

SEED CHARACTERISTICS AND GERMINATION BEHAVIOUR OF SOME IMPORTANT CONIFEROUS TREES OF CENTRAL HIMALAYA, INDIA

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TEWARI, P., TEWARI, A. & RAM, J. 2001. Seed characteristics and germination behaviour of some important coniferous trees of Central Himalaya, India. Eight coniferous species present around Nainital were studied for their seed characteristics and germination behaviour. The colour of the mature cone varied from brown, yellow to grey and seed shape varied from triangular to elliptical. The largest seed was of *Cedrus deodara* (13.7 × 3.6 mm) and the smallest was of *Cupressus torulosa* (4.2 × 2.3 mm). Seed mass was heaviest in *Pinus roxburghii* (10.58 g/100 seeds on fresh weight basis) and lightest in *C. torulosa* (0.46 g /100 seeds). No germination occurred in the case of *Taxus baccata*. However, in the remaining species maximum germination occurred in 24 to 30 days. A majority of species showed optimum germination at 25 °C, while *C. torulosa* showed better germination in sand after 15 days of air-drying.

Keywords: Seeds - conifers - germination - Himalaya

TEWARI, P., TEWARI, A. & RAM, J. 2001. Ciri-ciri biji benih dan tingkah laku percambahan beberapa pokok konifer yang penting di Himalaya Tengah, India. Ciri-ciri biji benih dan kelakuan percambahan lapan spesies konifer yang terdapat di sekitar Nainital dikaji. Warna kon yang matang berubah-ubah daripada coklat, kuning kepada kelabu dan bentuk biji benih berubah-ubah daripada tiga segi kepada bujur. Biji benih yang paling besar ialah *Cedrus deodara* (13.7 x 3.6 mm) dan biji benih yang paling kecil ialah *Cupressus torulosa* (4.2 x 2.3 mm). Jisim biji benih *Pinus roxburghii* adalah paling berat (10.58 g/100 biji benih berdasarkan berat baru) dan yang paling ringan adalah dalam *C. torulosa* (0.46 g/100 biji benih). Tidak berlaku percambahan dalam biji benih *Taxus baccata*. Bagaimanapun, di dalam spesies yang tinggal percambahan maksimum terjadi dalam masa 24 hingga 31 hari. Majoriti spesies menunjukkan percambahan optimum pada suhu 25 °C, manakala *C. torulosa* menunjukkan percambahan yang lebih baik di dalam pasir selepas 15 hari pengeringan udara.

Introduction

Conifers are gymnosperms which belong to the large order Coniferales, comprising 40 living genera and over 540 species and are dominant forest-forming species around the world. In India only 21 species of gymnosperm are present. Large scale felling of coniferous trees for timber, raw material for various industries, packing, etc. has resulted in massive destruction of these forests. To reduce the imbalance

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in the ecosystems and to increase the forest cover, studies of seed characteristics and germination are of great importance to regenerate the forest. Successful afforestation requires large quantities of seeds and seeds need great care from collection to germination.

Seeds of woody plants exhibit a great range of variation in shape, size, colour and seed coat. Knowledge of seed morphology is advantageous for artificial regeneration as it can influence the collection, processing, storage, and treatment of seeds. The external and internal morphology of seeds is remarkably stable; therefore, they provide reliable criteria for the positive identification of unknown seeds (Kozłowski 1972, Kramer & Kozłowski 1979). Some studies have been made on the various aspects of *Pinus* species, viz. a study on viability and vigour of pine seeds after 50 y of storage (Barnett & Vozzo 1985); seed extraction of pine at different temperatures (Maithani *et al.* 1986); and leachate conductivity for pine seed quality (Bonner 1991). Other studies on tree seeds in India were mainly confined to tropical trees, and there is little or no information on the seed characteristics and germination behavior of Himalayan temperate trees. Thus, the present study deals with the seed characteristics and germination behaviour of some important conifers of Central Himalaya.

