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Seed technology in high altitude conifers with special reference to temperate conifers of Kashmir valley

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ABSTRACT

Seed is essential in the regeneration of forests. It is the primary method used by conifers to reproduce, maintain genetic variability, and become established on appropriate sites. Seed germination of most temperate coniferous species is inhibited by seed dormancy. Conifer seeds generally have physiological dormancy and this can be overcome by cold stratification at 2^0C-5^0C, some conifer seeds may require one month or less cold stratification to overcome dormancy. Seed dormancy in many conifers such as *Abies alba, Abies pindrow, Abies procera, Picea smithiana , Pinus densiflora and Cedrus deodara* can be overcome by cold stratification and over wintering for varying periods of time from 21 to 90 days. The duration of cold stratification required to overcome physiological dormancy of the seed from different populations may differ in several species. The conifer trees are sporadic in nature in their seed production, the good seed year occur in conifers after long intervals. So it is important to collect the abundant quantity of healthy seeds in good seed year and then store them under favourable conditions for the use in the lean seed years. Successful storage to a large extent depends on maintaining seeds at are below critical moisture content (5%-9%) and storing at lower or below-freezing temperatures.

***Key words :** Regeneration, Conifers, Seed, Dormancy, Stratification.*

Evolution

Conifers bear naked seeds, unlike angiosperms, and differ from other gymnosperms by having the seeds arranged inside cones. During the Carboniferous period (300 million years ago), conifers represented a minor group of gymnosperms, but they evolved rapidly as conditions became drier and colder during the Permian (286–240 million years ago). Temperate coniferous forests were most widely distributed during the Tertiary period (90–15 million years ago), with coastal redwood (*Sequoia sempervirens*) and dawn redwood (*Metasequoia*) distributed throughout both Eurasia and North America. Today, conifers are the dominant representatives of gymnosperms with about 50 genera and 550 species, predominantly in the Northern Hemisphere (Raven et al., 1986). Conifers are well adapted to arid and cold conditions. The surfaces of needle-shaped leaves are protected by waxes and sunken stomata and a large proportion of their stems consists of sapwood that serves as a storage reservoir, as well as a conduit for transport of water from roots to leaves.

Geographic Distribution

Today, temperate evergreen coniferous forests cover approximately 2.4 × 106 km2 (Melillo *et al.*, 1993; Landsberg and Gower, 1997). Conifers dominate the montane forests in North America, Europe, China and India. Smaller areas of temperate conifers are located in montane regions of Korea, Japan, Mexico,

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Nicaragua, and Guatemala. In Europe, the distribution of native and introduced conifers has been expanded into areas more climatically favorable to hardwoods. Pines (*Pinus*), represented by more than 90 species, are the most widely distributed conifer and their range has increased by widespread planting in the Southern Hemisphere. Other important genera include the firs (*Abies*), spruces (*Picea*), hemlocks (*Tsuga*), false-hemlocks (*Pseudotsuga*), larches (*Larix*), cypresses (*Cupressus*), cedars (*Chamaecyparis, Thuja, Libocedrus*) and juniper (*Juniperus*). In the yews (*Taxus*), the seeds are not borne in cones but are enclosed within a fleshy structure. Additional conifer genera (*Araucaria, Fitzroya, Austrocedrus*) are present in the Southern Hemisphere, where they were once more widely distributed (Axelrod *et al.*, 1991).

Ecological Distribution

The potential ecological niche of temperate conifers falls within regions of >250mm in annual precipitation that experience subfreezing conditions, down to, but not below - 45 °C, which is the limit for supercooling of water. Only boreal tree species, which include some pines and spruces, are adapted to temperatures below this limit (Waring and Running, 1998). In regions where precipitation is well distributed throughout the growing season, deciduous hardwoods usually dominate over temperate conifers. Following major disturbances, however, conifers can become established and achieve temporary dominance (Landsberg and Gower, 1997). In the Pacific Northwest region, where summer drought is common, the situation is reversed and many long-lived conifers replace earlier established hardwoods (Waring and Franklin, 1979). To explain these shifts in dominance requires an appreciation of how resources are captured by temperate evergreen conifers throughout the year.

