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Seed germination and seedling establishment of two closely related *Schima* species

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Abstract. Seed germination of *S. khasiana* from Upper Shillong and *S. wallichii* from Shillong, Umsaw and Burnihat in Meghalaya, north-eastern India, and seedling establishment and growth of these species/populations in reciprocal cultivation were studied. Seeds lost viability and germinability gradually within a year when stored at 5 cm below the soil surface under natural conditions or at 20° C in the laboratory. Storage at 0° C permitted retention of 15–25% viability. Seeds germinated better on the surface layers (0–2 cm) of the soil. *S. khasiana* had a lower temperature optimum (15° C) of germination while the populations of *S. wallichii* had a higher temperature optimum (20/25° C). At a temperature of 30° C, the lower altitude population of *S. wallichii* from Burnihat gave higher germination than the high altitude population from Shillong. A given species/population of *Schima* gave better seedling establishment and growth in its own natural habitat as compared to the introduced populations from the other altitudinal sites. This is indicative of the close adaptation of the natural populations to their habitat and ecotypic differentiation in this species.

Keywords. Tree adaptation ; seed germination ; tree seedling establishment ; altitudinal ecotype ; *Schima*.

1. Introduction

Germination and establishment represent two critical phases in the life-cycle of a plant species and these two aspects have been related to adaptation and distribution pattern of species in space (Koller *et al* 1962 ; Harper 1965 ; Cohen 1967 ; Ramakrishnan 1972 ; Ross and Harper 1972 ; Thompson 1973 ; Boojh and Ramakrishnan 1981a) and in time (Kapoor and Ramakrishnan 1973). However, this aspect of the problem in relation to adaptive strategy of tree species has received little attention (Kozlowski 1971 ; 1979). Although the size of a single species population is to some extent related to seed supply, it is ultimately determined by favourable conditions available for germination and establishment (Harper *et al* 1970). Further, a large gap often exists between the seeding potential of a species and the actual number of seedlings established in that area, depending upon environmental conditions.

S. khasiana Dyer and *S. wallichii* (D C) Korth family Ternstroemiaceae are two closely related and economically important timber tree species of north-eastern hills of India. These species show a distribution pattern on an altitudinal basis where *S. khasiana* is restricted to higher elevations (1800–1900 m), while *S. wallichii* shows a wide distribution ranging from 100 to 1600 m. These two species are early successions and come up in the secondary fallows after slash and burn agriculture (*Jhum*). These are light-demanding and regenerate profusely in the open, through light wind-dispersed seeds. The present study is a comparative investigation of seed germination and seedling establishment of these two species along an altitudinal gradient in the Khasi Hills of Meghalaya.

2. Climate

All the three sites are characterised by marked seasonal changes in climate. The year could be divided into 3 distinct seasons : (i) Monsoon season of high temperature and humidity extending from May to October when over 80% of the rainfall occurs, (ii) Winter season (November to February) of lower temperature which is comparatively dry except for a few winter showers, and (iii) A warm, dry and windy summer in March–April (table 1).

3. Methods of study

Mature fruits of *S. khasiana* were collected from Upper Shillong and that of *S. wallichii* from 3 sites at Shillong, Umsaw and Burnihat, in the months of February-March, 1978. Seeds were separated out by air drying. The fruit and seed weight measurements were based on 100 fruit/seed with 20 replications.

Table 1. Comparison of climatic data at study sites during 1978–79.

	Upper Shillong	Shillong	Umsaw	Burnihat
Location				
Latitude (N)	25·34	25·34	25·45	26·02
Longitude (E)	91·56	91·56	91·54	91·52
Altitude (m)	1900	1400	800	100
Temperature (° C)				
Mean monsoon maximum	22	24	30	32
Mean monsoon minimum	15	16	22	24
Mean winter maximum	16	16	20	25
Mean winter minimum	3	6	10	12
Precipitation (mm)	2400	2000	1800	1600

Seeds were stored in the laboratory at 20 ± 5° C and 0° C in BOD incubators in tightly closed plastic bottles. In nature, seeds were similarly stored 5 cm below soil surface. The moisture content of seeds at the time of storage was 10%. Viability and germinability of stored seeds were tested at intervals of 3 months with four replicates of 50 seeds of each species/population. For testing the viability of seeds a freshly prepared 5% aqueous solution of 2, 3, 5-triphenyltetrazolium chloride (TZ) was used. Seeds were first soaked in water for 10–12 hrs, then seed coats were punctured to facilitate entry of the TZ solution and were left in the dark at 30° C for upto 24 hrs. Seeds with completely stained (red colour) embryos were scored as viable. Germinability was tested by placing seeds in petri-dishes over moist filter-paper at a constant temperature of 15° C for *S. khasiana* and 20° C for *S. wallichii.*

