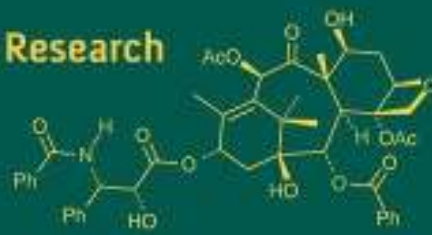
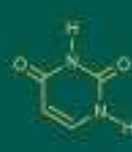
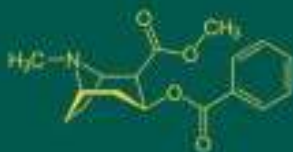


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; SP-10(4): 545-552
www.biochemjournal.com
Received: 13-01-2026
Accepted: 16-02-2026

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Effect of storage conditions on viability of *Abies pindrow* seeds in Kashmir Valley

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DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i4Sg.8155>

Abstract

The present investigation was carried out in order to find out the best condition for storage and to determine the viability of *Abies pindrow* seeds. The total storage duration was of two years and its effect on seed viability was observed at two months interval. The experiment was laid in CRD (Factorial). In all, there were seventy two treatment combinations comprising of twelve storage durations (2 to 24 months i.e D₁ to D₁₂), two storage temperatures (T₁ and T₂) and three storage containers (C₁, C₂ and C₃) to study the viability of seeds of *Abies pindrow* Royle through germination tests and record the variation in various germination parameters. The germination parameters recorded were germination percent, germination energy, germination value, peak value and mean daily germination. In case of storage temperature, the seeds stored at 4±1°C temperature (T₂) excelled over room temperature (T₁) by registering maximum values for germination percentage, germination energy, germination value, peak value and mean daily germination 31.04%, 17.97%, 1.55, 1.73 and 1.30 respectively. In case of storage duration, duration of 2 months D₁ excelled over all the storage durations (D₂ to D₁₂) by registering maximum values for germination percentage, germination energy, germination value, peak value and mean daily germination 40.69%, 28.29%, 2.55, 2.67 and 1.92 respectively. All the germination parameters were significantly influenced by the three type of containers used for the study. Airtight plastic container (C₂) outperformed the other types of container by registering maximum value of 31.92%, 18.39%, 1.53, 1.78 and 1.31 for germination percentage, germination energy, germination value, peak value and mean daily germination. Seeds stored at 4±1°C temperature (T₂) in airtight plastic container (C₂) after two months duration (D₁) i.e D₁C₂T₂ excelled all other treatment combinations by registering maximum value of 45.42%, 32.65%, 3.28, 3.10 and 2.08 for germination percent, germination energy, germination value, peak value and mean daily germination. Hence, the treatment combination of 4±1 °C temperature (T₂) in airtight plastic container (C₂) and duration period of two months (D₁) was observed to be best.

Keywords: Viability, *Abies pindrow*, airtight plastic container, room temperature, duration

Introduction

Abies pindrow Royle, though widely spread globally, thrives mainly across North and Central America, Europe, Asia, and North Africa. In the Western Himalayas including regions of India, Afghanistan, Nepal, and Pakistan it grows prominently at altitudes between 2000 and 3600 meters (Kunwar *et al.*, 2020) [31]. This impressive conifer is typically found in pure stands, but it also coexists with other species like *Abies spectabilis*, *Pinus wallichiana*, *Picea smithiana*, and *Cedrus deodara* (Tiwari *et al.*, 2020) [48].

In Kashmir, the Silver Fir a dominant conifer extends from the valley to Nepal, flourishing at elevations of 2550 to 3350 meters (Joshi and Samant, 2004) [24], occasionally found as low as 2150 meters or as high as 3650 meters. It is a towering evergreen, reaching heights of 40-60 meters and girths of up to 7.5 meters, with a single robust trunk and relatively short branches. Its dark green, needle-shaped leaves among the longest in firs feature two silvery lines beneath, a characteristic trait of the species (Kumar and Kumar, 2017) [30]. The tree holds significant commercial value as timber for construction, joinery, paneling, and furniture (Tiwari *et al.*, 2020) [48]. In Jammu & Kashmir and Ladakh, its bark extract is used in traditional medicine to treat ailments such as asthma, cough, constipation, bronchitis, ulcers, and wounds (Gairola *et al.*, 2014) [15].

