Chemical stimulation of seed germination in *Angelica archangelica* Linn. (Apiaceae), a threatened high altitude aromatic herb

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Abstract: *Angelica archangelica* (Apiaceae) is threatened aromatic herb for which *ex situ* cultivation is recommended as a conservational tool. However, earlier reports suggested poor seed germination in this species and therefore, domestication was not done. Present paper deals with improvement of germination potential of the species. Seeds from different natural populations were tested in polyhouse and nursery bed conditions by using different soil compositions. Pre sowing treatments of various concentrations of Potassium nitrate (KNO_3), Sodium Hypochlorite ($NaHClO_3$) and Thiourea (CH_4N_2S) were also used to enhance the germination. Germination potential differed significantly in the laboratory, as well as in the polyhouse conditions of the seeds from different populations. Among the pre sowing treatments, KNO_3 150 mM and Thiourea 200 µL L^{-1}, germination was improved significantly. Furthermore, mean germination time was reduced under laboratory conditions as well as inside polyhouse condition. Pretreatments of the seeds by these chemicals also improved germination in polyhouse condition. The results of these treatments inside polyhouse and laboratory are presented here and possible reasons for enhancement in germination discussed. [Journal of American Science 2009;5(5):59-70]. (ISSN: 1545-1003).

Key words: endangered, exploitation, germination, mean germination time, nitrogenous compounds.

1. Introduction

Angelica archangelica Linn. (wild Parsnip or European angelica) of family Apiaceae is native to Europe and widely distributed to Austria, Belgium, Denmark, Germany, Greenland, Hungary, Ice-land, Poland and Central Russia. It also has been naturalized in the UK and other parts of Europe (Sarker et al., 2004). In India it is found in Western Himalaya between an altitudes of 1000-3900 m asl in Kashmir and 2600-3900 m asl in Garhwal and Kumaon regions. It is also reported from Sikkim at (3000-3300 m) in North East Himalaya, India. *A. archangelica* is biennial or short-lived perennial aromatic herb. Leaves ovate, 2-3 pinnate, ultimate pinnate toothed; flowers white in large compound umbels; schizocarps ellipsoid, Oblong or sub-quadrate; seeds dorsally much compressed. (Anonymous, 1985).

A. archangelica has a long history of association with magic and long medicinal history having also been attributed to helping cure the Black Plague of the fifteenth century. American Indian used *Angelica* to help fight respiratory problems and as a tonic after an illness. *A. archangelica* is believed to possess angelic healing power. This plant has been used in traditional and folk medicine as a remedy for nervous headaches, fever, skin rashes, wounds, rheumatism, and toothaches. The roots of this plant have been used internally for digestive problems, including gastric ulcers, anorexia, and migraine, bronchitis, chronic fatigue, and menstrual and obstetric complaints. It has been shown to stimulate gastric and pancreatic secretions. *A. archangelica* can be used as an antiseptic, expectorant, emmenagogue and a diuretic. The root is aromatic and is reported to posses' diaphoretic and diuretic properties, and is used in flatulent colic. The roots from Kashmir yield five furocoumarins. An isocoumarin, angelicain (mp 194°C), a new flavonone, archangelenone (mp148°C; yield 0.005%) and diprenyl maringenin are also present. The coumarins are reported to be useful in curing leucoderma. In Europe, the essential oil from *A. archangelica* is employed in liquors, dental preparations and in high-grade perfumery to impart a musky note, which can not be distinguished easily from that of true musk (Anonymous, 1985; and Sarker et al., 2004).

In the Indian Himalayan region, this species is facing severe threats due to habitat degradation and exploitation for aromatic and medicinal purposes. Recently, natural populations were surveyed in Garhwal region for the determination of threat status of the species (Vashistha et al., 2006) and it was affirmed as endangered species. Increasing biotic interferences has also led to low regeneration of the species in natural habitats. The poor seed germination in the species of Apiaceae is known, probably due to dormancy and plant growth regulators have been used to break the same (Chaudhary et al. 1994). Earlier, Ojala (1985) and Butola et al. (2004 a) suggested dormancy and irregular pattern of seed germination in *Angelica* species.