Forest Cover Distribution in Jammu and Kashmir

Jammu and Kashmir has a total forest cover of 20230 Sq. Kms (20.23 lakh hectares) accounting for 19.95% of the total Geographical area of 101387 Sq. Kms on this side of line of control. All India figures indicate a percentage of 24.47% geographical area under forests. Out of the total forest area of 20230 sq. kms, the area under reserved forest is 2551 Sq. Kms., protected forest is 17643 Sq. Kms and the rest 36 Sq. Kms is unclassified. Out of the total forest area, 12066 Sq. Kms are in Jammu Region, followed by Kashmir Region with 8128 Sq. Kms and Ladakh Region with only 36 Sq. Kms. Kashmir Region has 40.17%, Jammu Region has 59.64%, while Ladakh Region has 0.17% area under forest cover. The position of the total Geographical area under forest is as unde 19.8 Forests cover 48 percent of the total geographical area of the State excluding Ladakh region, which is above the national average of 24.47 percent. Per capita forest area accounts to 0.17 hectares for Jammu and Kashmir State as against 0.07 hectares at all India level.

In Jammu and Kashmir the area under pure conifers is 8,270 km2 and under mixed conifers is 10,076 km^2. Conifers are the major element but they are associated with some broadleaved texa. They generally prefer the northern aspect, whereas broadleaved vegetation is mainly confined to southern aspect. *Pinus wallichiana, Cedrus deodara, Taxus baccata, Picea smithiana, Abies pindrow* are the conifers, associated with the broad leaved species represented by *Quercus, Rhododendron, Aesculus, Acer and Betula* etc, (Bhattacharyya *et al.*, 1998).

Seeds in Conifers

A seed has been defined as a "mature ovule" or a reproductive unit formed from fertilized ovule. Seed is essential in the regeneration of forests. It is the primary method used by conifers to reproduce, maintain genetic variability, and become established on appropriate sites. A conifer seed has three main components: Seed coat, Embryo, and Mega-gametophyte.

Seed coat

Protects the inner structures from damage, but can also restrict oxygen uptake, gas exchange, water uptake, or radicle emergence due to its anatomical structure, it is the readily observable feature of the seed and protects the inner tissues from insects, fungi, adverse conditions and mechanical damage. True firs (*Abies spp.*), hemlocks, and western redcedar have resin vesicles in their seed coats (Singh, 1978). These vesicles are surrounded by epithelial cells that produce and secrete the resin into the vesicle. Resin vesicles form early in seed development in the middle or outer layer of the seed coat and are usually more abundant on the lower surface of the seed (formerly in contact with the ovuliferous scale).

Embryo or Zygote

After the fertilization of an ovule, the embryo develops to maturity by a complex series of stages known as embryogeny. All of the rudimentary structures and information necessary to produce a mature tree are contained in the embryo. The embryo is the only seed component containing genetic information from both parent trees.

Mega-gametophyte

The mega-gametophyte surrounds the embryo, providing protection and nourishment for initial growth. It originates from the mother tree and is haploid. The mega-gametophyte cells are large, thin-walled, and spherical in shape In Douglas-fir, the dry weight composition of the mega-gametophyte is 60% lipids, 16% proteins, and 2% sugars (Owens, *at al.*, 1993). Lipids are an efficient means of energy storage due to the larger number of carbon-hydrogen bonds that release a greater amount of energy when oxidized than other organic compounds (Slack and Browse, 1984).

Seed Handling System

The seed handling system that encompasses all seed handling activities from cone collection to sowing in the nursery. The system begins with the collection of cones from seed orchards, wild stands, or plantations. Post-collection handling, including temporary storage, monitoring and transport of cones to a processing facility, it is a key step in the production of high quality seeds. It is generally recommended that the cones of most species should be field-stored (interim storage) for approximately four weeks prior to shipping to the extractory to reduce moisture content and risk of damage.

Cones are generally opened through a kilning process and the seeds extracted by tumbling or screening. Cones of *Abies spp*. should not be kilned at some facilities as their cones naturally disintegrate with additional conditioning. The drying process and separation of seeds from cones, by either method, constitutes cone processing.

Seed Collection

Cone collection and post-collection handling of cones is very important in determining seed lot quality. Several aspects are worth emphasizing here. The first step is locating stands that meet your demands (e.g., Amabilis fir in the Maritime seed planning zone above 800 m) followed by monitoring the crop throughout cone development. One should have a very good idea about cone and seed maturity, potential yield and degree of pest activity before collecting cones. Sampling should become more frequent as cones and seeds are approaching full maturity (generally August to September) (Eremko *et al.*, 1989).

Seed collection requires good planning in advance regarding deployment of trained staff, arrangement of transportation facilities, seed collection equipments, measures to ensure the safety of workers, packing and labeling material, and maintenance of the records, etc. Cones from natural stands and seed orchards may be collected using any of several methods, including by Helicopters, climbing, felling, squirrel caches, etc. Cone collection method and efficiency will vary with species and crop intensity. Seed Collection Time of Different Conifers in India in given in table 1and table 2 represents the seed production interval of Different Conifers in India.

