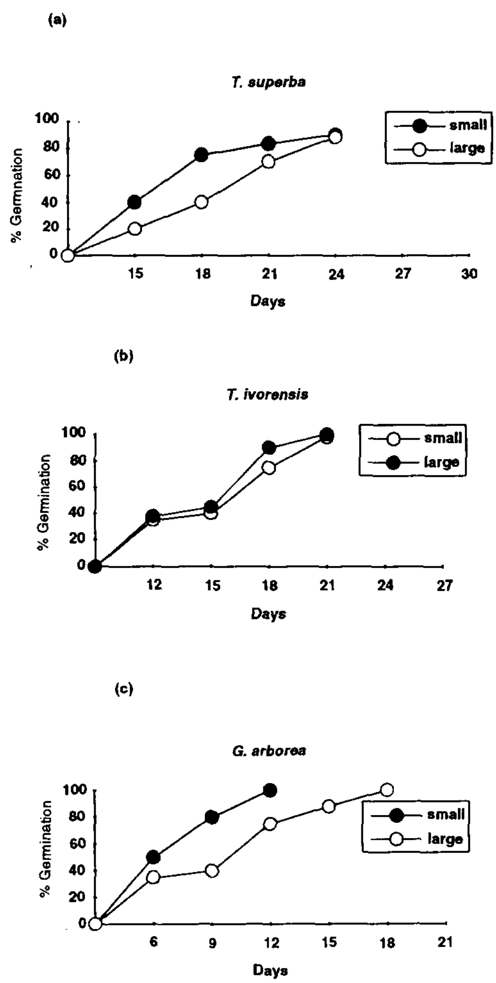

Figure 1. The effect of seed size on the rate of germination of seeds of three tropical species. Each point is the mean of 5 replicates. ○ = Large-sized seeds, ● = small-size seeds.

There was no significant effect of seed size on the growth of 1- to 3- month-old seedlings of *T. superba* and *T. ivorensis* (Table 1). This is because the dry weights of root and shoot, leaf number, leaf area and weight of seedlings raised from small- and large-sized seeds in each age group did not differ significantly. The size of seeds had a significant effect (p =0.05) on the dry weight of shoot, root, leaf area and height in 1- to 3-month-old seedling of *G. arborea*. The total dry weight of seedlings (i.e. addition of the dry weights of shoot and root) raised from large-sized seeds was observed to be 2 - 3 times more than those raised from small-sized seeds of *G. arborea* in all the age groups (Table 1). In general, it was observed that the effect of size of seeds in *G. arborea* was manifested most in the total leaf area and the dry weights of seedlings.

Table 1. The effect of seed size on seedling growth of *Terminalia superba*, *T. ivorensis* and *Gmelina arborea*

Age (months)	Dry wt. (× 10² g)				Leaf No.		Leaf area (cm²)		Height (cm)	
	Shoot		Root							
	Ss	Ls	Ss	Ls	Ss	Ls	Ss	Ls	Ss	Ls
	T. superba									
1	3.0 ± 1.3	4.2 ± 0.3	2.8 ± 0.5	3.4 ± 0.2	5	5	47.6 ± 17.2	479.6 ± 1.3	2.9 ± 0.1	3.3 ± 0.1
2	25.4 ± 1.6	34.2 ± 1.4	24.4 ± 1.8	26.4 ± 0.8	6	6	1078.2 ± 49.9	1001.8 ± 6.7	6.1 ± 0.1	6.1 ± 0.1
3	49.6 ± 1.3	49.2 ± 1.4	29.6 ± 0.4	28.2 ± 0.9	12	12	1352.0 ± 14.2	1470.4 ± 9.6	11.6 ± 9.6	12.2 ± 0.9
	T. ivorensis									
1	2.2 ± 0.4	4.0 ± 0.4	2.4 ± 0.2	2.4 ± 0.2	6	6	84.6 ± 4.0	88.2 ± 6.3	2.6 ± 0.1	2.8 ± 0.1
2	5.2 ± 0.4	6.6 ± 0.2	5.0 ± 0.5	5.2 ± 0.5	7	7	139.8 ± 2.4	139.8 ± 2.4	5.2 ± 0.4	5.0 ± 0.1
3	220.8 ± 0.6	21.2 ± 1.0	11.0 ± 0.6	10.0 ± 0.6	7	10	325.4 ± 9.5	325.4 ± 9.5	8.3 ± 0.1	8.9 ± 0.5
	G. arborea									
1	5.0 ± 0.6	*12.4 ± 1.1	2.6 ± 0.3	*5.4 ± 0.7	6	6	324.4 ± 3.5	*435.2 ± 6.5	4.6 ± 0.3	*16.2 ± 0.1
2	11.0 ± 0.7	*33.0 ± 0.7	5.8 ± 0.4	*14.0 ± 2.5	8	8	663.4 ± 22.1	*1070.0 ± 18.4	10.7 ± 0.3	*12.4 ± 0.4
3	26.0 ± 2.2	*43.6 ± 0.6	8.4 ± 0.5	*11.5 ± 0.3	10	12	409.4 ± 41.2	*4786.0 ± 56.6	17.0 ± 0.1	*23.2 ± 0.9

