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Effect of Shade and Moisture Gradients on Seedling Growth of *Quercus leucotrichophora* and *Pinus roxburghii* in Kumaun Himalaya

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Quercus leucotrichophora A. Camus. (banj oak), a late successional species, and *Pinus roxburghii* Sarg. (Chir pine), an early successional species were compared for seedling growth as a response to shade and moisture gradients. Chir pine showed wider ecological amplitude for soil moisture, but narrower amplitude for shade tolerance. Under soil moisture stress, both the species attained similar heights, but in terms of dry weight, banj oak performed better. The chir pine had higher leaf weight ratio (LWR), while banj oak had higher root: shoot ratio, compared to the other.

Key Words: *Quercus leucotrichophora* **(banj oak),** *Pinus roxburghii* **(chir pine), Seedling growth, Stress, Response breadth**

Introduction

Quercus leucotrichophora A. Camus. (banj oak) and *Pinus roxburghii* Sarg. (chir pine) dominate large areas of the Kumaun Himalaya. Banj oak is a climax species (Troup 1921, Champion & Seth 1968, Puri et al. 1982), while chir pine is an early colonizer of the barren areas created by landslides, fire or clear felling of the forests (Singh & Singh 1984, Rao & Singh 1986). Chir pine often remains a stable community under biotic pressure (Champion & Seth 1968). The banj oak fail to regenerate in many areas due to increasing disturbances and chir pine often encroaching in these forests (Saxena et al. 1985). Since regeneration is critical, this paper compares response of the seedlings of banj oak and chir pine to gradients in shade and moisture.

Climate and Species Distribution

In the Central Himalaya, chir pine is vigorous at an elevation of 1500 m with a range of 800–2000 m, while banj oak is vigorous at an elevation of 1800–2000 m with a range of 1200–2200 m (Champion & Seth 1968). In this altitudinal range the annual rainfall varies between 1500–2500 mm, of which nearly three-fourth occurs from mid-June to mid-September (wet summer season). Snow fall during the winter season (December–February) is frequent at an altitude of 2000 m, but rare below 1500 m. The mean daily temperature ranges from 6.0 (January) to 30.2°C (May) (Singh & Singh 1984). In both the species seed fall occurs during the winter season. Seed germination occurs during the transition period (March-April) between winter and summer (Rao et al. 1984). The winged seeds of chir pine are wind-dispersed and heavier banj oak seeds are dispersed by animals, or slide down through gravity (Rao & Singh 1986).

Methods

One seedling per polythylene bag filled with farmyard manure and garden soil in the ratio of 1 : 3 was raised from the seeds collected from the 1981 seed crop.

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Seedlings of both the species were subjected to three shade levels by constructing sheds of 1 m height covered with one, three and five layers of musline cloth. Light intensity measured under these sheds using a Lux meter was expressed as percentage of full sunlight in the open. Three light regimes, namely, 70%, 50%, and 18% of the full light were obtained. These levels are designated as low, intermediate and high shade regimes respectively. A control set was maintained in the open (100%). Twenty-five bags of each species were placed under each shed and in open. The bags were moistured to keep the soil in the bags at field-capacity.

In another experiment, the seedlings were subjected to four watering frequencies i.e., daily, and at five, ten and fifteen days intervals, and referred to as control, low, intermediate and high moisture stress, respectively. Twenty-five seedlings of each species were placed under each watering regime and the experiment was done in a glass house.

Seedling height was measured at monthly intervals and the dry weight yield of seedlings at bi-monthly intervals, after the roots were carefully washed and the different plant parts separated and dried at 80°C for 48 hr. Leaf weight ratio (LWR), relative growth rate (RGR) and net assimilatory rate (NAR) were determined following Evans (1972).

Measure of response breadth was calculated using Levins's niche breadth metric (1968):

$$B = \frac{1}{\left(\sum_{i=1}^{s} P_i^2 \right) S}$$

where, P_i is the proportion of seedling height growth or total seedling dry weight response in state i, and S is the total number of states (treatments). The resulting measure, B, is a scale from 0 to 1, with 1 being the widest breadth. The degree of similarity between the two species was calculated as in Schoener (1970):

$$PS_{ij} = 1 - \tfrac{1}{2} \sum_{h=1}^{s} \left[P_{ih} - P_{jh} \right]$$

Where, PS_{ij} is the degree of similarity between species i and j and P_h is the proportion of response of a species, i or j, in state h. These values also range from 0 to 1 with 1 being maximum similarity.

