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# EFFECTS OF VARIATION IN SEED SOURCES AND PRE-SOWING TREATMENTS ON SEED GERMINATION OF *TERMINALIA CHEBULA*- A MULTI-PURPOSE TREE SPECIES

**Manzoor A. Dar[1] and S. K. Agnihotri[2]**

[1]Doon P.G. College of Agriculture Science and Technology, Dehradun (Uttarakhand), India.
[2]Govt. P. G. College, Rewa (Madhya Pradesh), India.

## Abstract

Seeds collected from 4 states with 3 different locations for each state (Total 12 provenances) were evaluated for seed morphology, fruit and seed parameters and seed germination under different pre-treatments. Considerable morphological and physiological variations between provenances for all the fruit and seed traits including germination were found among the seed sources. Fruit and seed parameters varied differently from different provenances. Among different parameters, number of fruits as well as seeds per kilogram was maximum from P7 (Uttar Pradesh) provenance; whereas, maximum fruit length and fruit diameter as well as seed length and seed diameter were recorded from P4 (Uttarakhand). Among various pre-treatments, $\mathbf{T_4}$ (fruits depulped and soaked in cold water for 48 hours) was more effective in breaking dormancy of seeds than other treatments. Germination percentage, germination period and germination values were found maximum with $\mathbf{T_4}$ treatment that resulted in healthy and vigorous seedlings.

***Key words :*** Provenances, pre-treatments, dormancy, germination percentage, germination value.

## Introduction

*Terminalia chebula* of family Combretaceae is a moderate to large sized deciduous tree, occurs naturally from the sub-Himalayan region of Nepal and Northern India to Sri Lanka, Myanmar, Thailand, Indo-China and Southern China (Saleem *et al*., 2001; Li *et al*., 2011). In India, this tree is found in sub-Himalayan tracks form Ravi eastwards to West Bengal, Assam, ascending up to an altitude of 1500 m in the Himalayas. This tree is wild in the forests of Northern India, Uttar Pradesh, Bengal, Madras, Tamil Nadu, Karnataka, Mysore and Southern Maharastra. It is used in traditional medicines and is commonly called as Black myrobalan, Ink tree or chebulic myrobalan. It flourishes well on lateritic soils and chief associate is *Eugenia jambolana*. The quality of seed produced by the trees varies considerably in different years. The germination of seed is said to be poor due to hard seed cover (Troup, 1921).

Germinability is a measure of the ability of population of seeds to germinate or the maximum percentage of seeds that will germinate under favourable conditions (Bewley and Black, 1978). Variation in seed germination is due to a complex of environmental and genetic factors during seed formation and subsequent handling of treatments (Wang *et al*., 1982). Depending on the species, germination responses of seed vary according to geographical and environmental factors, *viz*. latitude, elevation, soil moisture, soil nutrient, temperature, kind and density of plant cover, degree of habitat disturbance of the site where the seed matures.

Low germination percentage as well as long time requirement is believed due to the hard seed coat and thick fleshy pulp of fruits. A considerable body of evidences suggested that germination of seeds with hard seed coat is enhanced by pre-sowing treatments (Palani, *et al*., 1996). If untreated, the seeds germinate slowly and irregularly. This delayed and irregular germination of seeds in the nursery is a serious constraint of efficient nursery management and plantation establishment. Though reports on the pre-sowing and breaking dormancy treatment of other species are available, the information on *T. chebula* is inadequate and scanty. The objective of the present investigation was to understand the nature of 7 dormancy and to determine treatments that promote

maximum germination and the effect of various treatments in breaking the dormancy and to draw conclusions in order to combat with the problem of natural regeneration the species is facing over a period of time.

## Materials and Methods

### Study site

The study was conducted in the laboratory and field/ garden of Doon (P.G.) College of Agriculture Science and Technology, Dehradun (U.K.), India. The experimental site lies approximately at $36^0$21'44" N Latitude and $77^0$5'12" E Longitude at 516.5 m above mean sea level. The climate at experimental area is subtropical with hot summer and cool winter with a wide variation in the mean maximum and mean minimum temperature. The meteorological data indicate that the monthly temperature varies from $14.8^0$C-$38.0^0$C during July. December to mid February is the coldest month and mid June is the hottest month. The area receives good rainfall (1700-2000 mm) annually, 80% mostly from south west monsoon during June-Sept and about 20% in winter.

### Fruit/Seed collection areas

In the present study, the fruits/seeds were collected from the natural areas *i.e.* Himachal Pradesh, Uttarakhand, Uttar Pradesh and West Bengal (table 1).

### Morphological variation studies

### Fruit

The fruits were measured for number of fruits in 1 kg, fruit length and diameter, weight of 100 fruits, colour, and length/diameter ratio.

