DOES ACORN WEIGHT INFLUENCE GERMINATION AND SUBSEQUENT SEEDLING GROWTH OF CENTRAL HIMALAYAN OAKS?

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PUROHIT, V. K., TAMTA, S., NANDI, S. K., RIKHARI, H. C. & PALNI, L. M. S. 2003. **Does acorn weight influence germination and subsequent seedling growth of central Himalayan oaks?** The effect of acorn weight on germination and subsequent seedling performance in terms of survival, growth and dry matter accumulation was studied for two important central Himalayan oak species, *Quercus leucotrichophora* (Banj oak) and *Q. semecarpifolia* (Kharsu oak). A wide variation in acorn size and fresh weight existed within these species and germination was found to be correlated with acorn weight. The larger acorns showed higher germination (65.6 and 53.3% for *Q. leucotrichophora* and *Q. semecarpifolia* respectively) compared with medium and smaller acorns. Higher survival and height increment was recorded in seedlings that emerged from larger acorns for both the species, in comparison to medium and smaller acorns. Dry matter accumulation in seedlings derived from acorns of different weight classes was significantly different for various components. Total mass for seedlings derived from larger acorns was about 45 and 31% higher for *Q. leucotrichophora* and *Q. semecarpifolia* respectively, compared with seedlings obtained from acorns of medium weight. Relative growth rate of seedlings was found to increase with increasing acorn weight and seedling shoot height, whereas a reverse trend was recorded for stem height:stem dry mass ratio. This study has implications for the forestry plantation programmes.

Key words: Dry mass - *Quercus leucotrichophora* - *Q. semecarpifolia* - survival

PUROHIT, V. K., TAMTA, S., NANDI, S. K., RIKHARI, H. C. & PALNI, L. M. S. 2003. **Adakah berat akorn mempengaruhi percambahan dan seterusnya pertumbuhan anak benih oak Himalaya tengah?** Pengaruh berat akorn terhadap percambahan dan seterusnya prestasi anak benih dari segi kemandirian, pertumbuhan dan pengumpulan jirim kering dikaji untuk dua spesies oak Himalaya tengah yang penting iaitu *Quercus leucotrichophora* (oak Banj) dan *Q. semecarpifolia* (oak Kharsu). Terdapat variasi yang besar dalam saiz akorn dan berat basah kedua-dua spesies ini dan percambahan didapati berkait dengan berat akorn. Akorn yang lebih besar menunjukkan percambahan yang lebih tinggi (masing-masing 65.6 dan 53.5% untuk *Q. leucotrichophora* dan *Q. semecarpifolia*) berbanding akorn bersaiz sederhana dan kecil. Pertambahan kemandirian dan ketinggian bagi kedua-dua spesies paling tinggi dalam anak benih yang tumbuh daripada akorn besar berbanding akorn sederhana dan kecil. Pengumpulan jirim kering dalam anak benih yang tumbuh daripada akorn berlainan kelas berat adalah berbeza secara bererti untuk pelbagai komponen. Jumlah jisim anak benih yang tumbuh daripada akorn besar adalah

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masing-masing lebih kurang 45 dan 31% lebih tinggi untuk *Q. leucotrichophora* dan *Q. semecarpifolia* berbanding anak benih daripada akorn yang sederhana beratnya. Kadar pertumbuhan relatif anak benih meningkat dengan peningkatan berat akorn dan ketinggian pucuk anak benih. Sementara itu, corak yang sebaliknya dicerap untuk nisbah tinggi batang:jisim kering batang. Kajian ini mempunyai kesan terhadap program ladang hutan.

Introduction

Oaks show a wide variation in acorn size within a species, and the resulting seedlings exhibit differential competitive performance due to variation in the time of emergence and subsequent growth rate (Barik *et al.* 1996, Garrison & Augspurger 1983, Tripathi & Khan 1990, Khan & Shankar 2001). Studies also indicate that seed size in plants is positively correlated with different fitness variables (Mazer 1989). Theoretical models predict an increase in optimal offspring size as conditions for juvenile survival become more stringent (Brockleman 1975, Kolding & Fenchel 1981). Moreover, higher germination success, better seedling survival and a tendency to produce faster growing seedlings has been reported for larger acorns in some oak species (Tripathi & Khan 1990, Khan & Shankar 2001).