Despite its ecological and economic importance, *Abies pindrow* is under threat due to both natural and human-induced pressures. Natural challenges like poor regeneration, accumulation of undecomposed humus, and low germinative capacity of seeds especially in years with a high proportion of empty seeds are accelerating its decline (Kimothi *et al.*, 2021) [26]. These issues, along with overexploitation and erratic seed production, call for urgent conservation and plantation efforts.

Conifers such as *Abies pindrow*, tend to have irregular seed production cycles typically once every 10 years for this species and every 5-6 years for *Picea smithiana* (Khanna, 2009) [27]. To support consistent afforestation efforts, it is essential to collect and store high-quality seeds during productive years to ensure a continuous supply for nursery propagation. Proper seed storage becomes vital to maintain seed viability from the time of collection until sowing (Holmes and Buszewicz, 1958) [21]. Effective storage requires knowledge of seed behavior, maturity, moisture levels, temperature sensitivity, and appropriate storage methods. High temperatures and humidity increase seed respiration, which shortens viability (Roberts, 1973) [38]. According to FAO (1995) [14], forest seed storage serves three primary purposes: (a) preserving seed viability between collection and sowing, (b) protecting seeds from pests and pathogens, and (c) maintaining a reserve of seeds for unproductive years.

Seeds are living entities and are susceptible to environmental stress, which can affect quality and longevity. Seed viability and vigor differ by species and variety and are influenced by factors like initial quality, moisture content, temperature, storage material, packaging, and gas exchange (Doijode, 1988) [12]. Fungal contamination is also a major cause of deterioration. Since seeds are hygroscopic, environmental fluctuations in humidity and temperature can degrade their quality. Using vapour-proof containers like polyethylene bags is more effective for long-term storage than permeable options like cloth or jute bags. Sustained reforestation programs require research into optimal storage conditions to retain seed germination potential, focusing on controlling moisture, temperature, and storage duration (Colville, 2017; Kim, 2018) [9]. Storage containers must support easy handling and help maintain seed quality. Moisture-proof containers combined with controlled temperatures offer the best protection during storage and transport (Robbins, 1984) [39].

Temperature plays a critical role in seed longevity. Storage temperatures should be species-specific and suited to the intended duration. Schubert (1952) [41] observed that *Abies concolor* seeds, stored at 5 °C with moisture levels below 10%, remained viable for up to 21 years. Coniferous seeds vary widely in their storage potential, and since many species don't produce seeds annually, preserving seeds during good years is crucial. Proper storage helps retain germination capacity over time. Good storage hinges on the balance between temperature, moisture, packaging, and duration. Reducing seed respiration without harming seed quality is key to prolonging shelf life.

Seed aging is a major challenge, particularly in India, where high heat and humidity, along with poor storage practices, accelerate degradation. Multiple factors including cytological, biochemical, and ultrastructural changes can lead to viability loss (Swati, 1977) [45]. Incorrect storage conditions trigger degradation in key biomolecules such as carbohydrates, proteins, lipids, phenols, and enzymes, and can cause toxic buildup and membrane damage (Abdul-Baki

& Anderson, 1970; Ghosh & Choudhary, 1984; Roberts, 1972) [1, 16, 37].

Therefore, investigating these biochemical changes can help assess storage effectiveness and predict seed viability duration. Since seed longevity and ideal storage conditions vary by species, identifying suitable temperatures, packaging materials, and durations is essential. With this aim, the current study was undertaken to determine optimal conditions for preserving high viability in *Abies pindrow* seeds.

Materials and Methods

The current study was conducted at the Forest Biology and Tree Improvement Laboratory, Faculty of Forestry, Benhama, Ganderbal, Kashmir, over a two-year period from February 2024 to February 2026. Located in the western Himalayan range, the Kashmir Valley spans latitudes 32°20' to 34°54' N and longitudes 73°55' to 75°35' E. Covering a total geographical area of approximately 159,480 km², around 8,126 km² (50.95%) of the valley is forested. The region has an average elevation of 1,850 meters above sea level.