**Table 1 :** Geographic origin of the investigated population.

| S. no. | Place of collection | Accession | Symbols used |
|---|---|---|---|
| 1. | Himachal Pradesh | Sirmour | P1 |
| | | Una | P2 |
| | | Hamirpur | P3 |
| 2. | Uttarakhand | Timli Forest Range | P4 |
| | | Rudraprayag | P5 |
| | | Bageshwar | P6 |
| 3. | Uttar Pradesh | Saharanpur Forest Division | P7 |
| | | Rohilkhand Forest Division | P8 |
| | | Sonebhadra | P9 |
| 4. | West Bengal | Muraghat Range | P10 |
| | | Sambalpur | P11 |
| | | Nilpara Range | P12 |

### Seed

For seed measurement, the same procedure was followed as for the fruit measurement, except colour which was almost same for the entire seed source. Seeds were measured for seed length and diameter thickness, weight of 100 seeds and Seed length/diameter ratio.

### Germination studies

The seed germination study of *Terminalia chebula* was carried out in open laboratory conditions in Department of Forestry, Doon (PG) College of Agriculture Science and Technology, Selaqui, Dehradun at $30^o$C±$2^o$C temperature. Seeds of this species were collected from different provenances and different pre-treatments were applied to assess the possibility of increasing the germination rate (table 2). For seed germination studies, 400 seeds per treatment (table 1) were taken (4 replicate of 100 seeds each) and sown in plastic trays and were kept under room temperature $30^o$C±$2^o$C in laboratory. The seeds were surface sterilized (0.01% w/v) with Mercuric chloride solution (was prepared by 0.1 gm of mercuric chloride in 100 ml of distilled water) to avoid fungal attack during experiment. Different seed studies carried out during this investigation were:

### Imbibition period, germination period, germination percentage, germination value and germination energy

**Germination period :** It is an expression of time between the first germination and the end of germination (GP).

**Germination percent :** Germination percent was recorded by the formula:

Germination percent = Seed germinated / Total seed sown × 100

**Germination value :** Germination value is the index combined speed and completeness of seed germination. Daily germination counts were recorded and calculated as per the method given by Czabator (1962).

GV = PV × MDG

Where, PV = Peak value of germination, MDG = Mean daily germination.

**Germination energy :** Germination energy (GE) was calculated on the basis of percentage of total number of seed that had germinated when germination reached its peak.

GE = Number of seed germinated up to the time of peak germination / total number of seed sown × 100

**Table 2 :** Different pre-treatments provided to seeds of *Terminalia chebula*.

| S. no. | Treatment |
|---|---|
| $T_0$ | Control (intact fruits without depulping and soaking) |
| $T_1$ | Fruits were depulped but were not soaked in water |
| $T_2$ | Fruits were depulped and soaked in cold water for 12 hours |
| $T_3$ | Fruits were depulped and soaked in cold water for 24 hours |
| $T_4$ | Fruits were depulped and soaked in cold water for 48 hours |
| $T_5$ | Fruits were depulped and soaked in hot water (80°C to 100° C) for 2 minutes and were immediately washed in cold water. |

## Results and Discussion

### Fruit

For number of fruits per kilogram, maximum (290.34) number of fruits were recorded in one kilogram collected from P7 seed source provenance followed by (284.27) number of fruits collected from P8 provenance and minimum (274.46) number of fruits were recorded in one kilogram collected from P6 seed source/ provenance. As regards of fruit length and fruit diameter, maximum fruit length (4.71 cm) and fruit diameter (1.54 cm) were recorded from provenance (P4) collected from Uttarakhand followed by (4.35 cm) fruit length and (1.45 cm) fruit diameter in provenance P7 collected from Uttar Pradesh while, minimum fruit length (3.33 cm) were recorded in provenance P1 collected from Himachal Pradesh (3.33 cm). Maximum (1.54 cm) fruit diameter was recorded in provenance P4 while as, minimum (1.13 cm) fruit diameter were recorded in provenance P12 collected from West Bengal.

### Seed

Regarding number of seeds per kilogram, maximum (784.99) number of seeds were recorded in one kilogram in provenance P7 seeds collected from Uttar Pradesh followed by (774.04) number of seeds collected in one kilogram collected from Himachal Pradesh provenance (P2) and minimum (713.36) number of seeds were recorded in one kilogram collected from West Bengal seed source/ provenance (P11). As regards seed length and seed diameter, maximum seed length (4.19 cm) and seed diameter (1.25 cm) were recorded in provenance (P4) collected from Uttarakhand followed by (4.11 cm) seed length in provenance (P1) collected from Himachal Pradesh and (1.12 cm) seed diameter were observed in provenance (P3) also collected from Himachal Pradesh while, minimum seed length (3.33 cm) were recorded in provenance (P12) collected from West Bengal and (0.84 cm) seed diameter also collected from West Bengal provenance (P12). Maximum (4.35 cm) length/diameter ratio was also observed from provenance (P4) collected from Uttarakhand and minimum (2.92 cm) were recorded in provenance (P3) also collected from Uttarakhand.