Quercus leucotrichophora (Banj oak) and *Q. semecarpifolia* (Kharsu oak) from the family Fagaceae, both late successional, evergreen tree species of Central Himalaya, are important forest species at lower (1200–2400 m elevation) and higher (2400 m) altitudes respectively (Singh & Singh 1987, Negi & Naithani 1995, Rikhari *et al.* 1997). These species are subjected to severe stress not only because of lopping and felling of trees for fodder, fuelwood, charcoal, agricultural tools and tasar (a type of silk) culture but also because of poor or failure of natural regeneration due to non-availability of viable seeds (insect or animal predation), unfavourable microsites and grazing of seedlings by animals (Singh & Singh 1987, Rikhari & Adhikari 1998). In view of considerable importance of these oaks for the region, and the associated difficulties in propagation by vegetative methods using cuttings (Tamta *et al.* 2000) and by *in vitro* methods (Purohit *et al.* 2002a, b), improvement of natural regeneration of oaks using seeds is significance. Therefore, it was thought relevant to evaluate seed germination, survival and subsequent growth of seedlings in relation to acorn weight to develop a simple method for obtaining larger seedlings under nursery conditions for use in plantation programmes.

Materials and methods

About five thousand mature acorns (seeds) each of *Q. leucotrichophora* and *Q. semecarpifolia* were collected in December and June 1998 from Daulagad-Kosi, Almora (1500 m elevation) and Kilbury, Nainital (2400 m elevation) respectively. The acorns were collected from a number of trees growing in the area. These were brought to the laboratory and floated in water to remove insect-infested acorns. Based on fresh weight, healthy and non-predated acorns were categorised into three weight classes, namely, < 2.2 g (small; S), 2.2–3.3 g (medium; M) and > 3.3 g (large; L) for *Q. leucotrichophora* and < 4.9 g (S), 4.9–9.0 g (M) and > 9.0 g (L) for

Q. semecarpifolia. Mean weights for small, medium and large acorns was determined by averaging the values for the respective weight classes. The relative proportion of acorns in each weight class was calculated by dividing the number of acorns in each class by the total number of acorns. Acorn length and diameter were measured using vernier callipers for 25 randomly picked samples from each weight class. The acorns of different weight classes were stored separately in sealed plastic bags at 4 °C until used.

For each species, three beds (one each for small, medium and large acorns) were established at 1200 m elevation at the Institute's nursery using a randomised block design recommended for simple experiments with limited number of treatments (Allen 1989). In each bed, 90 polybags (16 cm height and 8 cm diameter) containing soil and farm yard manure (FYM; 3:1 v/v, approximately 950 g soil) were placed in three rows, i.e. 30 polybags per row. Ninety acorns from each weight class were randomly taken and subjected to treatment with a systemic fungicide Bavistin (0.2% w/v, aqueous solution, 30 minutes) to avoid fungal contamination. The treated acorns were equally divided into three batches, each with 30 acorns as replicates, and sown in polybags at a depth of 2.5 cm. The germination studies for *Q. leucotrichophora* was carried out in February 1999 and that of *Q. semecarpifolia* in July 1998.

Acorns were considered germinated when the seedlings became visible above the soil surface. For *Q. leucotrichophora*, per cent germination was recorded at weekly intervals. Germination of *Q. semecarpifolia* was not recorded since acorns germinated quickly (i.e. < 1 month) during the rainy season. In both species, each germinated seedling was marked and survival recorded following six and 12 months of growth. Height, collar diameter, leaf number and total leaf area (total leaf number × average leaf area) were recorded following 12 months of growth. Leaf area was determined by multiplying leaf length with average leaf width. Collar diameter was measured using vernier callipers. Growth performance of seedlings was calculated following Evans (1972).

Three one-year-old seedlings of each species were harvested for each weight class. The seedlings were excavated carefully to avoid the loss of roots. Roots were washed to remove soil and root length was measured. All samples were oven dried at 60 °C to a constant weight before dry matter yield was determined.