Temperatures in the valley vary seasonally, with minimum temperatures dropping to -4.41 °C in January and peaking at 29.34 °C in July. Annual precipitation ranges between 949 and 1,100 mm, with most falling as snow, blanketing the mountainous regions for about 160 to 195 days each year. The experimental site is situated at 34.08°N latitude and 74.83°E longitude, at an elevation of approximately 1,587 meters above sea level. In general, the valley zone of Kashmir lies at altitudes between 1,500 and 2,300 meters above mean sea level.

A set of mature seeds were collected, thoroughly cleaned, dried and stored from the nearest mother tree to test the viability. In this experiment two storage temperatures were set i.e T1 (Room Temperature / Ambient temperature) and T2 (4±1 °C). The different storage containers used were C1 (Earthen pots), C2 (Airtight plastic container) and C3 (Muslin cloth bags). Storage was done for a period of two years and evaluation of stored seeds in different containers and temperature, its effect on seed viability was observed after every two month interval. The experimental design used was Completely Randomized Design (Factorial) repeated three times. Germination test was conducted at 2 months interval to test the viability. For each germination test, testing period was 28 days. The germination test was carried out by placing the seed on moist filter paper in petri plates in germinator at 25 °C. For that a sample of 300 seed divided into three replications of 100 seed each from two different temperatures and three different containers will be used to run the germination tests. Germination was recorded every day in all seed lots until no more germination was observed. Seed germination was defined as radicle emergence (>2 mm), and germinated seeds were left in the Petri dish until normal seedlings were produced. The germination data were analyzed using the formula by Shannon *et al.*, (1983) [42], with germination energy calculated as per Williams (1985) [53]. Germination value, peak value, and mean daily germination were calculated following Czabator's method (1962) [10]. The germination process was monitored daily, with appropriate sterilization procedures to prevent contamination, and seeds were checked regularly for fungal or bacterial growth. The data were statistically analyzed as per the method of Cochran and Cox (1957) [8] for Completely Randomized Design (Factorial).

Results and Discussion

A. Effect of seed storage temperature on germination parameters

The germinability of seeds in storage was significantly influenced by storage temperature as can be observed from the tables below. The seeds stored at 4 ± 1 °C temperature (T_2) excelled over room temperature (T_1) by registering maximum values for germination parameters. At this temperature maximum values of germination parameters such as germination percentage, germination energy, germination value, peak value and mean daily germination 31.04%, 17.97%, 1.55, 1.73 and 1.30 were recorded. Room temperature (T_1) proved to be less effective by registering minimum values for germination parameters as 26.97%, 15.01%, 1.32, 1.49 and 1.19 respectively.

The better performance of germinability parameters at 4 ± 1 °C (T_2) is possibly due to slow rate of biological processes in seeds at this temperature. During the resting stage or storage the loss of viability in seeds is largely governed by the rate of destructive metabolism and temperature plays a key role in this process.

Comparable results were observed by Palomeque *et al.* (2020) [33] in their study on three native tree species *Cedrela montana*, *Weinmannia fagaroides*, and *Oreocallis grandiflora*. Their findings revealed that seeds stored at cooler temperatures (5 °C and 10 °C) for 3 to 6 months exhibited significantly higher germination rates, viability, and germination speed in *C. montana* and *W. fagaroides* compared to seeds stored at ambient (room) temperature. These observations are consistent with our findings and align with those of several other researchers: Pompelli *et al.* (2018) [35] on *Jatropha curcas*, Husain *et al.* (2017) [22] on *Pinus halepensis*, Pradhan *et al.* (2012) [34] on *Swertia chirayita*, Tommasi *et al.* (2006) [49] on *Ginkgo biloba*, Arya and Arya (2006) [4] on *Acacia auriculiformis*, *Butea monosperma*, *Pongamia pinnata*, and *Pterocarpus marsupium*, Mughal and Thapliyal (2006) [32] on *Cedrus deodara*, and Takos and Merou (2001) [46] on *Cedrus deodara* and *C. libani*.

Erkuloğlu (1995) [13] reported that *Cedrus libani* seeds maintained best viability when stored at -5 °C with a moisture content of 7-9%. Additionally, Harrington (1972) [19] proposed that, within the acceptable range of moisture and temperature, every 1% reduction in seed moisture or a 5 °C decrease in temperature effectively doubles seed longevity. In contrast, higher temperatures especially room temperature (T_1) were found to negatively impact germination parameters, as supported by Husain *et al.* (2017) [22]. The loss of seed viability at room temperature may be attributed to the increased activity of internal fungal species (mycoflora), which thrive under favorable conditions, decompose the endosperm by utilizing stored nutrients, and render seeds nonviable.