Seeds were tested under two conditions, of continuous light under an incandescent fluorescent tube (500–600 1×) or under continuous darkness by covering the petri-dishes inside thick black paper, at a constant temperature of 20° C. Seed germination in dark was counted under green light. Germination at different constant (15, 20, 25, 30 and 35° C) and alternating (25/15 and 25/20° C) temperature regimes were tried in BOD incubators maintained at these temperatures. The effect of different soil depths of 0, 2, 4, 6, 8 and 10 cm on germination was tested in pots filled with soil, by placing seeds at the appropriate depth.

All germination experiments were replicated 4 times with 50 seeds in each test. The emergence of radicle was taken as an indicator of germination. Tests in all cases were done for 20 days after the seeds were placed for germination.

Ten replicates of 100 viable seeds (viability was ascertained for a given seed-lot on the basis of preliminary germination tests) of each species/population were sown at a depth of 5 cm at all the 4 study sites both in the open and under forested situations, in May 1978. The depth of 5 cm for sowing was chosen in order to avoid washout of seeds under heavy rainfall. Observations on the seedling emergence and establishment were taken at monthly intervals. Seedlings were harvested at the end of one year period and after noting plant height and leaf area using a planimeter, the root and shoot portions were separated and dried to a constant weight at 85 ± 2° C.

4. Results

4.1. *Fruit and seed characters*

The capsules and seeds of *S. khasiana* were heavier than that of the populations of *S. wallichii*. While the fruit weight of the populations of *S. wallichii* were not very different, significantly higher seed weight was noticed for the Burnihat population of this species compared to that of the two other populations (table 2).

4.2. *Germination studies*

4.2a. *Effect of storage* : When seeds were stored in the soil or in the laboratory at a temperature of 20 ± 5° C, both viability and germinability of the seeds of all the populations decreased markedly with passage of time so that after one year, seeds were totally non-viable or gave very poor germination. However, storage at 0° C maintained better viability and germinability after 1 year storage (figure 1).

4.2*b*. *Depth of burial* : As seen from figure 2, the depth of burial affected both the time and the final percentage of germination. Maximum germination was found to occur at 2 cm depth and it decreased at the depths greater than this for all the species and populations. At soil surface though faster germination occurred the total percentage was lesser than at 2 cm depth.

Table 2. Fruit and seed weight of *Schima* species/populations.

	Fruit weight (g)	Seed weight (mg)
S. khasiana	1·67±0·09	1·18±0·03
S. wallichii		
Shillong	1·13±0·07	0·46±0·06
Umsaw	1·04±0·03	0·44±0·02
Burnihat	1·07±0·05	0·53±0·01

(± S.E. of the mean)