The cost of growing seedlings from acorns of different weight classes was calculated based on transport expenses and time involved in various activities including collection of acorns, their grading according to size, sowing, preparation of beds, filling of polybags with soil, and maintenance (weeding, watering, etc.) of seedlings, as well as mortality, for a period of one year. The total time involved in carrying out these various activities was converted into man-days (8 hours = 1 man-day). The man-days were converted into Indian Rupees (US$1 = Rs. 48) by multiplying the total number of man-days with Rs. 78 (approved daily wage for unskilled labour).

Statistical analyses were carried out using the method of Snedecor & Cochran (1967), and a computer package Microsoft Excel Programme®. Group means were statistically compared either with one or two-way analysis of variance (ANOVA).

Results and discussion

For both species significant variations in acorn length, diameter and weight were recorded (Table 1). Coefficients of variation (CV) indicated higher variation in acorn weight of *Q. semecarpifolia* (56.7%) compared with *Q. leucotrichophora* (32.6%). Acorns of *Q. semecarpifolia* were generally larger (in width and weight) than that of *Q. leucotrichophora* (Table 1). The observed variation in the size and weight of acorns may be genetic as the acorns of each species were collected from the same locality having homogenous environment. Variation in acorn weight has also been reported for other oaks (Tripathi & Khan 1990, Afzal-Rafii *et al.* 1992, Khan & Shankar 2001). The variation in seed weight of a given population has been attributed to different position of acorns on the mother plant, resulting in different seed fillings (Gutterman 1992). The relative proportion of acorns for *Q. leucotrichophora* under different weight classes was within a narrow range (31 to 37%) compared with that observed in *Q. semecarpifolia* (28 to 43%, Table 1). These values are within the reported range (21 to 47%) of relative proportion for acorns of *Q. semiserrata* (Khan & Shankar 2001).

It has been observed that seeds of a single species collected from different altitudes vary greatly in size and germination behaviour (Holm 1994, Vera 1997, Saklani *et al.* 2001). However, in the present study analyses revealed significant differences (p = 0.05) in germination behaviour of acorns of different weight classes collected from the same locality (Table 1). Germination was found to increase with increasing acorn weight, and the larger acorns exhibited 65.6% germination in *Q. leucotrichophora* and 53.3% in *Q. semecarpifolia*. Dumroese and Wenny (1987) had earlier reported that the germination percentage and germination energy in western white pine (*Pinus monticola*) were directly related to seed diameter. In the present study, the germination percentages for the two oaks are lower compared with reported values for *Q. leucotrichophora*, *Q. semiserrata* and *Q. floribunda* under different light conditions in the laboratory (Rao & Singh 1987, Saklani *et al.* 2001). The observed low germination values for *Q. semecarpifolia* in this study may be due to temperature difference as the species generally grows above 2400 m altitude. Temperature-dependent germination has also been recorded in *Q. floribunda*, another species found in the region (Saklani *et al.* 2001). As reported elsewhere (Khan & Shankar 2001), larger acorns of *Q. leucotrichophora* in this study also started to germinate earlier than the smaller ones, i. e. within a week, and peaked at 65.6% within nine weeks (Figure 1). Based on the ANOVA, significant differences were observed for percentage germination and time of seedling emergence for acorns of different weight classes (p = 0.001). The patterns for germination in medium- and small-size acorns were similar but the overall per cent germination was lower. Further, the smaller acorns required longer time to achieve maximum germination percentage (Figure 1). Germination of *Q. semecarpifolia* acorns was not recorded at different time intervals since all acorns germinated quickly (< 1 month) during the rainy season. The observed higher and faster germination in larger acorns may be due to the presence of greater amounts of reserves in the cotyledons and rapid reserve mobilisation (Bewley &

Table 1 Percent seed germination and seedling performance in relation to acorn weight at the end of one-year-growth in the nursery (mean ± SE)