Results and Discussion

Effect of Shade Levels

Plant height and dry weight of one-year-old seedlings increased with decreasing shade upto low shade level, then decreased in the open (table 1). Compared to banj oak, the chir pine attained greater height growth under all shade levels except under high shade in which banj oak had more height. The seedling dry weight of banj oak was invariably higher than that of chir pine and the difference increased with increasing shade level (figures 1 & 2).

The response breadth in terms of height were similar for both the species, and in terms of dry weight, it was markedly wider for banj oak than for chir pine (table 2). Differences in dry weight between treatments were significant ($P < 0.001$). Values of proportional similarity between the species indicate that the degree of similarity was more for height than for dry weight (table 2).

The species differed with respect to leaf weight ratio (LWR) and root: shoot ratio (table 3). Under all shade levels, chir pine had higher proportion of dry weight allocated to leaves than for banj oak. In banj oak, the value was markedly higher under high shade than under other shade levels. Except under high shade, root: shoot ratio was higher for banj oak than for chir pine. RGR and NAR for both the species followed similar patterns as for plant height and dry weight. The height per unit dry weight of stem was conspicuously higher in high and intermediate shade levels than in low shade and open (table 3). This tendency was particularly strong in chir pine seedlings.

Table 1 *Relative performance (value in given shade level/value in unshaded control) of one-year-old seedlings of* Quercus leucotrichophora *and* Pinus roxburghii *under different shade levels. The values for different parameters are given in parentheses*

Parameters	*Q. leucotrichophora*				*P. roxburghii*			
	Control	Low	Intermediate	High	Control	Low	Intermediate	High
Seedling height	1.000 (13.0)	1.530 (19.8)	1.333 (17.3)	1.283 (16.6)	1.000 (15.9)	1.629 (25.8)	1.446 (22.9)	0.759 (12.0)
Seedling dry weight	1.000 (3.7)	1.666 (6.2)	0.734 (2.7)	0.435 (1.6)	1.000 (3.4)	1.751 (6.0)	0.427 (1.5)	0.191 (0.7)