Seed Maturity

Seeds of many orthodox species that are immature when collected (or extracted from fruits) are likely to

Table 1. Region wise forest cover of Jammu and Kashmir (Area in Sq. Kms)

S. No	Region	Total Geographical Area	Forest Area	Percentage of total geographical area
1	Kashmir	15948	8128	50.97
2	Jammu	26293	12066	45.89
3	Leh	45110	29	0.06
4	Kargil	14036	7	0.05
Total	101387*	20230	19.95	

*Indicates geographical area on this side of actual line of control. These area figures exclude 120849 Sq. Kms under illegal occupation of China and Pakistan.
(Source: Digest of Statistics 2011)

Table 2. Specie wise Forest cover under different conifers in Jammu and Kashmir

Coniferous (SoftWood)	Area sq. kms.	%age of total
Deodar	1075	5.31
Chir	1825	9.02
Kail	1969	9.74
Fir	3401	16.81
Mixed Conifers	10076	49.8
Total Area under Coniferous	18345	90.68

Source: DFO Forest Statistics Div., J&K

Table 2. Seed Production Intervals of Different Conifers in India

Species	Moderate Seed Year	Good Seed Year
Pinus wallichiana	2	2-3
Pinus roxburghii	3	4-5
Cupressus torulosa	3	7-8
Cedrus deodara	3	4-5
Picea smithiana	3	6-7
Abies pindrow	6	10

(Khana, 2007)

Table 3. Seed collection time of different conifers in India

Species	Seed Collection Time
Pinus wallichiana	Sep – Oct
Pinus roxburghii	March – April
cupressus torulosa	Oct – Nov
Cedrus deodara	Oct – Nov
Picea smithiana	Oct – Nov
Abies pindrow	Oct – Nov
Pinus gerardiana	Sep – Oct
Taxus baccata	Oct – Nov

(Khana, 2007)

fare poorly in storage (Bonner *et al.*, 1974). For conifers like the pines, storage of immature cones for several weeks prior to extraction of the seeds appears to enhance seed maturity and viability retention during storage (Bonner, 1983).

Mughal and Thapliyal (2006) resulted increase in the germination percentage in seeds of *Cedrus deodara* towards the cone maturity (Table 4). It increased from 0.02% in August to 59.50% at maturity in October at North Kashmir. In South Kashmir, germination percentage increased from 6.55% in August to 75.50% at maturity in September while germination percentage increased from 1.0% in August

Table 3. Fruit types, Collection time, Seed weight, Viability and Germination characteristics of the conifers in India.

Species	Local Name	Fruit Type	Seeds/kg (Apprx.)	Viability Months	Pre-sowing treatments	Ger. period (days)	Ger. %	Sowing Season
Abies spectabilis	Himalayan Fir	Cone	20,500	6	ST	30-40	70	Feb
Cedrus deodara	Deodar	Cone	8,000	4	ST	25-62	70	Dec-Jan
Cehalotaxus griffthii	*Cehalotaxus*	Cone	12,800	4	ST	42-95	15	Feb-Mar
Cryptomeria japonica	Suji	Cone	3,38,000	6	ST	21-28	30	Feb-Mar
Cupressus recurva	Dhupi	Cone	2,40,000	18	ST	20-40	55	June
Juniperus recurva	Himalayan Cedar	Cone	3,600	24	N	25-62	50	Oct - Mar
Larix griffithii	Larc	Cone	1,00,000	5	ST	30-75	55	Nov
Picea spinulosa	Spruce	Cone	62,000	7	ST	28-52	40	March-April
Pinus gerardiana	Chilgoza pine	Cone	3,000	6	N	Oct-25	60	Feb-March
Pinus kesiya	Khasi pine	Cone	58,800	24	N	Jun-15	80	Feb-March
Pinus merkusii	Merkus pine	Cone	76,000	24	N	Jun-15	74	Feb-March
Pinus roxburghii	Chir pine	Cone	10,000	24	ST	May-15	85	March-April
Pinus wallichiana	Blue pine	Cone	19,250	18	ST	Jun-15	82	March-April
Taxus baccata	Yew	Cone	40,000	6	ST	45-80	30	Oct-Nov.
Tsuga dumosa	Himalayan Hemlock	Cone	4,00,000	6	ST	30-45	80	March-April

Source: SFRI, Information bulletin no. (7) 1999.

to 67.50% at maturity in the month of October at Jammu. They concluded it was the result of loading of seeds with the carbohydrates, fats and proteins, which proceed gradually across the season to maturity, commonly known as germinability.