Parameter	*Quercus leucotrichophora*				*Quercus semecarpifolia*			
	Small	Medium	Large	LSD*	Small	Medium	Large	LSD*
Mean acorn weight (g)	1.86 ± 0.12	3.00 ± 0.06	3.70 ± 0.17	0.42	4.21 ± 0.29	7.32 ± 0.24	13.51 ± 0.43	0.61
Acorn length (mm)	20.3 ± 0.55	23.5 ± 0.32	24.9 ± 0.31	1.36	15.4 ± 0.25	19.3 ± 0.44	23.5 ± 0.85	2.42
Acorn width (mm)	11.8 ± 0.32	13.8 ± 0.19	15.3 ± 0.47	1.14	18.2 ± 0.41	23.7 ± 0.65	28.6 ± 0.33	1.18
Relative proportion(%) •	32.3	31.1	36.6	-	27.6	42.7	29.7	-
Germination (%)	36.8 ± 4.2	51.1 ± 3.3	65.6 ± 3.3	7.3	23.3 ± 2.7	33.3 ± 2.7	53.3 ± 7.2	5.9
Survival (%)	37.0	45.0	70.0	-	44.0	100.0	100.0	-
Height (cm)	19.3 ± 0.7	24.3 ± 1.4	36.5 ± 4.2	9.5	12.4 ± 1.6	18.2 ± 2.0	32.8 ± 4.6	12.9
Collar diameter (mm)	3.0 ± 0.1	3.7 ± 0.4	5.0 ± 0.1	0.8	3.2 ± 0.1	3.3 ± 0.2	3.5 ± 0.2	0.7
Leaf number/seedling	15.7 ± 2.6	14.0 ± 2.2	24.0 ± 0.5	7.4	7.7 ± 1.2	12.0 ± 0.9	14.7 ± 1.2	6.0
Leaf area (cm^2)/seedling	173.6 ± 17.2	245.0 ± 54.2	568.8 ± 13.7	399.7	52.4 ± 9.9	140.4 ± 17.9	272.0 ± 46.8	205.3
Root length (cm)	36.7 ± 5.4	41.7 ± 5.4	35.0 ± 0.9	16.7	20.2 ± 2.0	25.3 ± 1.2	29.3 ± 2.8	9.0

*Least significant differences p = 0.05

• Relative proportion of acorns per 100 acorns in different weight classes

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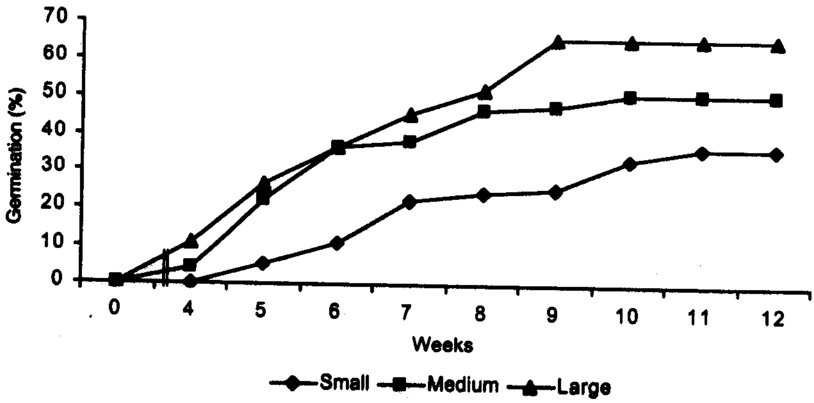

Figure 1 Seedling emergence time in relation to acorn weight classes for *Quercus leucotrichophora*

Black 1994). Similar observations with regard to earlier and improved germination of larger acorns have also been recorded for some other oaks (Tripathi & Khan 1990, Khan & Shankar 2001).