Therefore, objectives of the present study included (i) to develop effective pre- sowing treatments to stimulate seed germination and reduce mean germination time (MGT) in laboratory condition as well as in nursery condition. (ii) to standardize best sowing depth and soil composition for this species under nursery conditions. (iii) to compare the effect of polyhouse versus open nursery bed conditions on seed germination and MGT. These observations were aimed to develop an appropriate multiplication protocols for the domestication so that commercial cultivation could be carried out in near future and natural populations can be restored.

2. Materials and Methods

Seeds of *A. archangelica* were harvested after ripening during the month of September - October 2003 from four natural populations having altitudes between 3000-4000 m asl. These populations include Tungnath (TN) and Kedarnath (KN) in Rudraprayag district and The Valley of Flowers (VF) and Rudranath (RN) in Chamoli district of Garhwal, Uttarakhand, India (29°26'- 31°28' N and 77°49'-80°6'E). Harvested seeds were air dried for one week and stored in airtight bags for further observations. Following observations were carried out and method for each observation is described below.

The percentage moisture content of seeds was determined by oven dry method *i e.* at 103°C for 17 hours as per ISTA rule (1985). For imbibitions test, five seeds from each population were weighted in triplicate and soaked in distilled water. Seeds were wiped with blotting paper to remove excess water and weighted. Imbibitions rate was observed after 24 hrs and 48 hrs as:

$$\text{Imbibition Rate} = \frac{\text{Imbibed weight - Initial weight}}{\text{Initial weight}} \times 100$$

Impact of storage conditions on seed viability was also observed for one year. Seeds were kept in airtight polythene bags separately, at low temperature (4°C - 6°C) in refrigerator and at room temperature (10-35°C). Viability of these stored seeds was tested by the method of Moore (1962) with pH adjusted at 6.0.

2.1 Germination Study

2.1.1 Under field conditions

Seed germination study was carried out at Pothivasa (PV) nursery site (2200 m, 30°28'N Lat. and 79°16'E Long.) during the month of March- April and Tungnath (TN) at alpine garden (3600 m, 30° 14'N Lat. and 79°13'E Long.) during May-June. For experiments, polyhouses were used. Experiments carried out at TN aimed to compare natural (open beds) versus polyhouse beds for better germination. During experiments, temperature inside polyhouse was ranged between 15.8 ±2.2°C- 29.1 ±2.1°C at PV while it was between 5.0±2°C -18°C at TN. Details of given pretreatments are presented in Table 1.

2.1.2 Under laboratory conditions

Seeds were surface sterilized by dipping in 0.1% aqueous solution of Mercuric chloride ($HgCl_2$) for one minutes followed by ethanol for two minutes and then rinsed thoroughly (3-4 times) with distilled water. Seeds were kept in glass Petri dishes on single layer of Whatman No.1 filter paper after pretreatments as describe below. All observations were taken in 16 hrs light and 8 hrs dark at 25±2°C conditions. Each treatment contained three replicates of 20 seeds. Details of given pretreatments are presented in Table 2.

2.2 Data analysis

Seeds were considered to have germinated upon the initiation of radicle. Number of seeds germinated was counted daily. Mean germination time (MGT) was calculated following the formula given by Ellis and Roberts (1981) as:

$$MGT = \Sigma D_n / \Sigma n$$

Where n = number of seeds germinated on day; D = number of days since the sowing of seeds.

During the present observations, mean values of treatments with standard deviation (±) are presented. ANOVA was used to interpret the variation and to identify the best treatment and population for improved germination potential.

Table 1. Details of treatments given inside polyhouse at PV and TN nurseries

SN	Treatments	Methods	Remarks
1	Soil compositions Soil: Sand: Litter	Garden soil (control) 1:1:1 1:2:1 1:1:2	48 seeds with triplicate in Styrofoam seedling trays inside polyhouse for each composition
2	Sowing depth	1.0 cm 0.5 cm	48 seeds with triplicate in Styrofoam seedling trays inside polyhouse
3	Hormonal and chemical pretreatments	As mentioned in Table 2	48 seeds with triplicate in Styrofoam seedling trays inside polyhouse
4	Natural condition at TN (3600 m asl)	Inside polyhouse Soil: Sand: Litter (1:1:1) Open bed condition	48 seeds with triplicate in Styrofoam seedling trays inside polyhouse (0.5 cm) depth In the natural, open-bed condition, 50 seeds were sown in triplicate directly in garden soil