The study carried out by Sofi and Bhardwaj, (2008) represents that seed weight has a significant effect on the germination and seedling growth parameters (table 5). They found that Medium sized seeds (0.10-0.22g/seed) resulted in the maximum germination of 74.20% followed by large size seeds (>0.22g/seed) with 70.32% and least in small size seeds (<0.10 g/seed) with 57.50%. and they also reported the same trend in the seedling growth parameters were plant height was 19.24 cm, collar diameter was 2.73 mm, shoot root ratio of 3.06 and total biomass was 3.82 g in case of medium size seeds.

Sowing dates have significant effect on germination and other nursery parameters of the conifers, there are various studies which justified the sowing conifers seeds in the nursery are influenced by sowing dates the table "6" and "7"given below represents the effect of sowing date of different conifers seed.

Mughal *et al.*, (2007), found the effect of various sowing dates on the germination parameters of *Pinus wallichiana* and *Cupressus torulosa* table 6, they recorded the maximum germination of 92% in *Pinus wallichiana* in seeds sown at two fortnights of February (winter). However it was at par with the germination of seeds sown in the December. In case of *Cupressus torulosa* they recorded maximum germination of 98% in the seeds sown during the December, February and during the 1st fortnight of March. They reported the survival percentage of 86% in *Pinus wallichiana* for seeds sown in 1st February. Though germination was at par during 1st March, they reported the survival percentage of 98% in case of seeds sown during second fortnight of February for *Cupressus torulosa*. From this they concluded they survival percentage is affected by the fact that the temperature during December and January is below freezing point which probably damage the seeds as well as the small germinations as the result of incidence of frost. They further concluded that the insect and pest activity during the spring is more which damage the seedlings. The time of 165 days was taken by the seeds to complete the germination which was sown on in autumn and 65 days for the seed sown in summer for *Pinus wallichiana* and in

Table 4. Variation in Germination % during different stages of maturity in *Cedrus deodar*

Altitude	Site A (North Kashmir)				Site B (South Kashmir)			Site C (Jammu)			
	Aug	Sept	Oct	Mean	Aug	Sept	Mean	Aug	Sept	Oct	Mean
1,500-1,700 m	0.02 (0.81)	30 (33.465)	69 (56.38)	(29.94)	13.60 (21.49)	82 (65.03)	(43.26)	1.5 (5.34)	47 (43.22)	73 (58.92)	(35.82)
1,700-1,900 m	0.02 (0.81)	9 (17.42)	69 (56.76)	(24.72)	7.60 (15.94)	78 (62.49)	(39.21)	2.5 (9.01)	16 (15.52)	70 (56.90)	(39.14)
1,900-2,100 m	0.02 (0.81)	7 (15.42)	68 (55.68)	(23.64)	2 (6.24)	75 (60.95)	(33.59)	0.02 (0.81)	43 (40.39)	70 (56.90)	(32.43)
above 2,100 m	0.02 (0.81)	7 (15.20)	32 (34.43)	(16.54)	32 (9.87)	67 (55.04)	(32.45)	0.02 (0.81)	34 (35.32)	57 (48.97)	(28.09)
Mean	0.02 (0.81)	13.25 (20.33)	59.50 (50.55	6.55 (13.38)	75.50 (60.88)	1.00 (3.99)	46.25 (42.61)	67.50 (55.93)			

Treatment	Critical difference (Site A)		Critical difference (Site B)		Critical difference (Site C)	
	5%	1%	5%	1%	5%	1%
Altitude	2.08	2.77	4.66	6.543	4.2	5.59
Month	1.63	2.17	3.3	4.62	3.64	4.84

Mughal and Thapliyal (2006)

Table 5. Effect of Seed Weight on germination and nursery parameters of *Cedrus deodara*

Seed weight	Ger. %	Plant height (cm)	Collar dia. (mm)	Shoot root ratio	Total biomass (g)
Large (>0.22g/seed	70.32	17.18	2.61	2.70	3.51
Medium (0.10 - 0.22 g/seed)	74.20	19.24	2.73	3.06	3.82
Small (<0.10 g/seed)	57.50	12.67	2.21	2.32	2.24
CD (0.05)	0.39	0.12	0.04	0.16	0.05

Sofi and Bhardwaj, (2008)

Table 6. Response of various germination parameters in *Pinus wallichiana* and *Cupressus torulosa* as influenced by various sowing dates in nursery

Sowing Dates		Germination parameters of *Pinus wallichiana*			Germination parameters of *Cupressus torulosa*		
		Ger. (%)	Completion of germination (Days)	Survival (%)	Ger. (%)	Completion of germination (Days)	Survival (%)
Autumn	15th Nov	84	165	68.66	94	128	77
	1st Dec	87	169	72.66	98	132	71
	15thDec	90	133	80.32	98	116	82
Winter	1st Jan	41	111	22	92	106	51
	15th Jan	81	104	70	90	91	44
	1st Feb	92	88	82.3	98	70	96
	15th Feb	92	89	86	98	65	98
Spring	1st Mar	56	75	38.66	98	51	82
	15th Mar	60	61	31.66	96	53	86
CD at 5%	5.92	0.07	3.82	1.64	1.09	1.06	