Storage at a temperature of 4 ± 1 °C (T_2) was found to be optimal for maintaining germination quality. These results are corroborated by earlier studies, such as Issac (1934) [23] on *Abies nobilis*, Rehmeder (1953) [36] on *Abies Alba*, and Zlobin (1973) [52], who identified -3 °C as the ideal storage temperature for *Pinus palustris*. Similar findings were also documented by Robbins (1983b) [40] for *Pinus oocarpa*, Sharma and Bhardwaj (1999) [43] in *Quercus*, and Kumar (2008) [29] in *Cedrus deodara*.

B. Effect of storage duration on germination parameters

The germinability of seeds in storage was significantly influenced by storage duration. Storage duration of 2

months excelled over all the storage durations (D_2 to D_{12}) as clearly indicated from the tables by registering maximum values for germination parameters. After two months of storage maximum values of germination parameters such as germination percentage, germination energy, germination value, peak value and mean daily germination 40.69%, 28.29%, 2.55, 2.67 and 1.92 were recorded respectively. Storage duration of 24 months (D_{12}) proved to be less effective by registering minimum values for germination parameters as 18.14%, 8.21%, 0.34, 0.54 and 0.56 respectively. Hence, a decreasing trend in germination parameters was observed with increase in seed storage from 2 months to 24 months.

The germinability of seed decreased with increase in duration of storage from 2 to 24 months. The results are in harmony with the findings of Beardmore *et al.*, 2008 in black spruce, white spruce and lodgepole pine. Tilki *et al.* (2006) conducted a study on effect of temperature, duration and storage on seed germination of *Ulmus glabra* and *Ulmus laevis*, the results revealed that *U. glabra* seeds could be stored at 4°C for two years without losing its viability. Our results are also in line with Heydecker (1972) [20] in *Pinus roxburghii*, Ahmed *et al.* (1993) [3] in some shade trees, Chaudhary and Malik (2006) [7] in *Jatropha curcus* and Kumar (2008) [29] in *Cedrus deodara*.

C. Effect of storage container on germination parameters.

All the germination parameters were significantly influenced by the three type of containers used for the study as evident from the tables. Airtight plastic container (C_2) outperformed the other types of container by registering maximum value of 31.92%, 18.39%, 1.53, 1.78 and 1.31 for germination percentage, germination energy, germination value, peak value and mean daily germination. The minimum values 27.21%, 14.64%, 1.35, 1.41 and 1.20 for germination percentage, germination energy, germination value, peak value and mean daily germination were recorded when the seeds were stored in muslin cloth bags (C_3).

The superior performance of the airtight container (C_2) could be attributed to its ability to retain seed moisture and prevent fungal and microbial contamination. These findings are consistent with previous research by Demelash *et al.* (2012) [11] on *Oxytenanthera abyssinica*, Tylkowski (2011) [50] on *Betula pendula*, Takos and Merou (2001) [46] on *Cedrus deodara* and *C. libani*, and Chaturvedi and Das (2004) [6]. Similarly, Handa *et al.* (2006) [18] reported that seeds of *Pongamia pinnata* stored in plastic containers showed better germination outcomes compared to those stored in other types of containers.

In contrast, the relatively poor performance of seeds stored in earthen pots (C_1) and muslin cloth bags (C_3) may be due to their permeability, which allows gas exchange and moisture fluctuation, thereby promoting fungal growth and seed deterioration. These observations align with the findings of Raj Kumar (2008) [29]. Furthermore, seed deterioration during storage can also result from physiological changes, particularly in respiratory metabolism, which is recognized as a key factor contributing to the loss of seed viability and reduced germination capacity (Abdul-Baki, 1980) [2].