Table 2. Details of pretreatments given in laboratory condition

SN	Pretreatments	Concentration	Remarks
1.	Control	-	Presoaked for 24 hrs in DH_2O
2.	Scarified seeds	-	Seed coat removed, no treatment, presoaked in DH_2O for 24 hrs
3.	Thiourea (CH_4N_2S)	200, 400 µL L^{-1}	Presoaked for 24 hrs washed with DH_2O
4.	Potassium nitrate (KNO_3)	100, 150 mM	Presoaked for 24 hrs washed with DH_2O
5.	Sodium Hypochlo ($NaHClO_3$)	5%	Presoaked for 30 and 45 minutes and washed with DH_2O

3. Results and Discussion

Germination potential of the species in field conditions were recorded at TN and PV nurseries and in laboratory conditions at Srinagar Garhwal (550 m asl, main central laboratory of HAPPRC). Since, in alpine region, germination was poor and it is not possible to domesticate the species in alpine region (TN) due to arduous climatic conditions, further emphasis was given to test germinability at lower altitudes (PV) which was found suitable for domestication and for future cultivation. Imbibitions capacity of *A. archangelica* seeds collected from different natural populations are shown in figure 1. Furthermore, maximum (90.7%) viability was recorded in the seeds of the KN while TN seeds had minimum (76.7%) viability at the time of harvesting. Contrary to this, moisture was maximum (11%) in the TN seeds while seed moisture content was only 8.2% in the KN seeds. After one-year storage, viability decreased further (31.3%) in the TN seeds at

room temperature. Low seed viability may be one of the reasons for the poor germination in nature (Nadeem et al. 2000). However, rate of decrease was much slower in refrigerator stored seeds. At the end of first year, 62.7% seeds from the KN were viable. Similarly, nearly 48% seeds from the TN were also viable after one year. Further, there was slight decrease in seed moisture being 10.2% in the TN and 7.1% in the KN seeds stored at room temperature at the end of a year (Table 3).

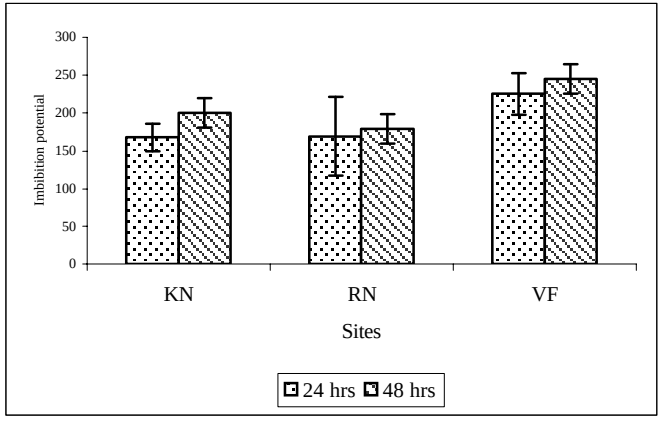

Figure 1. Imbibition potential of seeds of *A. archangelica* after 24 hrs and 48 hrs

Table 3. Percent viability and moisture content in seeds of *A. archangelica* after one year of storage

	%Viability			% Moisture content	
Populations	At the time of collection	At Room temperature	At Low temperature	At the time of collection	At Room temperature
KN	90.7±1.1	42.0±2.0	62.7±3.1	8.2±1.2	7.1±2.7
RN	81.3±2.3	36.0±2.0	56.7±2.3	10.7±0.7	9.7±0.5
VF	88.0±2.0	38.0±2.0	58.7±1.2	10.2±0.3	9.4±0.5
TN	76.7±2.3	31.3±2.3	48.0±2.0	11.0±5.0	10.2±0.2

*Room temperature varied from 10°C to 35°C; low temperature varied from 4°C to 6°C.