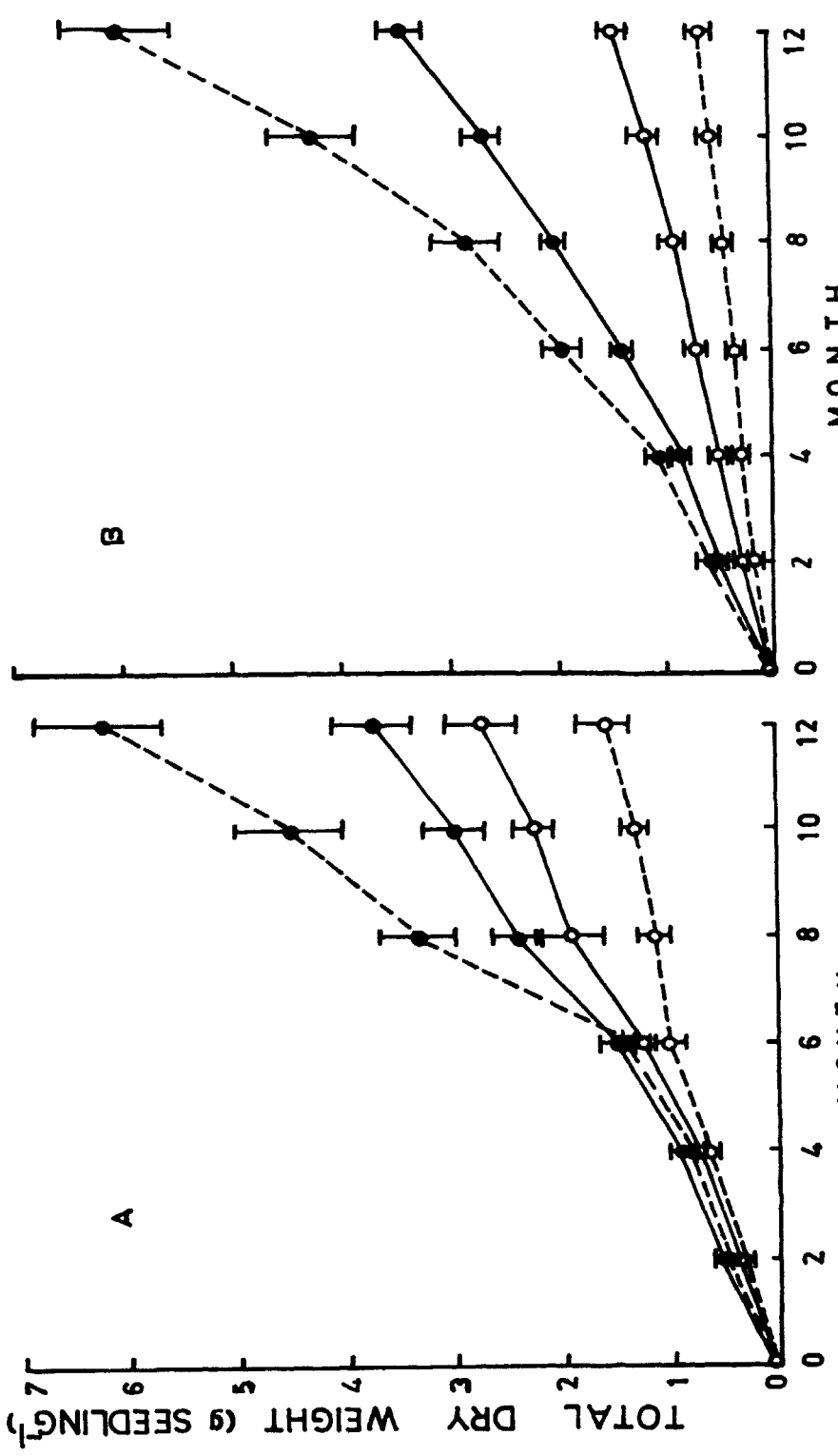

Figure 1 Cumulative total seedling dry weight (g seedling^{-1}) in different shade levels of (A) *Quercus leucotrichophora* and (B) *Pinus roxburghii* during one-year study period ●—●, unshaded control; ●....●, low shade; ○—○, intermediate shade, ○....○, high shade