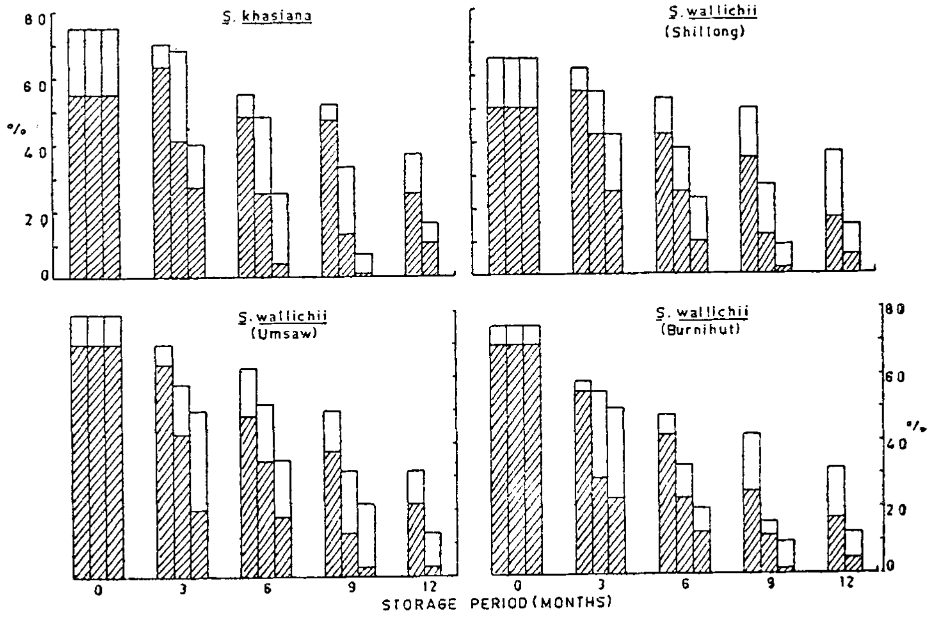

Figure 1. Viability (open columns) and germinability (hatched columns) of *Schima* seeds after different storage periods. First column, storage at 0° C ; second column storage at 20 ± 5° C ; and third column, storage under soil.

4.2c. *The effect of light and darkness* : There was germination both in the dark and light and the results obtained were not significantly different under these two conditions (table 3).

4.2d. *The effect of temperature* : Table 4 reveals the effect of various temperature regimes on the germination of the seeds of *Schima* species and populations

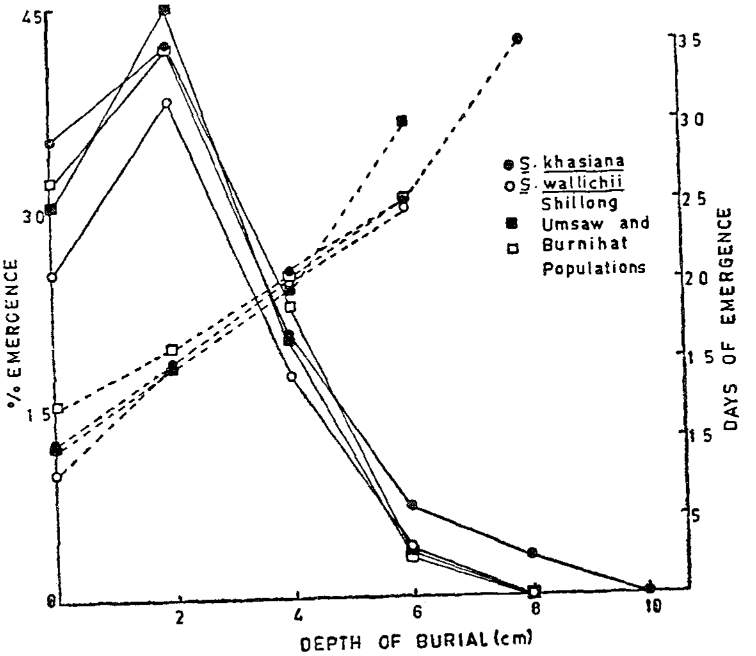

Figure 2. The relationship between seed depth, germination and emergence period of seedlings of *Schima* species/populations over a period of 35 days after sowing. Continuous lines represent % emergence of seedlings and broken lines represent number of days taken for emergence.

Table 3. The effect of light and dark treatment on seed germination of *Schima* species.

	Continuous light 20° C	Continuous dark 20° C
S. khasiana	50 ± 5·4	48 ± 3·4
S. wallichii	62 ± 6·4	57 ± 1·3

(± S.E. of the mean)
The seeds of populations of *S. wallichii* were pooled.

Table 4. Germination (%) of *S. khasiana* and *S. wallichii* seeds at various constant and alternating temperatures.

	Constant temperatures (° C)					Alternating temperatures (° C)	
	15	20	25	30	35	25/15	25/20
S. khasiana	55 ± 2·7	46 ± 3·6	44 ± 2·9	42 ± 2·2	0	46 ± 2·3	45 ± 5·5
S. wallichii							
Shillong	37 ± 4·3	48 ± 6·0	48 ± 6·8	33 ± 4·1	20 ± 7·5	48 ± 4·1	50 ± 4·6
Umsaw	42 ± 5·3	65 ± 3·7	58 ± 3·7	40 ± 6·8	27 ± 2·9	61 ± 3·7	70 ± 9·9
Burnihat	38 ± 2·2	69 ± 3·7	56 ± 5·4	50 ± 4·8	33 ± 7·6	59 ± 3·4	64 ± 3·6

(± S.E. of the mean)

S. khasiana showed maximum germination at constant 15° C, with a gradual decrease with increase in temperature, so that at 35° C no seeds of this species germinated. Populations of *S. wallichii* showed maximum germination at 20 and 25° C with decrease in germination on either side. At 30° C, the lower altitude population of *S. wallichii* from Burnihat gave higher germination than its higher altitude population from Shillong. Two alternating temperature regimes tried were favourable for germination for all the species/populations.