Viability test indicated that seeds of *A. archangelica* may not remain viable for extended periods at room temperature and even storage at low temperature (4°C - 6°C) for long. Loss of viability in stored seeds is a common phenomenon (Verma et al, 1996) and it increased with storage duration (Dell Aquilla 1987) with storage condition is another factor. However, it was also observed that seed moisture content did not played key role as population with low seed moisture at the time of harvesting had high viability in *A. archangelica*. Further, seed moisture was slightly decreased after one year storage. Loss of viability as well as variation in seed viability among different natural populations may have the relation with growth and development of embryo which caused morpho-physiological dormancy as suggested by Walek and Hidayati (2004) in another Apiaceae species *Osmorhiza depauperata*.

3.1 Germination study at laboratory condition

Seed germination study conducted under hormonal and chemical treatments revealed that untreated seeds (control) of different populations had varied germination response (Table 4). Scarified seeds from different populations showed improved germination *viz.*, 58.3% (RN) followed by 56.7% (VF) 55.0% (KN) and 53.3% (TN). The RN seeds had maximum germination of 63.3% in $NaHClO_3$ (45 minutes) treatment. Seeds of the VF population showed minimum germination of 31.6% in $NaHClO_3$ (30 min) treatment. KNO_3 has been reported to enhance seed germination possibly through oxidized forms of nitrogen causing a shift in respiratory metabolism to the pentose phosphate pathway (Roberts et al., 1977). However, it has also been found to substitute the light requirements for germination for many positively photoblastic seeds (Roberts 1973). Also, it has been used to stimulate the germination of dormant seeds (Mayers et al. 1989). Results further showed a significant difference ($p<0.05$) among populations and concentrations, which are in agreement with Qaderi and Cavers (2000), who reported that different populations and KNO_3 concentration significantly affect the germination response in *Onopordium acanthium* seeds. Bhatt et al. (2005) also observed enhancement in germination as well as lessening in MGT by KNO_3 pretreatment in *Swertia angustifolia*.

The effect of Thiourea in improving seed germination of alpine plants was reported earlier (Manjkhola et al., 2003). Pandey et al. (2000) revealed that among the nitrogenous compounds, Thiourea increased germination percentage in *Aconitum hetrophyllum* and *A. balfourii* but Potassium nitrate (KNO_3) enhanced germination in *A. balfourii* only. Thiourea is known to promote the germination of chilling requiring seeds (Agarwal et al., 1995). Detrimental results of thiourea were also observed by Begum et al. (1988) in seed germination trials of *Carica papaya.* Seed germination stimulating ability of Sodium Hypochlorite ($NaHClO_3$), a common surface disinfectant has been reported (Ho et al., 1995).

Compared to control, certain treatments *viz.*, $NaHClO_3$ (30 minutes) and Thiourea (400 µL L^{-1}) showed non-significant improvement in germination of the VF seeds. Likewise, seeds of the TN and RN populations did not show significant improvement in Thiourea (400 µL L^{-1}). Other treatments significantly improved germination. In the KN population seeds, barring $NaHClO_3$ (30 & 45 minutes) and Thiourea (400 µL L^{-1}), all treatments improved germination significantly ($p<0.05$). MGT was reduced through scarification of the seeds from all populations. Contrary to this, Thiourea (400 µL L^{-1}) treatment increased MGT (Table 4). Comparing expensive plant growth regulators, the use of KNO_3 and $NaHClO_3$ owing to low cost, was suggested to be beneficial tool to mass multiplication in the cultivation of *Heracleum candicans* (Butola et al., 2004b).

3.2 Germination study at nursery condition

Perez-Garcia et al. (1995) reported that populations of a species differ in their germination responses. The results of the present investigation clearly indicate that the germination response of *A. archangelica* differs among populations, treatments as well as in different soil compositions. Earlier reports suggest that various factors such as, mother plant environment *e.g.* nutrient, light and water (Baskin and Baskin 1998) and the position of the seeds on a plant influence the germination response of the seeds. Besides these, latitude and elevation could have played an important role in affecting germination responses among different populations. Seeds developing at different positions on the mother plant may not have the same germination requirements (Baskin and Baskin 1998). This could be one of the several factors as seeds of *A. archangelica* are arranged in primary and secondary umbels. These umbels ripened at different time with different set of climatic conditions, a characteristics feature of alpine environment. The study also revealed a moderate effect of Potassium nitrate, Thiourea, Sodium Hypochlorite and scarified seeds on germination of *Angelica archangelica* from all populations in laboratory as well as in polyhouse condition.