Mughal *et al.*, (2007)

Table 7. Response of various germination parameters in conifers (*Cedrus deodara, Pinus halepensis*) as influenced by various sowing dates in nursery

Sowing Dates		Germination parameters of *Cerdus deodara*					Germination parameters of *Pinus halepensis*				
		Ger. (%)	Completion of germination (Days)	Survival (%)	Ht (cm)	Dia (mm)	Ger. (%)	Completion of germination (Days)	Survival (%)	Ht (cm)	Dia (mm)
Autumn	15th Nov	84	158	44	17.4	2.28	79	147	32	16.9	2.51
	1st Dec	92	122	78	19.2	2.58	79	149	29	15.6	1.64
	15th Dec	94	118	66	20.4	2.27	79	132	32	14.1	1.7
Winter	1st Jan	88	102	32	15.5	2.08	79	112	52	13.3	1.86
	15th Jan	92	87	48	20.1	2.64	79	101	46	16.2	1.9
	1st Feb	98	71	92	21.1	2.29	79	86	70	17.7	1.67
	15th Feb	98	65	62	19.3	2.03	73	88	40	16.9	1.33
Spring	1st Mar	96	48	64	18.7	2.22	74	77	42	16.3	1.82
	15th Mar	48	37	30	17.3	2.2	74	61	48	16.6	1.34
CD at5%	3.7	4.5	4.5	1.6	0.37	3.26	1.63	2.8	2.07	0.22	

Khan *et al.*, (2007)

case of *Cuperssus torulosa* it was 128 days for seeds sown in autumn and 53 days for seeds sown in summer. They further concluded they once the seeds are moist chilled under natural conditions they develop the capacity to germinate even under the lower temperature as in present case the seeds the germination of 92% for *Pinus wallichiana* and 98% in Cuperssus torulosa was recored on temperature at 8.2 °C and 10.7 °C during the month of February.

Khan *et al.,* (2007) revealed the effect of various sowing dates on the germination parameters (table 7) of *Cedrus deodara* and *Pinus halepensis* which showed the significant difference among all the parameters, maximum germination percentage of 98% in *Cerdus deodara* was recorded in the seeds sown on the fortnight of February (winter). They recorded the maximum survival percentage of 92% in the seeds which were sown on 1st February. The maximum time to complete the germination was 158 for the seed which were sown on 15th November and the minimum time of 37 days was taken by the seeds which were sown on 15th March, seeds initially took more to complete germination, as ideal conditions in terms of precipitation, temperature, and stratification were not available up to January, they recorded as high 98% germination for seeds shown in February was completed in 92 days. In case of *pinus halepensis* they concluded that chilling may not be prerequisite for germination because germination percentage was 79% in all cases as shown in table 7. They recorded the maximum survival percentage of 72% in the seeds sown on 1st February, while it was only 32% in case of seeds sown on 15th November and 48% in case of seeds sown on 15th march they concluded that this was because of insect and pest activity in Autumn and spring season as the moisture available in the soil during this period is suitable for pathogens and insects thereby having impact on survival of seedlings. Time taken for germination to complete decreased from 147 days for seeds sown on 15th November to 61 days for seeds sown on 15thMarch. They recorded the maximum height of 21.10 cm at the end of growing season for the seeds sown on 1st February (winter) but it was at

Table 8. Storage dormancy, Moisture content and pretreatment summary of different conifers

