

Functional Importance of Seed Weight on the Seedling Establishment of *Syzygium bankense* (Hassk.) Merr. & L.M. Perry and *Quercus gemelliflora* Blume

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ABSTRACT

Seedling is the first and prominent phase of plant development. Seedling performance can be determined by seed and its embedded characteristics, among them is seed weight. In this study we would like to see how seed weight within species affect seedling establishment. The hypotheses tested were that heavier seed is regarded advantageous compared to lighter seed by functionally produce more competitive seedlings for better growth. Heavier seeds indeed resulted in higher shoot length than lighter seeds. The same pattern was also pronounced for the correlation between seed weight and shoot length of *Syzygium bankense* and *Quercus gemelliflora*. There was also a significant positive correlation between seed size and number of leaf within species.

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Key words: seed weight, *Syzygium bankense*, *Quercus gemelliflora*, seedling establishment, germination.

INTRODUCTION

The world is presently dependent on a few plant species. Only 30 plant species provide 95% of the world's food (FAO, 1996). Over exploitation of particular species lead them into extinction. According to the International Union for Conservation of Nature (IUCN), more than 13% of plant species is threatened (Walter and Gillet, 1997). In addition to food source, plant is mainly used as timber. There are more than 29 000 vascular plant species in Indonesia, of which less than 40 species are utilized for timber. One of the crucial questions in tropical-forest management today is the future of lesser-known, also known as underutilized plant species. Hence, it is important to identify the lesser known species potential for timber resources. Furthermore, another important facet is to understand the ecology of species, including the germination ecology with respect to seed characteristics and seedling of the underutilized plant species.

Seedling is the first and prominent phase of plant development. It may determine the success rate of a species to accomplish further ontogeny form.

Seedling establishment is, thus, important and critical to multi factor affecting species survival. Seedling performance can be determined by seed and its embedded characteristics, among them is seed size or seed weight. Seed weight encompasses amount of reserves that is contained by embryo to start its initial life phase. Seed weight ranges wide among species and within species. Difference of seed weight among species can be subjected to dispersal mode, and allocation pattern of mother tree. Seed weight and life history correlated with the formation of a soil seed bank determines further plant communities and vegetation structure (Honda, 2008). In addition, there are three mechanisms have been proposed to explain functional seed-seedling relationships (Leishman et al., 2000).

Two species were chosen, i.e. *Syzygium bankense* (Hassk.) Merr. & L.M. Perry and *Quercus gemelliflora* Blume to be tested in the study as both are recalcitrant seeds but perform different seedling bank characters. Seedling bank of *Q. gemelliflora* is abundant but not for *S. bankense*, this perhaps entitled to the difference of seed weight between species with regards to reserves in the cotyledon. However, we will focus on a within species analysis. A within-species analysis may therefore more clearly show the functional significance of seed size. Thus, in this study we would like to see how seed size within species affect seedling establishment. The hypotheses tested were that heavier seed is regarded

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advantageous compared to lighter seed by functionally produce more competitive seedlings for better growth. Heavier seeds referred to seeds with larger endosperms or storage tissues. The storage tissue of the seed can be considered to have two functions: sources of energy and of nutrients. The latter function could be expected to be especially important in nutrient-poor soils (Lee and Fenner, 1987).

MATERIALS AND METHODS

Seeds collection

Mother trees of *S. bankense* (V.B.116) and *Q. gemelliflora* (VIII.B.18) belong to the Bogor Botanic Gardens collection. The seeds of *S. bankense* were harvested from a single tree by picking. The seeds of *Q. gemelliflora* were collected from garden floor, produced by a single mother tree as it was not feasible to do climbing. *S. bankense* berries were cleaned from the flesh, then air dried for several hours and weigh individually before it was sown. *Q. gemelliflora* acorns were cleaned; nut and cap were separated, and nuts were then individually weighed before it was sown. The seeds collection and sowing were not carried out at the same time as fruiting and collection time differed.

Germination experiment and measurement

The sowing was carried out in a shaded glass house in Bogor Botanic Garden. The experiment was set up as random single factor design which involved eight replications, which represent four lighter seed and four heavier seed sowing blocks. Each replication consisted of thirty five seeds, giving a total measurement unit of 280 seeds/species. The observation was carried out after 105 days for *S. bankense*, and 61 days for *Q. gemelliflora*, as first leaf shed occurred on the respective days.

The sowing substrate used was nutrient poor sand. Seeds were sown on substrate surface without further being covered by the substrate. The seedlings were watered periodically with fixed sprinkler. There was neither nutrient addition nor dormancy breaking treatment to eliminate external facilitation effect on seedling establishment that can overshadow seed size role on seedlings.