Material and methods

Central Himalaya (28° 30'– 31° 30' N, 77° – 81° E) covers about 51 000 km². The chirpine (*Pinus roxburghii*) forest is distributed extensively between 1200 and 2000 m elevation in the region. Other conifers found on the higher elevation sites are *Cedrus deodara*, *Abies pindrow*, *Picea smithiana*, *Cupressus torulosa*, *Pinus wallichiana*, *Taxus baccata* and some junipers. The sites of the present study were distributed in the elevation range 1400–2600 m. The annual rainfall varies between 2500 and 3000 mm, of which nearly three-fourths occur during the monsoon period (mid-June to mid-September). Snowfall during the winter season (December to February) is quite frequent at the higher elevations. The mean daily temperature varies from 10 to 27 °C in different months.

The seeds of eight conifer species were collected from different sites at Nainital and adjacent areas during 1996–1997 from trees grown either naturally or planted. The eight species were *Abies pindrow*, *Cedrus deodara*, *Cupressus torulosa*, *Picea smithiana*, *Pinus roxburghii*, *Pinus wallichiana*, *Taxus baccata* and *Thuja orientalis*. Before seed collection, an extensive survey of the area was made and mature, phenotypically superior trees or healthy trees of reasonably good form and average growth and age were marked for seed collection. Trees exhibiting poor growth, abnormalities or disease were avoided. The times of seed development and maturation were ascertained through consultation of literature (Troup 1921, Ralhan *et al.* 1985) and by frequent field visits. Cones were collected either directly from trees, or freshly fallen, from the ground. All cones were disease and insect free. Extraction of seeds was done manually immediately after collection of cones by spreading them on cement floors in sunlight (except the cones of fir and deodara).

Seeds were collected, cleaned and packed in polyethylene bags for the detailed study of seed characteristics. The seed parameters measured were colour of cone at maturity, colour of seed and shape of the seeds and average seed dimensions (length and breadth) of 100 seeds. Fresh weight, weight after 15 days of air-drying in shade, oven-dry weight for 100 seeds and number of seeds per 100 g were also measured. Moisture content of seed was determined on fresh weight basis as:

$$\text{Moisture content (\%)} = \frac{\text{fresh weight} - \text{oven-dry weight}}{\text{fresh weight}} \times 100$$

Germination tests of each species were done by taking 5 replicates of 100 healthy seeds. Only seeds which sank to the bottom when dropped in water were used in these experiments. Seeds were sterilised in 0.1% HgCl₂ solution and then germinated under the following conditions:

Test 1. Petri dishes and germination paper were sterilised in an autoclave at 110–120 °C for 1/2 hour. The seeds were placed in the dishes between moistened papers, kept at room temperature, and observed for up to 5 weeks. The papers were regularly moistened at 2-day intervals.

Test 2 and Test 3. A two-chambered germinator was used in which seeds placed in sterilised Petri dishes were kept at 25 °C (Test 2) on one side and 35 °C (Test 3) on the other. The germinator was sterilised by keeping the temperature on maximum for 2 h and then wiping thoroughly with alcohol.

Test 4. Seeds were first soaked in water for 24 h and then placed between germination papers in sterilised Petri dishes. They were germinated at room temperature.

Test 5. Sand was sterilised at 110 °C in oven. Seeds were placed in the sand-filled clay pots and watered regularly.

Observations were carried out up to 5 weeks at 3-day intervals. Seeds were considered germinated when the length of the radical reached 3–5 cm.

Results

A majority of the conifers are monocious (male and female flowers produced on the same individuals). The flowering period for most of the species varies from March to November except for *C. torulosa*, which flowers in January–February; similarly, the seed maturation period varies from November to May (Table 1).