D. Interaction effect of storage duration, storage temperature and storage container.

The data in the tables clearly indicates that the interaction between (storage duration x storage temperature), (storage

temperature x storage container), (storage container x duration) and (storage duration x storage temperature x storage container) all exhibited significant influence on germination percentage, germination energy, germination value, peak value and mean daily germination. This may be due to the fact that biological processes of the seeds took place in different manner at different interactions of temperature, duration and container. The seeds stored at $4\pm 1^\circ\text{C}$ temperature (T_2) in airtight plastic container (C_2) after two months duration (D_1) i.e $D_1C_2T_2$ excelled all other combinations by registering maximum value of 45.42%, 32.65%, 3.28, 3.10 and 2.08 for germination percent, germination energy, germination value, peak value and mean daily germination. However, the minimum values of 12.34%, 5.87%, 0.24, 0.29 and 0.47 for germination percent, germination energy, germination value, peak value and mean daily germination were observed after 24 months (D_{12}) when seeds were stored at Room Temperature (T_1) and in muslin cloth bags (C_3) for the combination of $D_{12}C_3T_1$. The highest values of the germination parameters may be attributed to slow biological processes of seed stored at $4\pm 1^\circ\text{C}$ temperature (T_2) in airtight plastic container (C_2) after two months duration (D_1) in comparison to other

combinations of temperature, container and duration hence resulting in less physiological disturbance to seed longevity. The lowest values at room temperature (T_1) in muslin cloth bag (C_3) after duration of 24 months (D_{12}) may be due to faster biological processes leading to a change in physiological status in seeds. Kramer and Kozlowski (1960) [28] found that storing seeds in sealed containers at low temperatures for shorter durations helps reduce respiration rates, thereby improving seed longevity and overall storability. These findings are supported by similar studies conducted by Palomeque *et al.* (2020) [33] on *Cedrela montana*, Weinmannia *fagaroides*, and *Oreocallis grandiflora*; Pradhan *et al.* (2012) [34] on *Swertia chirayita*; Takos and Merou (2001) [46] on *Cedrus deodara* and *C. libani*; Mughal and Thapliyal (2006) [32] on *Cedrus deodara*; and Handa *et al.* (2006) [18] on *Pongamia pinnata*.

Overall, a decline in seed germination potential was observed as the storage period increased from 2 to 24 months. Among all the treatment combinations, the most effective was storing seeds at $4\pm 1^\circ\text{C}$ (T_2) in an airtight plastic container (C_2) for a duration of two months (D_1), which resulted in the highest germinability.

Table 1: Effect of Temperature (T), Container (C) and Duration (D) on germination percent of *Abies pindrow* Royle

Temperature ($^\circ\text{C}$)	T1 ($^\circ\text{C}$) Room Temperature				T2 ($^\circ\text{C}$) $4\pm 1^\circ\text{C}$					Factor means
Container Duration	C1	C2	C3	Sub mean	C1	C2	C3	Sub Mean	Duration	Container
D1	39.55 (6.28)	40.65 (6.37)	37.87 (6.15)	39.36 (6.27)	41.52 (6.44)	45.42 (6.73)	39.11 (6.25)	42.02 (6.48)	40.69 (6.37)	C1 =27.88 (5.28) C2 =31.92 (5.64) C3 =27.21 (5.21)
D2	37.31 (6.10)	38.86 (6.23)	37.12 (6.09)	37.76 (6.14)	39.87 (6.31)	42.71 (6.53)	38.65 (6.21)	40.41 (6.35)	39.09 (6.25)	
D3	36.06 (6.00)	37.01 (6.08)	35.35 (5.94)	36.14 (6.01)	37.84 (6.15)	41.12 (6.41)	36.05 (6.00)	38.34 (6.19)	37.24 (6.10)	
D4	32.77 (5.72)	35.33 (5.94)	32.24 (5.67)	33.45 (5.78)	34.44 (5.86)	39.46 (6.28)	33.57 (5.79)	35.82 (5.98)	34.64 (5.88)	
D5	31.41 (5.60)	32.79 (5.72)	30.54 (5.52)	31.58 (5.61)	33.52 (5.78)	37.04 (6.08)	31.96 (5.65)	34.17 (5.84)	32.88 (5.73)	
D6	26.78 (5.17)	29.56 (5.43)	25.32 (5.03)	27.22 (5.21)	28.52 (5.34)	36.07 (6.00)	28.52 (5.34)	31.04 (5.57)	29.13 (5.39)	
D7	24.33 (4.93)	27.51 (5.24)	23.62 (4.86)	25.15 (5.01)	26.76 (5.17)	33.18 (5.76)	26.73 (5.17)	28.89 (5.37)	27.02 (5.19)	
D8	21.18 (4.60)	25.33 (5.03)	21.05 (4.58)	22.52 (4.75)	25.13 (5.01)	31.71 (5.63)	26.41 (5.13)	27.75 (5.26)	25.14 (5.01)	
D9	18.51 (4.30)	23.91 (4.88)	17.67 (4.20)	20.03 (4.47)	24.19 (4.91)	29.76 (5.45)	24.77 (4.97)	26.24 (5.12)	23.14 (4.81)	
D10	17.63 (4.19)	21.66 (4.65)	16.56 (4.06)	18.62 (4.31)	21.72 (4.66)	28.44 (5.33)	22.81 (4.77)	24.32 (4.93)	21.47 (4.63)	
D11	15.67 (3.95)	19.72 (4.44)	14.71 (3.83)	16.70 (4.08)	19.83 (4.45)	26.78 (5.17)	20.32 (4.50)	22.31 (4.72)	19.51 (4.41)	
D12	15.31 (3.91)	17.61 (4.19)	12.34 (3.51)	15.09 (3.88)	19.31 (4.39)	24.53 (4.95)	19.72 (4.44)	21.19 (4.60)	18.14 (4.25)	
Sub mean	26.38 (5.13)	29.16 (5.40)	25.37 (5.03)	T1=26.97 (5.19)	29.39 (5.42)	34.69 (5.88)	29.05 (5.38)	T2=31.04 (5.57)		
Factors										C.D (p ≤ 0.05)
Duration (D)										0.21
Temperature (T)										0.35
Container (C)										0.33
Duration (D) × Temperature (T)										0.23
Duration (D) × Container (C)										0.22
Temperature (T) × Container (C)										0.19
Duration (D) × Temperature (T) × Container (C)										0.32