The observation was periodically carried out to record: (i) germination percentage (%); (ii) shoot length (cm); and (iii) number of leaves. The last two were considered as seedling performance or establishment indicators. During the observation, leaf was accounted when the width was larger than 2 mm for *S. bankense*, and was larger than 1 cm for *Q. gemelliflora*. For branched *S. bankense*, the shoot length was counted as the sum length of branches and main stem between branch fork and cotyledon. The length of *Q. gemelliflora* forked seedlings was counted as the sum of seedling branches.

Data analysis

Seed weight determines germination percentage and seedling establishment, represented by number of leaf and shoot length, were analyzed. As the data remained not normally distributed and variance unequal upon various transformation applied, Chi square test was employed to point out differences among groups. Seeds did not germinate were left out from correlation analysis applied for seed weight and seedling establishment indicators. Furthermore, Spearman rank correlation coefficient was used to determine the presence and strength of relationship between seed weight and seedling performance. Statistical analysis was performed under SPSS 15.0.0 for Windows.

RESULTS AND DISCUSSION

Seed weight

The span of average seed weight categorized in smaller and larger seeds category of *S. bankense* was only two fold, being 0.0358 g and 0.0796 g; whereas, it was more than three fold, i.e. 2.0151 g and 6.9908 g, for *Q. gemelliflora*.

Germination

The germination of *S. bankense* and *Q. gemelliflora* follow epigeal and hypogeal pattern, respectively. The germination of *S. bankense* was faster than *Q. gemelliflora*. This can be attributed to the thickness of seed testa. The germination was uniform for *S. bankense*, meaning that seedling emerged almost at the same time. Larger seeds of *Q. gemelliflora* germinated following uniformity and were faster than smaller ones. The mean germination rates of *S. bankense* and *Q. gemelliflora* were 98.57% and 54.64%. Smaller seeds of *Q. gemelliflora* did not germinate until the end of observation (Figure 1).

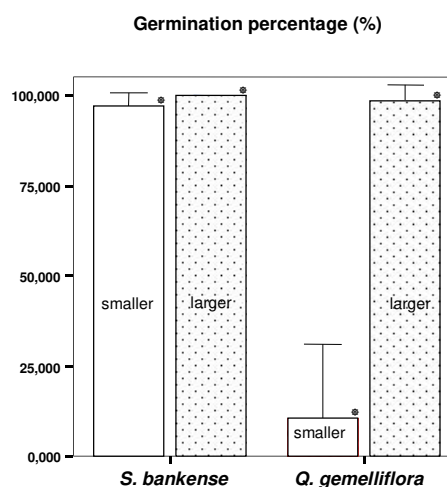


Figure 1. Germination percentage of smaller and larger seeds of *S. bankense* and *Q. gemelliflora*. Error bars show 95% CI of mean, bars show means.

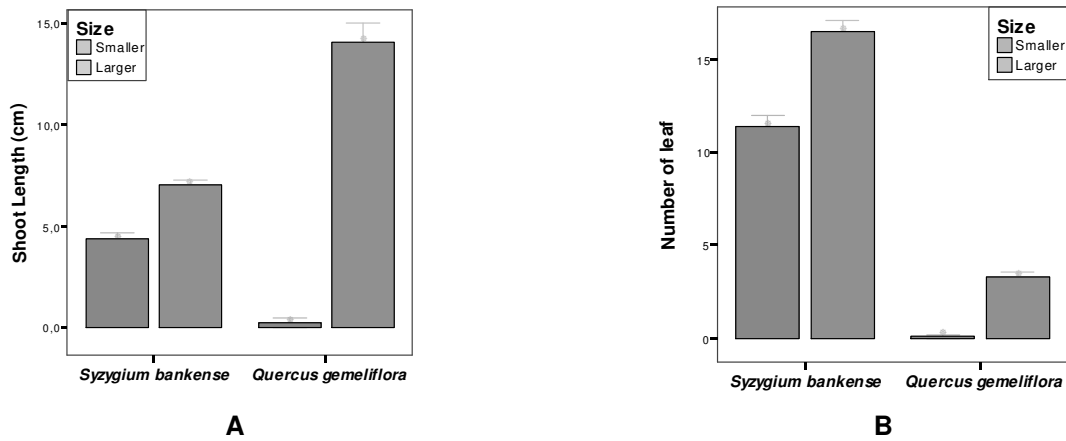


Figure 2.A. Shoot length emerged from smaller and larger seeds of *S. bankense* ($df= 73$, $Chi\ sq= 188.913^{**}$) and *Q. gemelliflora* ($df=68$, $Chi\ sq=171.286^{**}$). **B.** Number of leaf flushed from smaller and larger seeds of *S. bankense* ($df= 21$, $Chi\ sq= 297.913^{**}$) and *Q. gemelliflora* ($df=7$, $Chi\ sq=88.597^{**}$). Error bars show 95% CI of mean, bars show means.