Species	Common Name	Storage/dormancy characteristics	Storage moisture content and temperatures	Pre-treatment weeks cold (c. 4ºC)
Abies alba	Fir (European silver	Intermediate/Shallow	9–12% @ < -5ºC	8 (6–12)
Abies balsamea	Fir (balsam)	Intermediate/Shallow	9–12% @ < -5ºC	8 (6–12)
Abies concolor	Fir (Colarado white)	Intermediate/Shallow	9–12% @ < -5ºC	8 (6–12)
Abies fraseri	Fir (Fraser)	Intermediate/Shallow	9–12% @ < -5ºC	8 (6–12)
Abies grandis	Fir (grand)	Intermediate/Shallow	9–12% @ < -5ºC	8 (6–12)
Abies nordmanniana	Fir (Caucasian)	Intermediate/Shallow	9–12% @ < -5ºC	8 (6–12)
Abies procera	Fir (noble)	Intermediate/Shallow	9–12% @ < -5ºC	8 (6–12)
Cedrus atlantica	Cedar (Atlas)	Intermediate/Shallow	9–12% @ < -5ºC	8 (6–12)
Cedrus deodara	Deodar	Intermediate/Shallow	9–12% @ < -5ºC	8 (6–12)
Cryptomeria japonica	Japanese red cedar	Intermediate/Shallow	9–12% @ < -5ºC	6 (3–9)
Cedrus libani	Cedar (Lebanon)	Intermediate/Shallow	9–12% @ < -5ºC	8 (6–12)
Juniperus communis	Juniper	Orthodox/Deep	10–15% @ < 0ºC	24 (12–36)
Picea abies	Spruce (Norway)	Orthodox/Shallow	6–8% @ < 4ºC	6 (3–9)
Picea omorika	Spruce (Omorika)	Orthodox/Shallow	6–8% @ < 4ºC	6 (3–9)
Picea pungens	Spruce (blue)	Orthodox/Shallow	6–8% @ < 4ºC	6 (3–9)
Picea sitchensis	Spruce (Sitka)	Orthodox/Shallow	6–8% @ < 4ºC	6 (3–9)
Pinus contorta	Pine (lodgepole)	Orthodox/Shallow	6–8% @ < 4ºC	6 (3–9)
Pinus muricata	Pine (bishop)	Orthodox/Shallow	6–8% @ < 4ºC	6 (3–9)
Pinus nigra	Pine (Austrian)	Orthodox/Shallow	6–8% @ < 4ºC	6 (3–9)
Pinus pinaster	Pine (maritime)	Orthodox/Shallow	6–8% @ < 4ºC	6 (3–9)
Pinus radiata	Pine (Monterey)	Orthodox/Shallow	6–8% @ < 4ºC	6 (3–9)
Pinus sylvestris	Pine (Scots)	Orthodox/Shallow	6–8% @ < 4ºC	6 (3–9)
Taxus baccata	Yew	Orthodox/Deep	10–12% @ < 0ºC	40 (32–52)
Tsuga heterophylla	Western hemlock	Intermediate/Shallow	9–12% @ < -5ºC	6 (3–9)

(Gosling, 2007)

par with the seeds sown on 15th December and recorded the maximum diameter of 2.64 mm for the seeds sown on 15th January and was at par with the seeds sown on 15th November to 15th December but differed significantly for rest of treatments for *Cedrus deodara*. In case of *Pinus halepensis* the maximum height of 17.70 cm was recorded for seeds sown on 1st February and maximum diameter of 2.51 was recorded for the seeds sown on 15th November.

Seed Dormancy

Dormancy is considered a mechanism that eliminates the risk of germination in the autumn after seed have been released from their cones. Seed dormancy is overcome through the technique of imbibitions stratification (moist-chilling), which exposes the seed to cool (2–5°C) temperatures for a specific duration following the imbibitions of the seed. There are mainly two types of seeds dormancy. Physical and Physiological dormancy.

In physical seed dormancy, the seed possesses anatomical features that either restrict the entry of substances such as water and oxygen or restrain the emergence of the radicle. The physical restraint of the seed coat accounts for the majority of the dormancy exhibited by some pines from the south-eastern United States (Barnett, 1976). The seed coat thickness of ponderosa pine has constraint to germination (Barnett, 1991).

Physiological dormancy, also called embryo dormancy, is not well understood although it is widespread among conifers. Embryo dormancy is generally considered a balance of germination-inhibiting and –promoting hormones (Khan, 1975), although changes in tissue sensitivity to these hormones may be more important (Trewavas, 1981). For effective removal of physiological dormancy an optimal moisture content of between 30 and 35% exists (Edwards, 1982). The table 8 shows the storage dormancy characteristics of different conifers.

Stratification

Stratification (Imbibition Followed By Moist-Chilling) has mainly been described as a method to overcome embryo dormancy, but stratification may overcome coat-induced dormancy as well as offering other benefits. Many studies have indicated that stratification will improve the speed of germination and the uniformity of germination which are important considerations in producing a uniform seedling crop. The effectiveness of stratification in overcoming seed dormancy requires that certain conditions be met: an appropriate moisture level, temperature, duration, and access to oxygen.

Some conifer seeds may require one month or less of cold stratification to come out of dormancy, example *Abies balsamea* 28 days (Franklin, 1974), *Abies densa* 28 days (Beniwal and Singh, 1989), *Pinus contorta* 21 days (Hassis and Thrupp, 1931). Others such as *Pinus albicaulis* may require 90 to 120, while still others like *Pinus cembra* may require 90 to 270 days of stratification (Krugman and Jenkinson, 1974) to overcome dormancy. Cedrus deodara (D.Don) seeds have been reported to respond to chilling and 21 days pre-chilling is recommended by ISTA (ISTA, 1966, 1976). In *Cedrus deodara* higher germination percentage has been reported as a result of chilling of seeds (Thapliyal and Gupta, 1980). The length of stratification required depends upon the degree of dormancy which is influenced by seed source (Bonner *et al.*, 1974).