Growth performance of both species indicated clear differences along the acorn weight gradient. Seedlings that emerged from heavier acorns survived better compared with those derived from smaller acorns (Table 1). Data on seedling survival along acorn weight classes indicated higher seedling survival (44 to 100%) for *Q. semecarpifolia* compared with *Q. leucotrichophora* (37 to 70%). In both species, seedlings obtained from larger acorns generally had significantly higher shoot length, collar diameter, leaf number and total leaf area compared with those that emerged from medium and smaller acorns (Table 1). Significant difference in root length of seedlings derived from acorns of different weight classes was not observed in both species. In this study it was observed for both species that the height of seedlings derived from larger acorns was greater when compared with that of *Q. leucotrichophora* seedlings (16.6 to 24.6 cm) grown under different nutrient levels, either alone or in combination with *P. roxburghii* (Bargali & Singh 1992). Reports also indicated that seedlings produced from larger acorns have better seedling survival and growth than those from smaller acorns (Tripathi & Khan 1990, Khan & Shankar 2001). Larger acorn size, and thus increased seedling survival rate, in *Quercus* spp. is an adaptive feature for plants of higher latitudes, in view of a relatively short growing season (Aizen & Patterson 1990). Acorn size in *Q. rubra* is positively related with seedling size and survival after exposure to frost (Aizen & Woodcock 1992). In some plants, increased frost resistance has also been observed as a function of seedling and plant size (Maurata 1983).

Studies conducted to determine the effect of fruit size and seed number per fruit on germination and early growth of seedlings in *Mesua ferrea*, a subcanopy tree of moist tropical and subtropical forests in India, revealed seeds from smaller fruits were lighter in weight and achieved lower germination percentages and required greater germination time than the seeds from large fruits (Khan *et al.* 1999).

As expected, significant differences were noticed in dry mass accumulation for different seedling components derived from acorns of different weights ($p = 0.05$ for *Q. leucotrichophora* and $p = 0.02$ for *Q. semecarpifolia*). Total mass of seedlings that emerged from larger acorns was about 45 and 31% higher for *Q. leucotrichophora* and *Q. semecarpifolia* respectively compared with those derived from medium-size acorns (values derived from Figure 2). Higher rates of dry matter accumulation have also been reported for seedlings derived from larger acorns in other oaks (Tripathi & Khan 1990, Khan & Shankar 2001). The greater seedling survival, height, total leaf area and productivity following one year of growth are likely to be linked with the larger food reserves in heavier acorns (Tripathi & Khan 1990, Khan & Shankar 2001).

Various growth characteristics of seedlings derived from acorns of different weights are given in Table 2. Growth response of seedlings derived from acorns of different weight classes can be evaluated on the basis of their stem height:stem dry weight ratio, i.e. in terms of height required for the production of 1 g dry weight of stem. The seedlings derived from smaller acorns required more height to gain 1 g dry mass. Specific leaf area for seedlings derived from medium-size acorns was lower compared with large and small acorns indicating that seedlings derived from smaller and larger acorns required a larger leaf area to produce 1 g of dry matter. Root:shoot ratio increased with increasing total seedling biomass of *Q. semecarpifolia*. However, a definite trend was not recorded for *Q. leucotrichophora*. This suggests that root:shoot ratio is adjusted according to nutrient demand of the species. Increased proportional allocation of biomass to the root system and decrease in leaf weight ratio suggest more efficient use of nutrients in *Q. leucotrichophora*. This agrees with results by Singh and Bisht (1992). An increase in relative growth rate of seedlings along the acorn weight series is linked with greater food reserves in acorns of higher weight.

Table 2 Growth performance of seedlings derived from acorns of different weight classes

Parameter	Acorn weight class Small	 Medium	 Large
Quercus leucotrichophora			
Stem height:stem dry weight ratio (cm g^{-1})	46.2 ± 8.4	20.9 ± 2.8	14.8 ± 1.9
Leaf weight ratio (g g^{-1})	0.41 ± 0.02	0.27 ± 0.01	0.27 ± 0.02
Leaf area ratio (cm^2 g^{-1})	62.2 ± 13.1	34.4 ± 9.8	42.1 ± 3.8
Specific leaf area (cm^2 g^{-1})	149.0 ± 27.2	126.8 ± 35.1	161.2 ± 19.8
Root: shoot ratio	0.72 ± 0.06	1.33 ± 0.05	1.20 ± 0.11
Relative growth rate (g g^{-1} day^{-1})	0.0029 ± 0.0006	0.0055 ± 0.0002	0.0071 ± 0.0002
Q. semecarpifolia			
Stem height:stem dry weight ratio (cm g^{-1})	58.9 ± 19.4	29.4 ± 2.9	24.8 ± 1.4
Leaf weight ratio (g g^{-1})	0.20 ± 0.01	0.28 ± 0.01	0.30 ± 0.02
Leaf area ratio (cm^2 g^{-1})	25.8 ± 7.2	28.0 ± 3.4	38.0 ± 5.9
Specific leaf area (cm^2 g^{-1})	130.3 ± 37.2	102.5 ± 15.5	129.9 ± 19.5
Root: shoot ratio	2.05 ± 0.29	1.35 ± 0.25	1.07 ± 0.09
Relative growth rate (g g^{-1} day^{-1})	0.0018 ± 0.0005	0.0044 ± 0.0001	0.0054 ± 0.0004