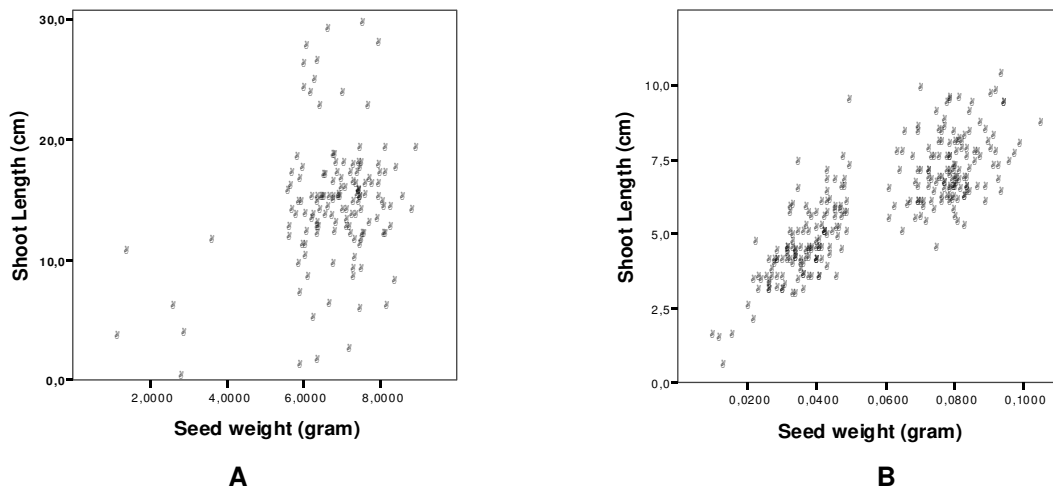


Figure 3.A. Seed weight of *Q. gemelliflora* correlates with seedlings' shoot length (Spearman's $r= 0.292^{**}$, $N=154$); **B.** Seed weight of *S. bankense* correlates with seedlings' shoot length (Spearman's $r=0.798^{**}$, $N=276$).

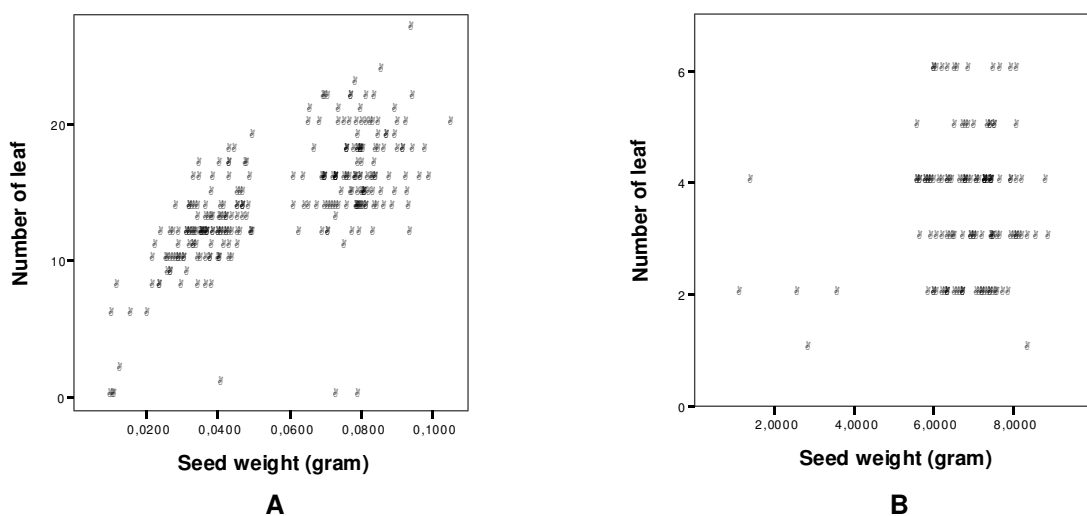


Figure 4.A. Seed weight of *S. bankense* positively correlates with number of leaf of emerged seedlings (Spearman's $r=0.719^{**}$, $N=276$); **B.** Seed weight of *Q. gemelliflora* positively correlates with number of leaf of emerged seedlings (Spearman's $r=0.219^{**}$, $N=154$).

Radicles, in fact, emerged from some seeds but hypocotyls elongation deteriorated at some point, indicating germination failure.