Germination potential of seeds harvested from natural populations was observed at alpine garden, TN considering it as a natural site of *A. archangelica.* Seeds were sown in open beds as well as inside polyhouse during May-June for comparative observations as polyhouse provide protective and much humid conditions. Seeds of VF population had poor

germination (44.67%) in nursery beds while it increased up to 58.33% inside polyhouse. Seeds from KN population showed 40.33% germination in open bed and 55.21% in polyhouse condition. Compared to open beds, polyhouse displayed significant improvement ($p<0.05$) in germination for the seeds of both populations. Germination studies among different populations provide helpful clues on genetic make-up of the species and its existence in the natural population (Baskin and Baskin 1998). MGT of seeds from VF was decreased up to 69.47 days inside polyhouse as compared to 98.87days in open bed condition. Further, MGT was 101.62 days in open bed and it reduced to 73.27 days inside polyhouse in the seeds of KN (Table 5).

Results on seed germination of *A. archangelica* inside polyhouse at PV are shown in Table 6. Seeds were sown in Styrofoam seedling trays after pretreatments of chemicals as described earlier at 0.5cm depth having a mixture of soil, sand and litter in 1:1:1 ratio. Among the treatments, maximum germination was observed in Thiourea (400 µL L^{-1}) for all populations with germination percentage of 67.7% (VF), 66.66% (KN), 63.54% (RN) and 61.53% (TN). In KN and VF populations, excluding Thiourea (200 µL L^{-1}), all treatments improved seed germination. Whereas, $NaHClO_3$ (30 minutes) and Thiourea 200 µL L^{-1} did not improved germination significantly in the seeds of TN and RN populations ($p<0.05$). Overall, $NaHClO_3$ (30 & 45 minutes) and KNO_3 (100 &150 mM) treatments significantly improved seed germination among all populations ($p<0.05$). KNO_3 (150 mM) treatment also reduced MGT as compared to control. MGT in KNO_3 (150 mM) treatment was observed 20.03 days in the seeds of KN, 22.07 days in VF, 23.39 days in RN and 24.05 days in TN (Table 6).

Deprive as well as deferred germination was observed at deep sowing depth (1.0cm) as compared to shallow depth (0.5cm). Maximum germination (70.42%) at 0.5 cm was recorded in the seeds of VF while only 51.25% seeds from KN were germinated at sowing depth of 1.0 cm (Figure 2). Beside soil, sand and litter in 1:1:1 composition, ratios of 1:2:1, 1:1:2 were also observed for best soil medium to achieve maximum germination with garden soil as control (Table 7). The soil composition with 1:1:1 ratio displayed maximum seed germination (70.42%) followed by 1:1:2 (60.42%) as compared to control (51.25%) in the seeds of the VF. Similar results were recorded for KN seeds although, germination was 63.75%. In general, all soil compositions significantly improved germination ($p<0.5$) as compared to control in the KN seeds. The soil composition in 1:1:1 and 1:1:2 ratio also significantly improved germination in the seeds of the VF. MGT reduced in soil composition of 1:1:1 (33.23 days) as compared to control soil (35.52 days) for VF population. In case of KN population, MGT also decreased in 1:1:1 (34.22 days) against control soil (36.63 days).

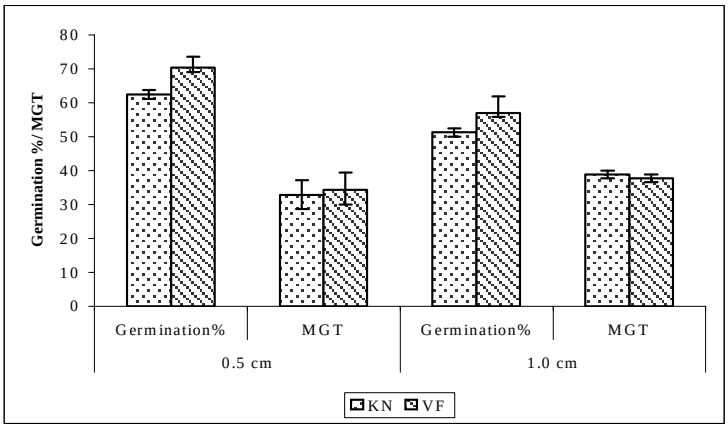

Figure 2. The effect of seeding depth on germination of *A. archangelica* at PV nursery. (Percent germination; MGT, mean germination time in days).