The optimum stratification temperature falls between +2 and +5°C. Temperatures below freezing should be avoided as they are ineffective in breaking dormancy and may injure the imbibed seeds. Stratification at 5°C resulted in faster germination than at 2°C, for ponderosa pine and Douglas-fir, but if the higher end of this range is chosen one should frequently monitor the seeds as germination under stratification conditions is possible, (Downie *et al.*, 1998). Trial work on 10 seed lots of lodgepole pine and interior spruce stratified at moisture contents between 15 and 45% indicated that maximum germination occurred at 30% moisture content for both species, (Hannam 1993).

The optimum stratification temperature falls between +2 and +5°C. Temperatures below freezing

Table 9. Effect of stratification duration on germination % and germination value of *Cedrus deodara*

Stratification Duration (days)	Ger %	Ger. Value
Control	57.10	9.86
15	62.47	10.79
30	66.40	12.55
45	70.14	15.10
60	78.20	17.40
75	82.10	19.50
90	68.50	14.60
CD (0.05)	0.90	0.46

Sofi and Bhardwaj, (2008)

should be avoided as they are ineffective in breaking dormancy and may injure the imbibed seeds (Stokes 1965). Stratification at 5°C resulted in faster germination than at 2°C, for ponderosa pine and Douglas-fir, but if the higher end of this range is chosen one should frequently monitor the seeds as germination under stratification conditions is possible (Danielson and Tanaka 1978).

Sofi and Bhardwaj, (2008) find that germination percentage and germination value increased with the increase in stratification period up to 75 days thereafter it decreased. Maximum germination of 82.10% and germination value of 19.50 was recorded in the seeds stratified for 75 days and they recorded minimum in the seeds which were not stratified (control) that is 57.10 and 9.86 respectively as shown in table 9.

The results pertaining to the table 10 and 11 as given by Rawat *et al.*, (2008), revealed the effect of GA3, moist–chilling and temperature on seed germination of *Abies pindrow* and *Picea smithiana* from five different provenances. Seeds were soaked in GA3 (10 mg/L-1) for 24 h, then chilled at 3⁰ -5⁰C for 15 days. Four temperature regimes viz. 10⁰C, 15⁰C, 20⁰C and 25⁰C were used for stimulating seed germination. Results showed that soaking and chilling significantly increased germination percentage. The germination percentage was highest at 10⁰C. Overall results showed that soaking seeds in GA3 (10 mg/L-1) for 24 h, moist chilling for 15 days, and germinating at 10⁰C produced an effective germination in both the species studied.

Conclusion

Every effort should be made to collect seed in good seed years when cones are plentiful, the quality of the seed is at its best, It is generally best to collect at

Table 10. Effect of different treatments and temperatures on seed germination percentage and germination value of *Abies pindrow* (Italics represent germination value)

Treatments	Bharsar	Dudatali	Ransolikhal	Surkanda	Tapovan
		10 ⁰C			
Control	22±3.75	26±4.86	26±4.01	21±2.92	32±2.00
	0.34±0.08	0.26±0.05	0.54±0.18	0.41±0.08	0.67±0.15
Chilling	34±1.87	56±5.80	45±4.19	45±5.49	52±5.84
	0.53±0.10	0.80±0.21	0.63±0.11	0.58±0.18	0.56±0.07
GA_3 (10 mg-L^{-1})	28±2.55	41±4.86	45±4.19	33±3.40	34±4.86
	0.39±0.04	0.64±0.14	0.69±0.12	0.48±0.11	0.47±0.14
		15 ⁰C			
Control	14±4.01	43±3.40	17±1.22	17±2.55	18±4.37
	0.30±0.10	0.54±0.09	0.22±0.06	0.39±0.09	0.25±0.14
Chilling	29±1.87	43±3.40	34±3.68	37±2.00	47±5.39
	0.29±0.02	0.54±0.09	0.51±0.11	0.45±0.09	0.64±0.11
GA_3 (10 mg-L^{-1})	27±5.16	25±1.58	21±2.92	21±4.31	31±2.92
	0.47±0.15	0.35±0.03	0.38±0.13	0.29±0.07	0.44±0.05
		20 ⁰C			
Control	15±3.17	15±3.54	22±9.59	21±7.50	17±2.00
	0.15±0.04	0.29±0.11	0.49±0.38	0.12±0.02	0.11±0.01
Chilling	31±4.90	33±2.55	28±3.00	33±4.64	30±2.74
	0.26±0.06	0.39±0.08	0.41±0.07	0.30±0.06	0.33±0.03
GA_3 (10 mg-L^{-1})	23±6.26	28±3.40	25±2.74	18±4.07	25±1.58
	0.44±0.08	0.47±0.17	0.27±0.07	0.20±0.06	0.26±0.03
		20 ⁰C			
Control	10±8.28	123±2.00	19±1.00	10±3.17	10±2.74
	0.30±0.28	0.19±0.05	0.26±0.05	0.09±0.03	0.10±0.05
Chilling	27±3.00	30±57.1	27±4.64	30±6.33	25±3.17
	0.36±0.05	0.43±0.13	0.43±0.13	0.39±0.11	0.27±0.05
GA_3 (10 mg-L^{-1})	20±6.53	16±4.31	23±2.00	26±4.86	21±2.45
	0.20±0.09	0.16±0.05	0.29±0.05	0.46±0.17	0.28±0.05