Variation among seed population with respect to seed dimension (length and breadth) and weight have earlier been reported in many species including *Cordia africana* (Loha *et al*., 2006); *Pinus roxbrughii* (Ghildiyal *et al*., 2009), *Dalbergia melanoxylon* (Amri *et al*., 2008) and *C. australis* (Singh *et al*., 2006b). Significant differences

**Table 3 :** Different fruit parameters of *Terminalia chebula*.

| Seed source/ provenance | No. of fruits /kg | Fruit length (cm) | Fruit diameter (cm) | Weight of 100 fruits (g) | Colour | Length/diameter ratio |
|---|---|---|---|---|---|---|
| P1 | 277.60 | 3.33± 0.12 | 1.38± 0.02 | 360.22±2.04 | yellow | 2.41± 0.02 |
| P2 | 280.64 | 3.89± 0.09 | 1.32± 0.02 | 356.32±1.97 | Yellow brown | 2.95± 0.02 |
| P3 | 276.09 | 3.79± 0.07 | 1.41± 0.02 | 362.21±2.05 | Yellow | 2.69± 0.02 |
| P4 | 276.04 | 4.71± 0.08 | 1.54± 0.02 | 362.26±2.05 | greenish yellow | 3.06± 0.02 |
| P5 | 278.30 | 4.34± 0.09 | 1.32± 0.02 | 359.32±2.06 | greenish yellow | 3.29± 0.02 |
| P6 | 274.46 | 4.23± 0.10 | 1.40± 0.01 | 365.44±2.12 | Orange brown | 3.02± 0.02 |
| P7 | 290.34 | 4.35± 0.13 | 1.45± 0.01 | 346.56±1.84 | Yellow | 3.27± 0.02 |
| P8 | 284.27 | 4.28± 0.14 | 1.21± 0.01 | 354.26±1.94 | yellow | 3.54± 0.02 |
| P9 | 280.09 | 4.19± 0.12 | 1.25± 0.01 | 358.54±2.02 | Yellow brown | 3.35± 0.02 |
| P10 | 276.21 | 4.05± 0.09 | 1.23± 0.00 | 363.42±2.09 | orange | 3.29± 0.02 |
| P11 | 281.54 | 3.98± 0.03 | 1.17± 0.00 | 356.56±1.86 | orange | 3.40± 0.02 |
| P12 | 278.22 | 3.85± 0.01 | 1.13± 0.00 | 359.42±2.03 | Orange brown | 3.41± 0.02 |
| Significance | | *** | *** | | - | NS |

NS = Non Significant, *** = Significant at 0.5%.

**Table 4 :** Different seed parameters of *Terminalia chebula*.

| Seed source/ provenance | No. of seeds /kg | Seed length (cm) | Seed diameter (cm) | Weight of 100 seeds (g) | Length/diameter ratio |
|---|---|---|---|---|---|
| P1 | 751.03 | 4.11± 0.21 | 1.09± 0.05 | 133.15±1.37 | 4.08± 0.09 |
| P2 | 774.04 | 3.37± 0.23 | 1.03± 0.05 | 129.20±1.04 | 3.27± 0.11 |
| P3 | 755.74 | 3.27± 0.20 | 1.12± 0.05 | 132.32±1.93 | 2.92± 0.08 |
| P4 | 718.33 | 4.19± 0.19 | 1.25± 0.05 | 139.21±2.05 | 4.35± 0.12 |
| P5 | 755.11 | 3.82± 0.17 | 1.03± 0.04 | 132.43±1.26 | 3.71± 0.07 |
| P6 | 728.54 | 3.71± 0.21 | 1.11± 0.04 | 137.26±1.31 | 3.34± 0.09 |
| P7 | 784.99 | 3.83± 0.15 | 1.04± 0.04 | 127.39±1.02 | 3.68± 0.09 |
| P8 | 773.30 | 3.76± 0.17 | 0.92± 0.04 | 126.65±1.02 | 4.09± 0.13 |
| P9 | 728.43 | 3.67± 0.12 | 0.96± 0.03 | 137.28±1.29 | 3.82± 0.11 |
| P10 | 717.56 | 3.53± 0.11 | 0.94± 0.04 | 139.36±1.36 | 3.76± 0.08 |
| P11 | 713.36 | 3.46± 0.13 | 0.88± 0.02 | 140.18±2.02 | 3.93± 0.08 |
| P12 | 734.17 | 3.33± 0.13 | 0.84± 0.02 | 1.36.21±1.39 | 3.96± 0.09 |
| Significance | | *** | *** | *** | NS |

NS = Non Significant, *** = Significant at 0.5%.