Figures in the parenthesis are sine transformed values

Table 2: Effect of Temperature (T), Container (C) and Duration (D) on germination energy of *Abies pindrow* Royle

Temperature (°C)	T1 (°C) Room Temperature				T2 (°C) 4±1 °C					Factor means
Container Duration	C1	C2	C3	Sub mean	C1	C2	C3	Sub Mean	Duration	Container
D1	28.43 (5.33)	29.71 (5.45)	23.76 (4.87)	27.30 (5.22)	27.67 (5.26)	32.65 (5.71)	27.54 (5.24)	29.29 (5.41)	28.29 (5.31)	C1 = 16.45 (4.05) C2 = 18.39 (4.28) C3 = 14.64 (3.82)
D2	24.54 (4.95)	25.62 (5.06)	20.43 (4.51)	23.53 (4.85)	25.68 (5.06)	29.89 (5.37)	24.33 (4.93)	26.63 (5.16)	25.08 (5.00)	
D3	23.71 (4.86)	23.89 (4.88)	18.71 (4.32)	22.10 (4.70)	24.71 (4.97)	28.45 (5.33)	23.31 (4.82)	25.49 (5.04)	23.80 (4.87)	
D4	20.12 (4.48)	22.16 (4.70)	16.00 (4.00)	19.43 (4.40)	22.22 (4.71)	25.76 (5.07)	20.91 (4.57)	22.96 (4.79)	21.20 (4.60)	
D5	17.65 (4.20)	19.87 (4.45)	15.12 (3.88)	17.55 (4.18)	20.18 (4.49)	23.56 (4.85)	18.51 (4.30)	20.75 (4.55)	19.15 (4.37)	
D6	14.72 (3.83)	17.66 (4.20)	14.21 (3.76)	15.53 (3.94)	18.53 (4.30)	20.89 (4.57)	16.43 (4.05)	18.62 (4.31)	17.07 (4.13)	
D7	11.19 (3.34)	14.52 (3.81)	12.36 (3.51)	12.69 (3.56)	17.41 (4.17)	18.43 (4.29)	14.52 (3.81)	16.79 (4.09)	14.74 (3.83)	
D8	9.74 (3.12)	11.69 (3.41)	10.56 (3.24)	10.66 (3.26)	15.72 (3.96)	16.34 (4.04)	11.18 (3.34)	14.41 (3.79)	12.54 (3.54)	
D9	8.68 (2.94)	10.23 (3.19)	9.74 (3.12)	9.55 (3.09)	13.81 (3.71)	14.17 (3.76)	9.78 (3.12)	12.59 (3.54)	11.07 (3.32)	
D10	7.42 (2.72)	8.78 (2.96)	8.51 (2.91)	8.24 (2.87)	11.88 (3.44)	12.11 (3.47)	8.42 (2.90)	10.80 (3.28)	9.52 (3.08)	
D11	6.34 (2.51)	7.77 (2.78)	7.23 (2.68)	7.11 (2.66)	9.83 (3.13)	10.75 (3.27)	6.87 (2.62)	9.15 (3.02)	8.13 (2.85)	
D12	5.87 (2.42)	6.85 (2.61)	6.57 (2.56)	6.43 (2.53)	8.78 (2.96)	9.58 (3.09)	6.26 (2.50)	8.21 (2.86)	7.32 (2.70)	
Sub mean	14.87 (3.85)	16.56 (4.06)	13.60 (3.68)	T1=15.01 (3.87)	18.04 (4.24)	20.22 (4.49)	15.67 (3.95)	T2=17.97 (4.23)		
Factors										C.D (p ≤ 0.05)
Duration (D)										0.16
Temperature (T)										0.21
Container (C)										0.24
Duration (D) × Temperature (T)										0.17
Duration (D) × Container (C)										0.15
Temperature (T) × Container (C)										0.12
Duration (D) × Temperature (T) × Container (C)										0.26