Seedling establishment

Heavier seeds indeed resulted in higher shoot length than lighter seeds. The shoot length of *S. bankense*, in general, was shorter than seedling of *Q. gemelliflora* (Figure 2A). The average leaf area of *Q. gemelliflora* was about a hundred and fifty fold larger than leaf area of *S. bankense*. Heavier seeds were provoked in more seedling leaves for both species. In general, *S. bankense* seedlings attributed with more leaves than *Q. gemelliflora* seedling (Figure 2B).

It can be referred that there was a positive correlation between seed weight and shoot length of *S. bankense* and *Q. gemelliflora*. The same pattern was also pronounced for the correlation between seed weight and shoot length of *S. bankense* and *Q. gemelliflora* (Figure 3A and 3B). Heavy seeds of *Q. gemelliflora* frequently produced more sprout from the cotyledon compared to *S. bankense*, whereas, smaller seeds of *Q. gemelliflora* produced single sprouted seedling. However, we did not measure the correlation between seed weight of *Q. bankense* and number of seedling sprouts produced. Smaller seeds of *Q. gemelliflora* produced less leaf per seedling, and slow developed leaf compared to seedlings leaves flushed from larger seeds. The survival (emergence) of smaller seed seedlings of *Q. gemelliflora* is lower than heavier ones.

There was also a significant positive correlation between seed size and number of leaf for within species relationship (Figure 4A and 4B). We did not measure other leaf characters than number. Nevertheless, it was apparent that except difference in number of leaf, there was no other leaf character difference, such as colour, width, or thickness.

Seed weight-germination

The ability of germination of *S. bankense* that did not differ regarding to weight were contrasted to of *Q. Bankense*. This was not fully in accordance with the expected pattern that germination or seedling emergence was regarded as seed size dependent. A flaw in the experiment design can be possibly subjected to the germination is that we did not look precisely at the emergence (from below substrate surface). Besides that, *Q. gemelliflora* seed collection from garden floor might result in accidental picking of small juvenile seeds. Insect attack can also be attributed to the discrepancy of seed size effect on seedling establishment on *Q. gemelliflora* as reported also in *Quercus suber* insect damage study by Branco et al. (2002), or other biotic factors on oaks (Andersson, 1992; Herrera, 1995).

As the seeds were not buried, germination is solely regarded as the protrusion of radicle from the seed coat, not the emergence from below substrate surface. In *S. bankense* seed size did not affect time

of radicle emerging from testa (personal observation). It could be indeed affecting germination when it is referred as seedling emergence, given seeds have to be buried at a given depth. Other study by Jankowska-Blaszczuk and Daws (2007) found also that with increasing seed weight, germination become less dependent on light.

Seed weight-seedling establishment

A positive correlation between seed weight and number of leaf and shoot, representing seedling growth, also supported the theory that seed size determines competitive ability within species (Turnbull et al., 1999; Leishman and Westoby, 1994), but still not profound for between species. This can address the fact that not all larger sized seedlings were more advantageous to smaller ones. The finding was in accordance with a study by Gross (1984) which tested correlation between seed size and growth form of six perennial plants, and that within species difference in seed size has a significant effect for seedling growth on non competitive cover.

In nutrient poor substrate as in pure sand, seed weight is expected to give more advantage for seedlings. Nutrients, particularly Nitrogen compound, are known to have important role in germination (Broncano et al., 1998), and hence, in nutrient poor condition seed weight is expected to be more determining in seedling establishment. Besides leaf number and shoot growth, relative growth rate or aboveground biomass is a good indicator for seedling performance as it will give insight into the importance of morphological and physiological plasticity for seedling performance (Broncano et al., 1998).

Cotyledon type-seedling performance

We expected that phanerocotylar (photosynthetic) cotyledon produced by epigeal germination of *S. bankense* provided seedlings better capacity to grow than cryptocotylar cotyledon by *Q. gemelliflora* hypogeal germination. Apparently some of *S. bankense* are photosynthetic cotyledons; several days after germination they turned greenish. Without observation on growth increment we can not determine whether there was additional effect of cotyledon on seedling growth of *S. bankense* and *Q. gemelliflora*.

Larger seeds of *Q. gemelliflora* tend to have hypogeal cotyledons as epigeal type can not be supported, given the cotyledons of *Q. gemelliflora* were bulky and heavy. Correlations among seed mass, seedling type, and other seedling traits suggest the evolution of a coordinated set of traits for seedling establishment, defined by a gradient from smaller-seeded species with epigeal foliar cotyledons, orthotropic stems, and dichotomous root systems at one extreme, to larger-seeded species with hypogeal reserve cotyledons, plagiotropic stems, and taproots at the other extreme (Baraloto and Forget, 2007).

CONCLUSION

It was profound that heavier seed provides germination and establishment advantage of the two underutilized species tested namely *S. bankense* and *Q. gemelliflora*. Hence, it is necessary to take seed size into consideration when planning a nursery for underutilized species development program.

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