Table 1. Phenological features of the conifers

Species	Flowering	Fruiting	Seed maturation
<i>Abies pindrow</i>	April–May	September–November	December
<i>Cedrus deodara</i>	June	October–November	December–January
<i>Cupressus torulosa</i>	January–February	September–November	April–May
<i>Picea smithiana</i>	March	October–November	December–January
<i>Pinus roxburghii</i>	March–April	November–December	February–April
<i>Pinus wallichiana</i>	March	September–November	December–April
<i>Taxus baccata</i>	April–May	November	November–December
<i>Thuja orientalis</i>	October–November	January–February	March–April

Physical characteristics

The various physical characteristics of different tree seeds are shown in Table 2.

Table 2. Physical parameters of seeds of the conifers

Species	Colour of cone	Colour of seed	Type of seed	Average seed size (mm)	Shape
<i>A. pindrow</i>	Greyish-black	Shining blackish-brown	Orthodox	9.3 × 2.5	Triangular
<i>C. deodara</i>	Brown	Yellow	Orthodox	13.7 × 3.6	Oval compressed seed
<i>C. torulosa</i>	Blackish-brown	Brown	Orthodox	4.2 × 2.3	Small and flat
<i>P. smithiana</i>	Shining yellowish-brown	Brownish-black	Orthodox	5.8 × 1.8	Irregular or somewhat triangular
<i>P. roxburghii</i>	Yellowish-brown	Greyish-brown	Orthodox	10.1 × 3.1	Slightly large brown oval seed
<i>P. wallichiana</i>	Pale brown	Brown	Orthodox	8.7 × 4.0	Oval shaped
<i>T. baccata</i>	Reddish-orange	Yellowish-brown	Orthodox	8.7 × 3.1	Small oval fruit composed of cup shaped disk
<i>T. orientalis</i>	Deep dark brown	Dark brown	Orthodox	4.1 × 2.4	Small oval seed

Most of the cones were coloured brown to black at maturity. The common colour of the seed was brown and yellow. All the seeds were orthodox (seeds can be dried to low moisture content of about 5% and successfully stored at low temperature for one year or more). The seed dimensions (length x width) varied from 4.2×2.3 mm for *C. torulosa* to 13.7×3.6 mm for *C. deodara*. The shapes of the seeds were triangular and oval (Table 2).

Seed mass and moisture content

The fresh weight of the seeds ranged between 0.46 g/100 seeds and 10.58 g/100 seeds, and oven-dry weight ranged between 0.36 and 9.35 g/100 seeds (Table 3). Weights taken after 15 days of drying under shade varied from 0.44 g/100 seeds to 10.11 g/100 seeds. The lower value was reported for *C. torulosa* and higher value for *P. roxburghii*. The number of seeds/100 g was lowest for *P. roxburghii* (944 seeds) and highest for *C. torulosa* (21 930 seeds). The lowest moisture content was 9.97% for *A. pindrow* and highest 26.19% for *P. smithiana*.

Table 3. Seed mass (g) and moisture content of the conifers

Species	Fresh weight/ 100 seeds (g)	Weight/100 seeds after 15 days shade drying (g)	Oven-dry weight/100 seeds (g)	No. of seeds/ 100 g	Moisture content (%)
<i>A. pindrow</i>	4.21	4.06	3.79	2 380	9.97
<i>C. deodara</i>	9.40	9.03	7.87	1 064	16.27
<i>C. torulosa</i>	0.46	0.44	0.36	21 930	21.73
<i>P. smithiana</i>	1.26	1.25	0.93	7 692	26.19
<i>P. roxburghii</i>	10.58	10.11	9.35	944	11.62
<i>P. wallichiana</i>	4.55	4.29	3.80	2 174	16.48
<i>T. baccata</i>	8.55	8.28	7.14	1 170	16.49
<i>T. orientalis</i>	1.20	1.19	0.91	8 333	24.17