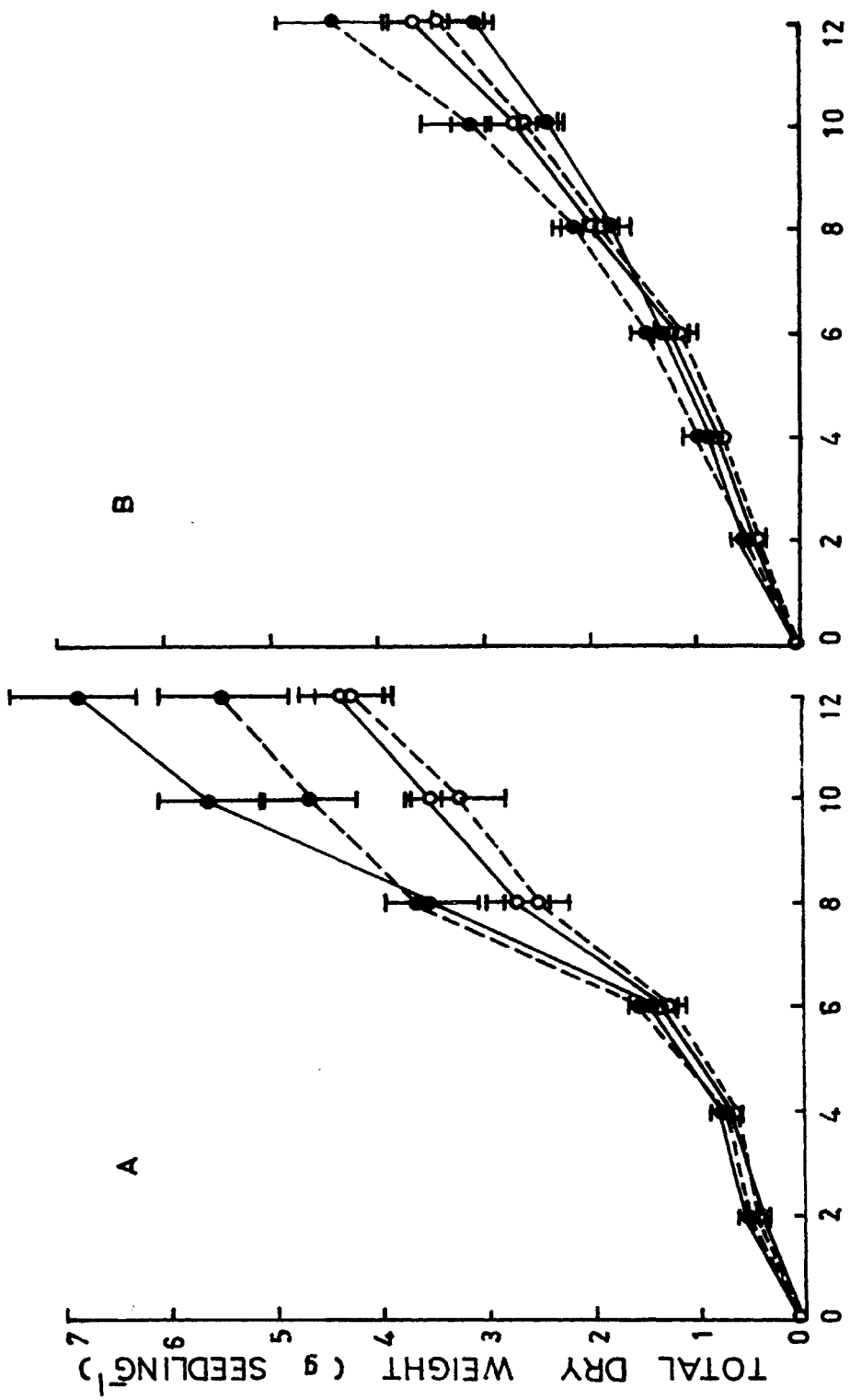

Figure 2 Cumulative total seedling dry weight (g seedling^{-1}) in different soil moisture levels of (A) *Quercus leucotrichophora* and (B) *Pinus roxburghii* during one-year study period. ●—●, control (unstressed); ●....●, low stress; ○—○, intermediate stress; ○....○, high stress

Table 2 *Growth responses of* Quercus leucotrichophora *and* Pinus roxburghii *seedlings on the shade gradient*

Parameters	Response breadth (B)		Proportional similarity (PS_{ij})
	Q. leucotrichophora	*P. roxburghii*	
Height	0.98	0.92	0.91
Total dry weight	0.82	0.66	0.88

Table 3 *Average values of growth parameters for one-year-old seedlings of* Quercus leucotrichophora *and* Pinus roxburghii *at different shade levels*

Parameters	*Q. leucotrichophora*				*P. roxburghii*			
	Control	Low	Intermediate	High	Control	Low	Intermediate	High
RGR ($g\ g^{-1}\ d^{-1}$)	0.0070	0.0087	0.0062	0.0048	0.0061	0.0076	0.0053	0.0038
NAR ($g\ g^{-1}\ d^{-1}$)	0.0232	0.0298	0.0206	0.0130	0.0152	0.0194	0.0132	0.0092
LWR ($g\ g^{-1}$)	0.366	0.364	0.357	0.427	0.490	0.514	0.497	0.454
Root: shoot ($g\ g^{-1}$)	0.654	0.649	0.687	0.464	0.434	0.341	0.429	0.498
Height: Stem dry weight (cmg^{-1})	17.5	13.1	27.9	41.0	24.1	17.9	98.4	77.7

Effect of Moisture Stress

Both, height and dry weight of seedlings (one-year-old) increased with decreasing moisture stress upto control in banj oak and only upto low moisture stress in chir pine (table 4). The maximum height of banj oak (in control) was about 30% greater than that of chir pine (low moisture stress). The suppression caused by moisture stress was markedly lower for chir pine (table 4) with the consequent wider response breadth for chir pine (table 5). The maximum dry weight of banj oak was about 54% greater than that of chir pine. However, the suppression caused by high moisture stress was relatively higher in banj oak. The two species showed similar response breadths (table 5). Proportional similarities between banj oak and chir pine were similar (table 5). The difference between the species dry weight was significant ($P<0.001$).