The rate of germination was faster at 15° C for *S. khasiana* and 20 and 25° C or alternating (25/20° C) for *S. wallichii* populations (figure 3).

4.3 *Seedling establishment*

4.3a. *Seedling emergence* : Only a small proportion of seedlings could emerge under field conditions at all the study sites. Further the differences in emergence were not significant (at 5% level) between species/populations (table 5).

4.3b. *Survivorship* : No seedlings could survive under forested situations beyond a period of 2 months. Under open grown situations, mortality was generally very high resulting in a steep decline in population upto January–February, at all the sites. At Upper Shillong, however, the rate of decline in population was slower for *S. khasiana* with an ultimately large population size compared to the populations of *S. wallichii.* At the other 3 experimental sites, however, the pattern of survivorship was not very different for the populations of *Schima*, though the local populations showed better survivorship than the introduced ones. *S. khasiana* gave the lowest final survival at these three sites (figure 4).

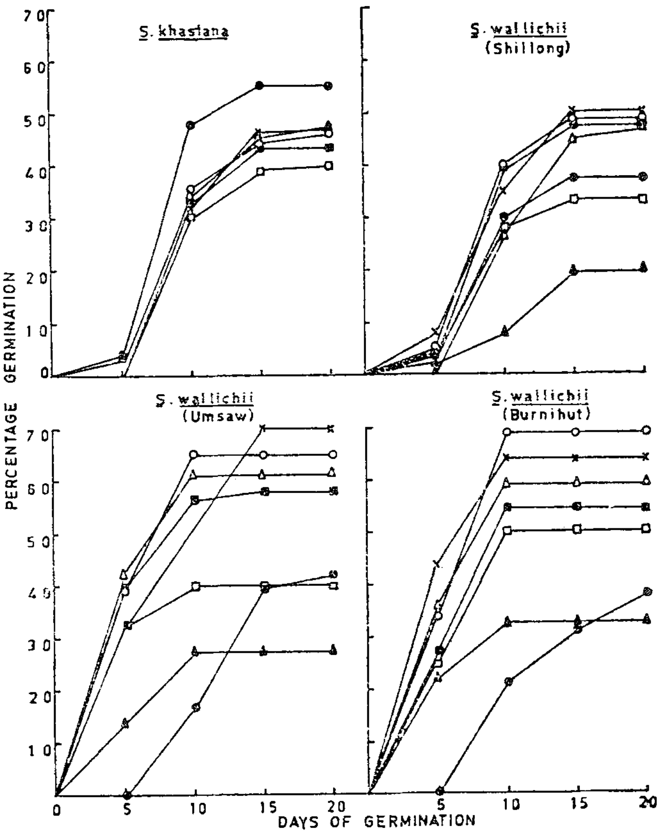

Figure 3. Percentage germination of *Schima* species/population at different periods, at constant and alternating temperature of 15° C (●); 20° C (○); 25° C (■); 30° C (□); 35° C (▲); 25/15° C (△) and 25/20° C (×).

Table 5. Seedling emergence (%) of *S. khasiana* and *S. wallichii* at different altitudinal sites.

Field stations	Species/Populations *S. khasiana*	*S. wallichii* Shillong	*S. wallichii* Umsaw	*S. wallichii* Burnihat
Upper Shillong	20 ± 4·6	10 ± 2·3	11 ± 1·8	14 ± 1·8
Shillong	19 ± 2·4	21 ± 3·9	10 ± 3·3	10 ± 2·1
Umsaw	16 ± 1·7	13 ± 2·7	13 ± 1·2	13 ± 2·5
Burnihat	16 ± 3·9	12 ± 1·7	11 ± 2·3	11 ± 0·6