Figures in the parenthesis are sine transformed values

Table 3: Effect of Temperature (T), Container (C) and Duration (D) on germination value of *Abies pindrow* Royle

Temperature (°C)	T1 (°C) Room Temperature				T2 (°C) 4±1 °C					Factor means
Container Duration	C1	C2	C3	Sub mean	C1	C2	C3	Sub Mean	Duration	Container
D1	2.37	2.50	2.13	2.33	2.73	3.28	2.29	2.77	2.55	C1 = 1.42 C2 = 1.53 C3 = 1.35
D2	2.19	2.29	1.97	2.15	2.44	2.87	2.47	2.59	2.37	
D3	1.89	2.11	1.79	1.93	2.20	2.42	2.24	2.29	2.11	
D4	1.67	1.87	1.62	1.72	1.99	2.12	2.10	2.07	1.90	
D5	1.58	1.67	1.44	1.56	1.73	1.97	1.87	1.86	1.71	
D6	1.45	1.47	1.31	1.41	1.66	1.73	1.63	1.67	1.54	
D7	1.23	1.26	1.15	1.21	1.38	1.35	1.32	1.35	1.28	
D8	1.17	1.20	1.01	1.13	1.23	1.26	1.17	1.22	1.17	
D9	0.89	0.91	0.85	0.88	0.94	0.97	0.95	0.95	0.92	
D10	0.68	0.74	0.63	0.68	0.78	0.81	0.80	0.80	0.74	
D11	0.54	0.58	0.51	0.54	0.62	0.65	0.63	0.63	0.59	
D12	0.27	0.35	0.24	0.29	0.38	0.41	0.39	0.39	0.34	
Sub mean	1.33	1.41	1.22	T1=1.32	1.51	1.65	1.49	T2=1.55		
Factors										C.D (p ≤ 0.05)
Duration (D)										0.14
Temperature (T)										0.05
Container (C)										0.07
Duration (D) × Temperature (T)										0.20
Duration (D) × Container (C)										0.25
Temperature (T) × Container (C)										0.10
Duration (D) × Temperature (T) × Container (C)										0.35

Table 4: Effect of Temperature (T), Container (C) and Duration (D) on peak value of *Abies pindrow* Royle