The height per unit dry weight of stem in banj oak was higher under intermediate and high stress levels than under low and control levels. In chir pine, there were considerably higher values in control condition than in other stress levels (table 6). The RGR and NAR for both the species, followed similar patterns as for their plant height and dry weight (table 6).

In conformity with the general opinion that early successional species produce smaller seeds with low food reserve, compared to mid and late successional species (Salisbury 1942, Monk 1966), banj oak seeds were considerably larger and heavier than chir pine seeds (Rao et al. 1986). Since survival of seedlings in the shaded environment is directly related to seed weight (Grime & Jeffrey 1965, Rao & Singh in press), oak seedlings would have an initial competitive advantage under canopy environment of a well stocked forest. Parrish and Bazzaz (1976, 1982), Werner and Platt (1976) indicated that early successional species exhibit broader responses on environmental gradients than do late successional species. Our findings are only partly in agreement with this view. Compared to banj oak, the early successional species chir pine showed a wider response breadth on the gradient of moisture stress. On the other hand, compared to banj oak, it showed a narrower response breadth on the gradient of shade. It seems that since early successional species tend to show poorer growth than late successional species under high shade (Odum 1969) an early successional species will only show a wider response breadth on a shade gradient when it requires comparatively low shade levels for optimal growth, compared to a late successional species. Investigations on allocation of dry matter to plant parts indicate that the patterns were consistent with the earlier findings (Monk 1966, Abrahamson & Gadgil 1973) in that chir pine had higher LWR than banj oak and the latter had higher root : shoot ratio.

Table 4 *Relative performance (value in a given moisture stress/value in unstressed control) of one-year-old seedlings of* Quercus leucotrichophora *and* Pinus roxburghii *under different moisture stress. The values for different parameters are given in parentheses*

Parameters	*Q. leucotrichophora*				*P. roxburghii*			
	Control	Low	Intermediate	High	Control	Low	Intermediate	High
Seedling height	1.000 (31.4)	0.704 (22.1)	0.622 (19.5)	0.574 (18.0)	1.000 (21.1)	1.131 (23.8)	0.907 (19.1)	0.870 (18.3)
Seedling dry weight	1.000 (6.8)	0.800 (5.4)	0.638 (4.4)	0.625 (4.3)	1.000 (3.1)	1.422 (4.4)	1.176 (3.6)	1.103 (3.4)

Table 5 *Growth responses of* Quercus leucotrichophora *and* Pinus roxburghii *seedlings on the moisture stress gradient*

Parameters	Response breadth (B)		Proportional similarity (PS_{ij})
	Q. leucotrichophora	*P. roxburghii*	
Height	0.95	0.99	0.91
Total dry weight	0.96	0.98	0.89

Table 6 *Average values for growth parameters for one-year-old seedlings of* Quercus leucotrichophora *and* Pinus roxburghii *under different soil moisture stress levels*

Parameters	*Q. leucotrichophora*				*P. roxburghii*			
	Control	Low	Intermediate	High	Control	Low	Intermediate	High
RGR ($g\ g^{-1}\ d^{-1}$)	0.0091	0.0081	0.0075	0.0069	0.0057	0.0072	0.0066	0.0066
NAR ($g\ g^{-1}\ d^{-1}$)	0.0334	0.0320	0.0268	0.0252	0.0146	0.0190	0.0182	0.0184
LWR ($g\ g^{-1}$)	0.394	0.352	0.356	0.364	0.475	0.482	0.438	0.435
Root: shoot ($g\ g^{-1}$)	0.460	0.576	0.668	0.667	0.399	0.377	0.484	0.599
Height: Stem dry weight (cmg^{-1})	15.3	15.8	20.5	20.3	31.4	21.8	19.0	25.0

Banj oak seedlings can withstand water stress at least as successfully as chir pine seedlings. Further observations on the responses of the species to wider environmental gradients, particularly of soil moisture would have been useful since dry spells longer than 15 days are quite common in this region outside the rainy season. Chir pine is known to colonize severely dry sites including rock out crop (Champion & Seth 1968). Recently, Singh et al. (1984) have shown that information on the growth performance of banj oak and chir pine on nutrient gradients may be useful in understanding the distribution and regeneration of these species in Kumaun Himalaya.

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