Seed germination

Seed germination of different species under various conditions is given in Figure 1. *Abies pindrow* showed 2-18% germination which is almost similar in all the conditions. The germination was highest at 25 °C and lowest in sand after 15 days air-drying. Germination started within 6 day of sowing and was complete in about 30 days. In *C. deodara* seed germination started within 6 days and was almost complete by 24-30 days under the various treatments. The percentage germination varied from 55 to 65%. *Cupressus torulosa* seeds started germinating in 12 days and germination varied from 18% at 35 °C to 44% in seeds after 15 days of air-drying in sand. Seed germination started in *P. smithiana* in 3-9 days and was complete in about 24 days. The percentage germination ranged between 25% at 35 °C and 38% at 25 °C. Germination started within 6 days in *P. roxburghii*

and was complete in about 24 days. The lowest germination (56%) was at 35 °C and the highest (90%) at room temperature (15–20 °C). Similarly, seed germination started within 3 to 6 days in *P. wallichiana* and was complete in 24–27 days. The lowest germination (38%) was reported at 35 °C and highest (70%) at 25 °C in the germinator. *Thuja orientalis* started germination within 6 days of sowing and this was complete in 24–30 days. The lowest germination (40%) was reported at 35 °C and highest (55%) at 25 °C. There was no germination in *T. baccata* seeds.