Data are means ± SE of 5 replicates. SE = Small sized, Ls = Large sized. Asterisks represent significant results: *p = 0.05

Further growth analysis showed that seed size had significant effect on the mean relative growth rate (RGR), net assimilation rate (NAR) and leaf area ratio (LAR) of *G. arborea* seedlings especially at the 1- 2 month stage. For example, at 1- 2 months the RGR of *G. arborea* seedlings raised from small-sized seeds was 1.8 g per gram per month ($g\ g^{-1}$ month $^{-1}$) as compared with 1.3 $g\ g^{-1}$ $month^{-1}$ given by seedlings from large seeds. By contrast, *G. arborea* seedlings from small seeds had comparatively higher LAR and NAR. In terms of performance, seedlings of *G. arborea* from small seeds with higher RGR were better than those from large seeds with lower RGR. It was generally observed that the mean RGR, NAR and LAR were higher in seedlings of *G. arborea* from small seeds. The results showed no significant effect of seed size on RGR and NAR of seedlings of *T. superba*. However, a highly significant effect of seed size on LAR was observed. The seedlings of the three tropical tree species investigated had comparatively higher mean LAR and RGR (Table 2).

Table 2. Growth analysis showing the contribution of the mean NAR and LAR to the mean RGR of 1- to 3-month-old seedlings of the three tropical tree species

	Mean RGR ($g\ g^{-1}\ month^{-1}$)	Mean NAR ($g\ cm^{-2}\ month^{-1}$)	Mean LAR ($cm^{-2}\ g^{-1}$)
Terminalia superba	2.14 ± 0.02	0.590 ± 0.001	896.4 ± 26.3
Terminalia ivorensis	0.82 ± 0.02	0.052 ± 0.001	127.9 ± 9.2
Gmelina arborea	1.88 ± 0.01	0.840 ± 0.010	318.0 ± 13.4

Data are means ± SE of five replicates

Discussion

Seed size had significant effect on the rate of germination, RGR, NAR and LAR of *G. arborea*. Seedlings raised from larger seeds tend to be more favoured. This result supports the observations of Putievsky (1980) on the effect of seed size on germination of corriander and dill. Large diachene fruit clusters germinated more readily than small fruit clusters. Marshall (1986), while working on the effect of seed size on seedling sucess in three species of *Sesbania* (Fabacecae), found that the small-seeded species, *S. macrocarpa*, had the higest percentage of seedling emergence and the quickest seed germination. Seedlings also grown from large seeds of this species tended to be larger, but significant differences in seedling size persisted only for some time. Within *S. vecaria*, larger seeds germinated in greater numbers and moreover, differences in seedling height based on initial size were found. Twainley (1967) is of the opinion that the effect of within-species seed-size differences varies among many plants and that seed size may affect final plant size. According to Staton (1984) the effect of seed size is most apparent under severe competition in plant stands.

The results of these and many studies on the effect of seed sizes on seedling survival favour the use of both seed sizes. Sometimes larger seedlings have higher survival (Schaal 1980) and sometimes they do not (Howell 1981). Dreissche (1965) and Hendrix (1984) are of the opinion that genetic attributes and conditions for germination in the field may produce substantial effect of seed size differences within and among plant species. Omoyiola (1974) found that seed food content, germination vigour and the number of seedlings produced in *G. arborea* increased with increasing weight of fruit stone. Okoro (1979) stated that the rate and final germination in *G. arborea* may depend largely on fruit size and age via seed food content. Other workers have also reported positive correlation between seed size and height growth in tobacco, rice, grass, lettuce (Sonada *et al.* 1972, Kretschemer 1978). However, Black (1969) pointed out that in plants with epigeal germination and without endosperm, seed size may influence early vegetative growth.

The relationship between the mean relative growth rate and leaf area ratio of the seedlings of most of the tropical tree species investigated such as *T. superba* and *G. arborea* showed that they are the fast growing types (Table 2). For example, those seedlings with higher mean leaf area ratio showed higher RGR (Table 2). However, all the seedlings showed comparatively low NAR. Hunt (1978) observed that woody temperate species such as the conifers showed low RGR. He was of the opinion that the lower mean RGR was due more to a low mean leaf area ratio. The growth rate of plants has been found to depend on the effectiveness of the leaf area. This is true when the leaf is the assimilating surface. The comparatively lower NAR observed in the seedlings (Table 2) supports the work of Hunt (1978) who found that woody species exhibited inherently lower NAR than herbaceous plants.