Table 4. Effect of pretreatments of different chemicals on germination and MGT of *A. archangelica* in laboratory condition (25 ±2°C)

Treatments	VF	TN	KN	RN	F value LSD
Control					
% germination	33.3±5.7	35.0±5.0	40.0±5.0	38.3±5.7	0.9, 7.9
MGT	32.1 ±0.6	38.1 ±3.8	38.1 ±3.1	38.8 ±3.5	3.1,4.5
Scarified seeds					
% germination	56.7±3.8*	53.3±2.8*	55.0±5.0*	58.3±2.8*	0.7,6.3
MGT	23.4 ±1.0	26.6 ±1.2	27.4 ±0.9	27.0 ±0.8	9.8*,1.4
$NaHClO_3$ (30min)					
% germination	31.6±2.8	46.7±2.8*	46.7±2.9	51.7±7.6*	10.8*,6.6
MGT	26.5 ±2.9	35.2 ±2.6	35.1 ±3.0	34.8 ±3.5	5.9*,4.4
$NaHClO_3$ (45min)					
% germination	46.7±2.8*	48.3±10.4*	45.0±5.0	63.3±4.5*	4.8*,9.6
MGT	30.2 ±1.5	30.3 ±1.6	30.7 ±1.5	31.15±0.8	0.3,2.0
KNO_3 100 mM					
% germination	43.3±2.7*	46.7±2.9*	50.0±5.0*	48.3±2.8*	1.2,6.2
MGT	30.2 ±3.7	31.8 ±1.6	31.7 ±1.6	32.3 ±1.2	0.5,3.3
KNO_3 150 mM					
% germination	53.3±2.7*	51.7±2.9*	56.7±7.6*	52.3±2.9*	0.4,7.6
MGT	30.5 ±0.2	32.6 ±2.1	31.7 ±2.0	31.7 ±2.9	0.5,3.0
Th 200 ppm					
% germination	46.7±5.7*	43.3±10.4*	51.7±7.6*	48.3±7.6*	0.5,11.7
MGT	28.5 ±3.2	34.9 ±0.6	34.83±0.9	34.6 ±0.9	5.4*,3.4
Th 400 ppm					
% germination	38.3±2.8	40.7±2.9	42.7±1.8	41.7±5.7	0.5,5.5
MGT	32.2 ±2.5	38.3 ±1.4	38.2 ±0.8	37.7 ±0.2	11.3*,2.2
F value LSD for % ger	14.2*,7.3	2.9*,8.3	3.7*,7.5	4.4*,7.2	
F value LSD for MGT	5.3*,3.1	10.1*,3.0	9.8*,2.9	8.6*,3.1	

Mean ± standard error for germination at 25°C ± 2°C, MGT is mean germination time in days.
* Significant ($p<0.05$)

Table 5. Seed Germination in *A.archangelica* in Nursery at TN

Treatments	KN	VF	F value LSD (P<0.05)
	40.33 ±2.52	44.67 ±2.01	5.28
Open Bed			3.79
Polyhouse	55.21 ±4.34*	58.33 ±3.18*	4.90
			6.25
F value	20.60*	16.08*	
LSD (P<0.05	5.83	4.42	
MGT of *A. archangelica* in TN Nursery			
	101.62 ±3.43	98.87 ±2.51	1.72
Open Bed			5.82
Polyhouse	73.27 ±2.70	69.47 ±4.22	1.72
			5.82
F value	107.58 *	126.67*	
LSD (P<0.05)	5.71	5.07	

* Significant ($p<0.05$)

Table 6. Effect of pretreatments of different chemicals on germination and MGT of *A. archangelica* in polyhouse condition in PV nursery.