Temperature (°C)	T1 (°C) Room Temperature				T2 (°C) 4±1 °C					Factor means
Container Duration	C1	C2	C3	Sub mean	C1	C2	C3	Sub Mean	Duration	Container
D1	2.58	2.62	2.43	2.54	2.77	3.10	2.53	2.80	2.67	C1 = 1.64 C2 = 1.78 C3 = 1.41
D2	2.50	2.54	2.27	2.44	2.57	2.87	2.44	2.63	2.53	
D3	2.31	2.42	2.11	2.28	2.45	2.81	2.27	2.51	2.40	
D4	2.06	2.33	1.96	2.12	2.35	2.51	2.04	2.30	2.21	
D5	1.93	2.05	1.83	1.94	2.21	2.42	1.97	2.20	2.07	
D6	1.58	1.86	1.34	1.59	2.06	1.91	1.54	1.84	1.72	
D7	1.21	1.62	1.18	1.34	1.87	1.65	1.26	1.59	1.47	
D8	0.98	1.35	0.95	1.09	1.65	1.41	1.15	1.40	1.25	
D9	0.79	1.06	0.74	0.86	1.23	1.17	0.85	1.08	0.97	
D10	0.64	0.89	0.61	0.71	1.03	0.96	0.73	0.91	0.81	
D11	0.48	0.76	0.45	0.56	0.96	0.88	0.58	0.81	0.69	
D12	0.32	0.69	0.29	0.43	0.84	0.74	0.34	0.64	0.54	
Sub mean	1.45	1.68	1.35	T1=1.49	1.83	1.87	1.48	T2=1.73		
Factors										C.D (p ≤ 0.05)
Duration (D)										0.13
Temperature (T)										0.05
Container (C)										0.06
Duration (D) × Temperature (T)										0.18
Duration (D) × Container (C)										0.22
Temperature (T) × Container (C)										0.09
Duration (D) × Temperature (T) × Container (C)										0.32

Table 5: Effect of Temperature (T), Container (C) and Duration (D) on mean daily germination of *Abies pindrow* Royle

Temperature (°C)	T1 (°C) Room Temperature				T2 (°C) 4±1 °C					Factor means
Container Duration	C1	C2	C3	Sub mean	C1	C2	C3	Sub Mean	Duration	Container
D1	1.87	1.93	1.79	1.86	1.98	2.08	1.85	1.97	1.92	C1 = 1.23 C2 = 1.31 C3 = 1.20
D2	1.79	1.84	1.74	1.79	1.88	1.99	1.82	1.90	1.84	
D3	1.68	1.74	1.65	1.69	1.77	1.87	1.68	1.77	1.73	
D4	1.54	1.65	1.51	1.57	1.66	1.74	1.57	1.66	1.61	
D5	1.49	1.54	1.44	1.49	1.56	1.69	1.50	1.58	1.54	
D6	1.30	1.34	1.25	1.30	1.40	1.51	1.36	1.42	1.36	
D7	1.02	1.06	1.04	1.04	1.18	1.26	1.15	1.20	1.12	
D8	0.87	0.93	0.89	0.90	1.05	1.12	1.03	1.07	0.98	
D9	0.78	0.86	0.82	0.82	0.87	0.96	0.84	0.89	0.86	
D10	0.69	0.77	0.73	0.73	0.81	0.85	0.78	0.81	0.77	
D11	0.56	0.65	0.59	0.60	0.72	0.77	0.69	0.73	0.66	
D12	0.50	0.54	0.47	0.50	0.61	0.65	0.57	0.61	0.56	
Sub mean	1.17	1.24	1.16	T1=1.19	1.29	1.37	1.24	T2=1.30		
Factors										C.D (p ≤ 0.05)
Duration (D)										0.08
Temperature (T)										0.03
Container (C)										0.04
Duration (D) × Temperature (T)										0.12
Duration (D) × Container (C)										0.15
Temperature (T) × Container (C)										0.06
Duration (D) × Temperature (T) × Container (C)										0.21

Conclusion

The current study is the first of its kind in which the effect of seed storage conditions on viability of *Abies pindrow* seeds has been conducted. The best seed storage temperature was 4±1°C temperature (T₂) in which all the germination parameters performed better as compared to Room temperature (T₁). Storage duration of two months (D₁) was proved to be the best as highest germinability was observed as compared to the other storage durations. With respect to storage container airtight plastic container was proved to be the best storage container due to preservation of moisture content and prevention of contamination by fungi and mycoflora. A combination of 4±1°C temperature (T₂) in airtight plastic container (C₂) and duration period of two months (D₁) should be used for storage of *Abies*

pindrow seeds and to attain highest germinability. Hence, the seeds of the current year can be used for raising of nursery stock in subsequent year.

Acknowledgement

The authors wish to express their gratitude to the scientists of Division of FBT, SKUAST-K for facilitating the use of lab and lab equipments for the current study.

Conflict of interest

There is no conflict of interest.

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