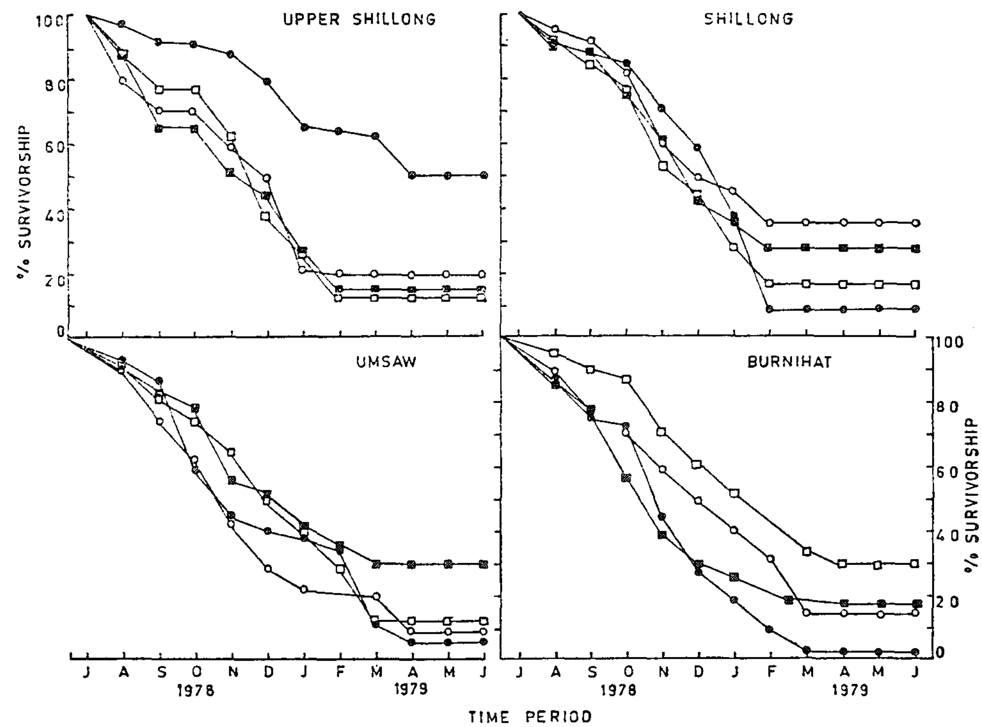

Figure 4. Survivorship of *Schima* seedlings under field conditions (in open). No seedlings could survive beyond 2 months under forested situations. *S. khasiana* (●) ; *S. wallichii*, Shillong (○), Umsaw (■) and Burnihat (□) populations.

4.3c. *Plant performance* : The growth characteristics of the different species/ populations at different sites, given in figure 5, show that the naturalized population for a given site was superior to the other introduced populations. Thus *S. khasiana* gave better growth yield under Upper Shillong site, while the populations of *S. wallichii* from 3 different sites did better in their respective natural habitats.

5. Discussion

Schima species being early successional colonizers depend for regeneration on the availability of open sites which favour their seed germination, establishment and growth. The most important factor limiting the ability of such species to colonize disturbed sites is the availability of seed, which must come either from a stand in close proximity or from storage in the soil. The latter is not possible for *Schima* as seeds do not remain viable in the soil for an extended period of time as seen from the present study where the viability of seeds is completely lost after storage in soil for one year. Thus, the species is fugitive in nature (Hutchinson 1951), where good dispersal mechanism would play an important role permitting the species to colonize new habitats (Salisbury 1942). *Schima* due to