C.D at 5% for Temperature = 0.28, Treatment = 0.47, Treatment X Temperature = 0.29

Table 11. Effect of different treatment and temperature on germination percentage and germination value of *Picea smithiana (Italics represent germination value)*

Treatments	Banjbagad	Hanumanchatti	Helang	Pandukeshwar	Tapovan
		10 °C			
Control	31±1.86	31±6.61	37±2.25	36±3.68	27±3.75
	0.54±0.11	0.83±0.29	0.69±0.09	1.26±0.30	0.68±0.09
Chilling	52±3.40	63±6.05	54±8.59	59±5.35	72±7.53
	0.73±0.18	1.17±0.21	0.82±0.27	1.48±0.29	1.26±0.31
GA_3 (10 mg-L^{-1})	42±5.62	53±4.07	45±5.01	52±3.75	56±6.01
	0.83±0.29	0.93±0.18	1.05±0.24	1.07±0.25	1.29±0.07
		15 °C			
Control	29±2.92	22±2.55	29±1.12	30±1.58	22±2.00
	0.49±0.09	0.41±0.10	0.59±0.05	0.61±0.05	0.82±0.17
Chilling	32±5.16	41±5.80	35±5.25	50±3.17	55±4.19
	0.31±0.04	0.50±0.09	0.38±0.10	0.99±0.32	0.84±0.13
GA_3 (10 mg-L^{-1})	38±3.00	30±4.48	38±6.65	38±2.00	36±5.58
	1.07±0.22	0.64±0.13	0.59±0.12	0.78±0.13	0.61±0.05
		20 °C			
Control	29±6.22	26±4.31	26±4.31	25±1.58	30±2.74
	0.57±0.13	0.55±0.09	0.46±0.08	0.42±0.06	0.71±0.21
Chilling	39±4.31	48±6.05	48±6.05	45±4.75	45±5.25
	0.49±0.07	0.91±0.18	0.62±0.16	0.41±0.15	0.57±0.11
GA_3 (10 mg-L^{-1})	36±3.68	43±3.75	43±3.75	54±11.90	42±2.00
	0.85±0.18	1.02±0.13	1.16±0.39	1.57±0.53	1.22±0.13
		25 °C			
Control	29±2.92	22±2.55	29±1.12	30±1.58	22±2.00
	0.49±0.09	0.41±0.10	0.59±0.05	0.61±0.05	0.82±0.17
Chilling	39±4.31	48±6.05	48±6.05	45±4.75	45±5.25
	0.49±0.07	0.91±0.18	0.62±0.16	0.41±0.15	0.57±0.11
GA_3 (10 mg-L^{-1})	38±3.00	30±4.48	38±6.65	38±2.00	36±5.58
	1.07±0.22	0.64±0.13	0.59±0.12	0.78±0.13	0.61±0.05

C.D at 5% for Temperature = 0.37, Treatment = 0.72, Treatment X Temperature = 0.46, Rawat *et al.*, (2008)

the earliest opportunity after seed maturation as this is the time when maximum amount of seed is available. Conifer seeds generally have physiological dormancy and this can be overcome by cold stratification (2⁰C-5⁰C). Some conifer seeds may require one month or less of cold stratification to overcome dormancy. Seed dormancy in many conifers such as *Abies alba, Abies pindrow, Abies procera, Picea smithiana and Pinus densiflora, Cedrus deodara* can be overcome by cold stratification and over wintering for varying periods of time from 21 to 90 days. Seed for long term storage should be dried in warm dry air until the moisture content is between 6% - 8%. The dried seed should then be placed in airtight containers and stored in a cold store.

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