Acknowledgements

I sincerely thank the staff of the library and seed store of the Forestry Research Institute of Nigeria, Ibadan for their technical assistance and the supply of seeds respectively. I also appreciate the help of the library staff of the International Institute of Tropical Agriculture (I.I.T.A), Ibadan, and the useful hints given by E.O. Etejere of the Department of Biological Sciences, University of Ilorin, Ilorin Nigeria.

References

AGBOOLA, D.A. 1992. Studies on the physiology of seed germination and seedling growth of some tropical tree specie. Ph.D thesis, University of Ilorin, Ilorin, Nigeria.

AGBOOLA, D.A. & ETEJERE, E.O. 1991. Studies on seed dormancy of some selected economic tropical forest tree species. *Nigerian Journal of Botany* 4 : 115 - 116.

BEADLE, C.L. 1982. Plant growth analysis. Pp. 19 - 25 in Coombs S.J. & Hall D.O. (Eds). *Techniques in Bioproductivity and Photosynthesis.* Pergamon Press, Oxford. 19-25pp.

BLACK, M. 1969, Light controlled germination of seeds. Pp. 193 - 194 in *Dormancy and Survival. Symposium of the Society of Experimental Biologist* 23.

CAPINERA, J. 1979. Qualitative variation in plants and insects: effect of propagule size on ecological plasticity. *American Naturalist* 114 : 350 - 361.

DRIESSCHE, R. VAN DEN. 1965. Studies on dry matter production in forest trees with special reference to mineral nutrition. Ph.D. thesis, University of Wales.

GROSS, K.L. 1984. Effects of seed and growth form on seedling establishment of six monocarpic perenial plants. *Journal of Ecology* 72 : 369 - 387.

GROSS, K.L. & SOULE, J.D. 1981. Differences in biomass allocation to reproductive and vegetative structures of male and female plants of a dioecious perenial herb, *Silene alba*. *American Journal of Botany* 68 : 801 - 807.

GROSS, K.L. & WERNER, P.A. 1982. Colonizing abilities of biennial plant species in relation to ground cover. *Ecology* 63 : 921 - 923.

HENDRIX, S.D. 1984. Variation in seed weights and its effect on germination in *Pastina sativa* (Umbeliferae). *American Journal of Botany* 71: 795 - 802.

HOWELL, N. 1981. Effect of seed size and relative emergence time on fitness in a natural population of *Impatiens carpensis* Mearb (Balsaminaceae). *American Midland Nature* 105 : 312 - 320.

HUNT, R. 1978. *Plant Growth Analysis Studies*. Biology Series No. 96. Edward Arnold London : 8 - 25.

KEAY, R.W.J., ONOCHIE, C.F.A. & STANFIELD, D.P. 1964. *The Nigerian Trees*. Federal Department of Forestry. Vol. II : 108 - 110, 343 - 347.

KRETSCHEMER, M. 1978. Influence of seed size on germination and vigour of Lambs's lettuce. *Gartenbauwissenschaft* 43(5): 210 - 213.

LAMB, A.F.A. 1968. *Fast Growing Timber Trees of Lowland Tropics*. Federal Department of Forestry, Ibadan. Technical Note No.1.

MARSHAL, D.L. 1986. Effect of seed size on seedling success in three species of *Sesbania* (Fabaceae) *American Journal of Botany* 73(4) : 457 - 464.

OKORO, O.O. 1979. Effect of tree age and fruit size on seed quality of *Gmelina arborea* Roxb. Paper presented at 8th Annual Conference of Forestry Association, Ibadan, Nigeria.

OMOYIOLA, A. 1974. Variation in early traits and productivity of *Gmelina arborea* under controlled environmental conditions. Ph.D thesis, University of Aberdeen.

PUTIEVSKY, E. 1980. Germination studies with seed of caraway, corriander and dill. *Seed Science & Technology* 8 : 245 - 254.

SCHAAL, B.A. 1980. Reproductive capacity and seed size in *Lupinus texensis*. *American Journal of Botany* 67 : 703 - 709.

SONADA, T., KAWAKATSU, M. & TAANABE, A. 1972. Differences in germination of sugar-beet seed according to seed parent. Pp. 131 - 136 in *Proceedings of Sugar Beet Research Association No. 19.*

STATON, M.L. 1984. Seed variation in wild radish: effect of seed size and number of offspring. *American Naturalist* 108 : 499 - 506.

TWAINLEY, B.E. 1967. Seed size and seedling in birds foot trefoil. *Canadian Journal of Plant Science* 47: 603 - 609.