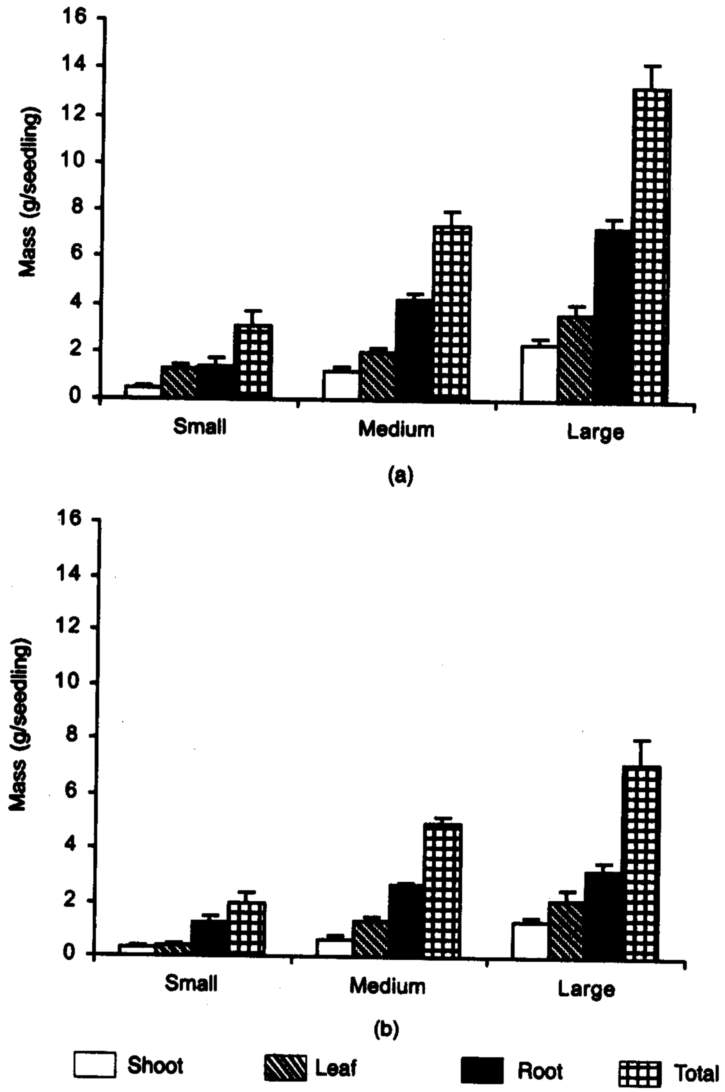

Figure 2 Dry mass accumulation in different components of seedlings in relation to acorn weight for (a) *Quercus leucotrichophora* and (b) *Q. semecarpifolia*. Lines above bars represent one standard error.

The cost involved to raise seedlings from larger acorns in the nursery has been estimated to be approximately Rs. 205/100 seedlings/year for *Q. leucotrichophora* and Rs. 175/100 seedlings/year for *Q. semecarpifolia*. These are about half the cost of seedlings obtained from acorns of smaller and medium weight classes. Thus, the seedlings raised from larger acorns in the nursery are not only cost-effective due to higher germination and lower mortality, but also require less nursery time and result in taller seedlings with stronger vigour after one year of growth. It would be desirable to examine the effects of acorn weight on germination and seedling performance of acorns from other provenances.

The results of this study will be useful for nurserymen, marginal farmers, non-governmental organisations and village panchayats to select acorns of suitable size for various plantation purposes. The study may also have importance in regenerative strategy for canopy gaps, burnt areas, gorges and channels devoid of vegetation.

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