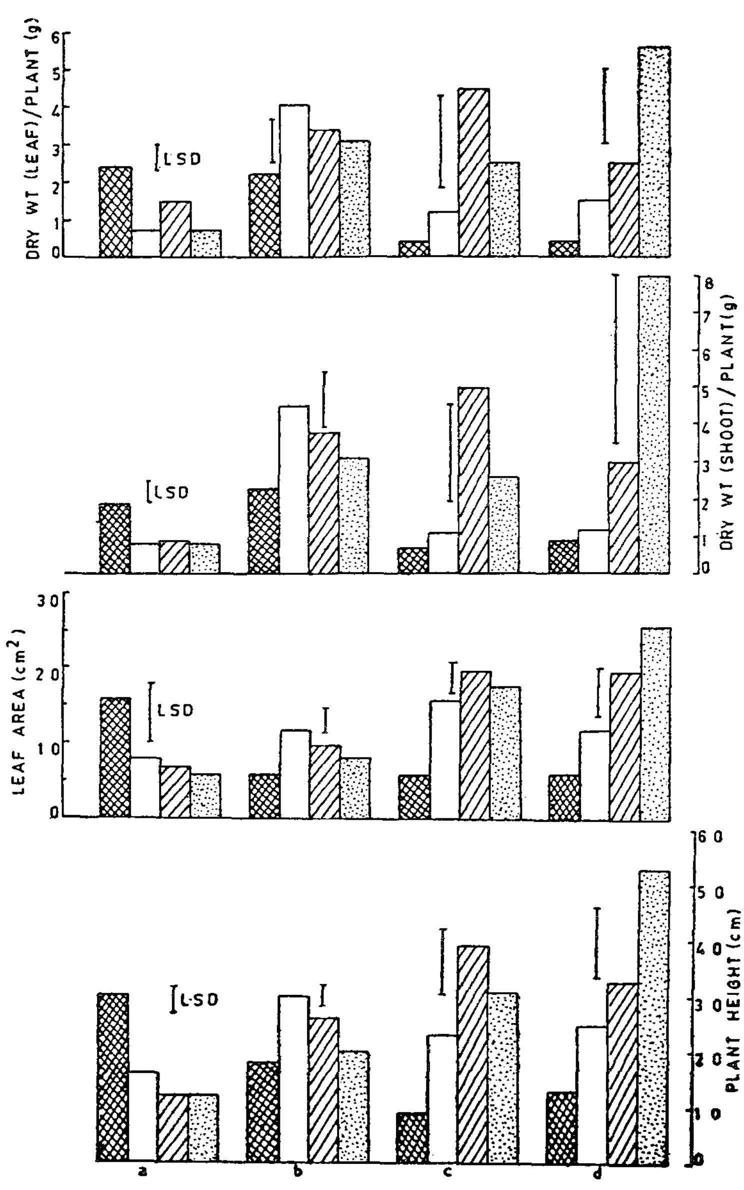

Figure 5. Growth performance of *Schima* species/populations at different field conditions. a = Upper Shillong; b = Shillong; c = Umsaw and d = Burnihat site; filled bars for *S. khasiana*, and hollow bars for Shillong; hatched bars for Umsaw and stippled bars for Burnihat populations of *S. wallichii*.

its light, mobile (winged) seeds often invades highly disturbed areas after slash and burn agriculture in the region. Similarly in temperate forests it has been reported that light seeded species *Fraxinus* and *Betula* play an important role in revegetation after clearcutting (Bormann and Likens 1979). The variation in seed weight in between species/populations may partly be related to climate

(Baker 1972 : Wearstler and Barnes 1977) and partly to ecotypic differences related to altitude which is supported by growth studies of the different *Schima* populations done at different altitudes discussed below.

The differences in germination behaviour in response to temperature as seen in the present case where *S. khasiana* germinated at a comparatively lower temperature compared to *S. wallichii* populations, have often been correlated with climatic conditions and seed source (Callaham 1970 ; Thomson 1973), whereby seeds from colder areas germinate better at lower temperature than those from warmer regions. Grose (1957) has demonstrated that montane species of *Eucalyptus* germinated best at a lower temperature of 16° C, in contrast to somewhat higher temperatures for species of warmer areas. Though the total number of seeds of a species which ultimately germinates at a given temperature is a good indicator of that species potential, however, the time taken to germinate is of much significance since the early germinating individuals enjoy a considerable competitive advantage (Ross and Harper 1972). The germination rate which was higher at 15° C for *S. khasiana* and at 20 or 25° C for *S. wallichii* populations is consistent with temperature optima for their germination. The rapidity of germination in this species without a dormancy mechanism is advantageous in colonizing new areas by producing a profusion of seedlings and this has been reported for a majority of tropical trees which has been termed as biological nomads (Ng 1978).

Schima seeds come under microbiotic category (Crocker and Barton 1953) as they normally lose viability and germinability within a year. Small and light seeds are reported to lose their viability faster (Quick 1961) and this has been reported in species of *Salix*, *Populus* and *Ulmus* (Wareing 1963) and *Alnus* (Boojh and Ramakrishnan 1981b). The better retention of viability and germinability under lower temperature storage may be attributed to slow biological and biochemical processes at such temperatures (Kamra 1967).

There exists a large gap between seeding potential of a species and the number of seedlings emerged at a given site. The failure of survival of seedlings under a forest canopy may be attributed to the shade intolerance of the seedlings. The differences in survival pattern for different species/populations under field conditions are suggestive of the adaptation of a given population to the natural climatic conditions in which they grow. This is suggested by the relatively better survival and performance of local species/populations to that habitat compared to the introduced ones. Thus, the lower altitude population of *S. wallichii* which is adapted to longer growing season, higher temperature and frost-free winter is adversely affected at higher altitude.

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