Treatments	KN	VF	TN	RN	F value & LSD
Control					
% germination	47.5 ±9.4	46.9 ±7.2	45.8 ±6.5	44.8 ±4.7	0.1, 10.5
MGT	31.8 ±3.2	33.3±4.3	33.8 ±3.8	34.08 ±3.4	0.2, 5.4
$NaHClO_3$ (30min)					
% germination	54.6 ±1.6*	53.7 ±3.2*	50.9 ±1.6	48.1 ±1.6	5.7*, 3.1
MGT	25.1 ±1.3	25.7 ±0.8	27.0±1.7	27.4 ±1.4	1.8,2.0
$NaHClO_3$ (45min)					
% germination	56.7 ±1.4*	55.8 ±1.4*	51.7 ±1.4	47.5 ±2.5	17.1*, 2.5
MGT	25.6 ±0.7	24.9 ±0.6	26.2 ±0.8	26.42 ±0.5	2.5,1.0
KNO_3 100 mM					
% germination	59.37±3.1*	60.4 ±1.8*	55.2 ±1.8*	54.1 ±1.8*	5.7*, 3.2
MGT	23.9 ±1.2	23.4 ±0.6	24.0 ±0.8	24.3±0.6	0.4,1.3
KNO_3 150 mM					
% germination	65.6 ±3.1*	66.6 ±1.8*	59.3 ±3.1*	57.2±1.8*	9.8*, 3.7
MGT	20.0 ±0.9	22.0 ±0.6	23.3 ±1.5	24.05 ±1.7	5.3*,1.9
Th 200 ppm					
% germination	48.6 ±3.18	50.6 ±2.4	47.9±3.6	45.2 ±2.4	0.7 , 4.3
MGT	25.6 ±0.9	26.2 ±1.2	26.7 ±1.5	27.5 ±2.2	0.7 ,2.3
Th 400 ppm					
% germination	66.6 ±4.7*	67.7±3.6*	63.5 ±6.5*	61.5±4.7*	0.5, 7.5
MGT	25.3 ±1.7	28.5 ±0.7	29.0±1.0	29.7 ±0.4	8.8*,1.6
F value & LSD for % germination	8.1 *, 6.4	13.3*,, 5.1	7.2*, 5.7	13.7*, 4.3	
F value & LSD for MGT	12.8*,2.3	12.7*,2.5	10.3*,2.6	10.7*,2.5	

* Significant ($p<0.05$)

Table 7. Seed Germination of *A. archangelica* in Selected Media Compositions at PV Nursery

Treatments	KN % G	VF % G	F value & LSD	KN MGT	VF MGT	F value & LSD
Control	48.7 ±0.7	51.25 ±0.72	32.0 1.28	36.6 ±2.0	35.5 ±3.3	0.24 4.52
(Soil:Sand:Litter) 1:1:1	63.7 ±4.5*	70.4 ±3.2*	4.4 6.4	34.2 ±3.5	33.2 ±4.9	0.08 6.98
1:2:1	57.08±2.6*	55.0 ±4.5	0.5 6.1	35.8 ±2.6	34.7 ±3.9	0.16 5.48
1:1:2	59.5 ±1.9*	60.4 ±0.72*	0.5 2.47	35.6 ±2.3	34.4 ±4.02	0.17 5.43
F value LSD)	16.2* 4.0	25.8* 4.09		0.16 ns 5.99	0.16 ns 5.99	

*Significant ($p<0.05$)
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Conclusions

Observations reveals variation in seed viability among the populations irrespective of moisture content which may suggests morpho-physiological type of dormancy in this species. Therefore, harvesting time is a key as time requires for the maturation of embryo may determined viability status of the seeds. The results of this study also indicate that Potassium nitrate and Thiourea (as well as Sodium Hypochlorite) are helpful for reducing the Mean germination time and stimulating seed germination in *A. archangelica*. These treatments

are quite simple and all the chemicals are inexpensive compared to PGRs, these can be widely used by the growers and nurserymen. On the basis of present observations, it is further suggested that seed stored at low temperature remain viable for one year. Likewise, polyhouse conditions beside aforesaid treatment can be used for raising seedlings. Since, their was great deal of inconsistency in nursery based germination results, further observations are needed to overcome morpho-physiological dormancy and bringing uniformity in germination behavior of *A. archangelica*.

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