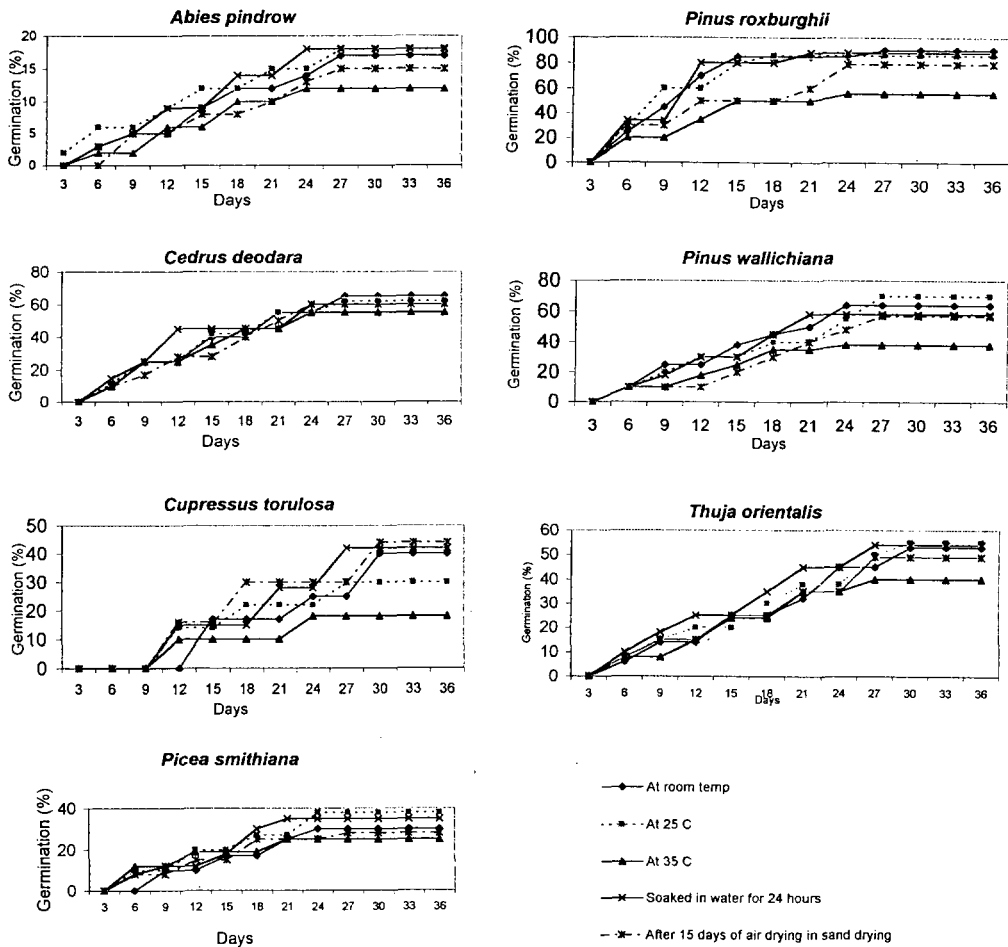


Figure 1. Percentage seed germination of the conifers under different treatments

Table 4. Optimal conditions for seed germination of the conifers

Species	Maximum germination (%)	Conditions for optimum germination	No. of days
<i>A. pindrow</i>	18	Moderate temp. 25 °C in germinator	27
<i>C. deodara</i>	65	Room temp. (15-20 °C)	27
<i>C. torulosa</i>	44	In sand after 15 days of air drying of seeds	30
<i>P. smithiana</i>	38	25 °C temp. in germinator	24
<i>P. roxburghii</i>	90	Room temp. (15-20 °C)	24
<i>P. wallichiana</i>	70	25 °C temp. in germinator	27
<i>T. orientalis</i>	55	25 °C temp. in germinator	30

Discussion

Gymnosperms arose in the middle Devonian about 365 million years ago, but there have never been more than a few thousand species. Evidence from fossilised cones shows that ancestors of Pinaceae had evolved by mid-Jurassic, and that *Pinus* had evolved by the lower Cretaceous (Richardson & Rundel 1998). Stewart (1983) reported that *Cedrus* appeared before the Tertiary and the remaining genera appeared in the early Tertiary or later. Knowledge of phenological characteristics would help in collecting large quantities of tree seeds in one or more species for conservation. Phenological features showed that the seedfall period for all the conifers was from December to April with the exception of *C. torulosa*, which extended its maturation into May. Variations in seed size, shape, colour and surface are important in identification of different species (Ram Prasad & Kandya 1992). Similarly, the change in colour of cones or fruits indicates seed maturity. Generally, green coloured cones indicate immaturity, mature cones are brown, yellow or grey coloured.

Seed shapes were oval, triangular or ellipsoid. Large seeded species had seed size > 10 mm in length, medium size 5 to 10 mm, and small size < 5 mm. Of the eight species, two (*C. deodara* and *P. roxburghii*) had large seeds, four species (*A. pindrow*, *P. wallichiana*, *T. baccata* and *P. smithiana*) had medium-sized seeds and the remaining two, *C. torulosa* and *T. orientalis*, had small-sized seeds. The data agree with those of Rao *et al.* (1984), who reported seed size of *P. roxburghii* (10.3 × 4.3 mm), *P. wallichiana* (8.9 × 4.1 mm) and *P. smithiana* (5.8 × 1.9mm).

Seed weight was measured for all eight species. Three species (*P. roxburghii*, *C. deodara* and *T. baccata*) are described as having heavy seeds (> 50 mg/seed), two species (*A. pindrow* and *P. wallichiana*) as medium and the remaining species have the lightest (< 25 mg/ seed) seeds.

The majority of species had the best germination at 25 °C, followed by room temperature (15-20 °C) and when the seeds were soaked in water for 24 h. The lowest germination was reported in sand and at 35 °C. No germination was reported in the case of *T. baccata*. Nandi *et al.* (1997) stated that *T. baccata* has limited regeneration (about 3%) and many seeds do not germinate until the

second year. The maximum germination was reported in 24 to 30 days for all species. The optimum conditions and maximum germination in various species are shown in Table 4. Four species have maximum germination at 25 °C, two at room temperature and *C. torulosa* seeds showed maximum germination in sand after 15 days of air-drying. Thus, it is concluded that *C. torulosa* is best adapted to sandy soil, *P. roxburghii* and *C. deodara* to low temperature (15–20 °C), and the remaining to moderate temperature (25 °C). It can therefore be stated that these conifers show the best germination when the temperature is 25 °C or less, and the maximum germination is attained in 24–30 days. Soaking in cold water for 24 h hastened germination only in *A. pindrow*, and in *C. torulosa* optimum germination was obtained after 15 days of air-drying.

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