**Table 5 :** Different pre-sowing treatments provided to *T. chebula* under laboratory conditions.

| S. no. | Treatment |
|---|---|
| $T_0$ | Control (intact fruits without depulping and soaking) |
| $T_1$ | Fruits were depulped but were not soaked in water |
| $T_2$ | Fruits were depulped and soaked in cold water for 12 hours |
| $T_3$ | Fruits were depulped and soaked in cold water for 24 hours |
| $T_4$ | Fruits were depulped and soaked in cold water for 48 hours |
| $T_5$ | Fruits were depulped and soaked in hot water (80° C to 100° C) for 2 minutes and were immediately washed in cold water. |

between populations of *Trigonobalanus doichangensis* were also observed in seed length and seedling morphological characters (Zheng *et al*., 2009). Singh and Bhatt (2008) found similar results in *Dalbergia sissoo* with great variation in seed length and seed breadth. Significant variation was also found in seed weight and has also been reported in *Albizia chinensis* (Dhanai *et al*., 2003); *Grewia optiva* (Uniyal *et al*., 2003) and *Celtis australis* (Singh *et al*., 2006a).

## Germination

The seeds were surface sterilized (0.01%) with Mercuric chloride solution to avoid fungal attack during experiment. Mercuric chloride solution was prepared by adding 0.01gm of mercuric chloride in 100 ml of distilled water.

## Imbibition period

Maximum values were recorded in $T_4$ treatment (fruits were depulped and soaked in cold water for 48 hours) in all accessions/provenances followed by $T_5$ (fruits were depulped and soaked in hot water (80°C to 100°C) for 2 minutes and were immediately washed in cold water treatment) and minimum values were recorded in $T_0$ (control-intact fruits without depulping and soaking). As regards to individual accessions maximum value of (43.67) was recorded in P1 (seeds collected from Himachal Pradesh) followed by (43.75) in P4 (seeds collected from Uttarakhand) and minimum (25.89) values were recorded in P12 (seeds collected from west Bengal).

Rashid *et al*. (1990) has shown that, whole fruits of *T. chebula*, pre-treated by soaking in water for 48 hours with successive treatment by 10% sulphuric acid for 20 minutes showed up to 70% germination. Nainar *et al*. has shown that among the seed pre-treatments including and mechanical scarification (MS), hot water treatment (with or without removing the testa) and sulfuric acid treatment (with or without breaking the testa), mechanical scarification gave the highest germination percentage (60%) in *T. chebula*. Rasebeka *et al*. (2014) observed soaking *A. tortilis* seeds in hot water also enhanced the germination. Similar results are in agreement with those of other authors who reported that immersing dry seeds of other tropical tree species in boiling water enhanced seed germination (Demel, 1998; Agboola and Etejere, 1991; Agboola and Adedire, 1998).

## Germination period

From the statistical analysis, it was revealed that the

**Table 6 :** Imbibition period of *T. chebula* seeds under different pre-sowing treatments.

| Accessions | Treatments | | | | | |
|---|---|---|---|---|---|---|
| | $T_0$ | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ |
| P1 | 28.75± 1.02 | 35.98 ± 0.02 | 33.91 ± 0.0 1 | 31.12 ± 0.01 | 43.67 ± 2.01 | 40.51± 2.37 |
| P2 | 27.15± 1.01 | 36.18 ± 0.01 | 32.90 ± 0.00 | 30.32 ± 0.01 | 42.32 ± 2.01 | 39.19± 2.17 |
| P3 | 27.05± 1.01 | 34.38 ± 0.01 | 33.77 ± 0.00 | 30.21 ± 0.01 | 42.11 ± 1.98 | 38.39± 2.10 |
| P4 | 28.65± 1.02 | 35.48 ± 0.01 | 32.49 ± 0.01 | 31.05 ± 0.01 | 43.75 ± 2.01 | 40.26± 2.29 |
| P5 | 27.32± 1.01 | 34.45 ± 0.01 | 32.19 ± 0.00 | 30.89 ± 0.01 | 41.89 ± 1.88 | 39.31± 2.07 |
| P6 | 27.33± 1.01 | 34.32 ± 0.00 | 32.22 ± 0.00 | 30.21 ± 0.00 | 43.01 ± 2.03 | 39.71± 2.11 |
| P7 | 26.41± 1.00 | 34.43 ± 0.00 | 32.32 ± 0.00 | 30.34 ± 0.00 | 42.23 ± 2.00 | 39.47± 2.00 |
| P8 | 27.65± 1.00 | 33.35 ± 0.00 | 31.41 ± 0.00 | 30.17 ± 0.00 | 42.79 ± 1.89 | 39.68± 2.02 |
| P9 | 26.68± 1.00 | 33.12 ± 0.00 | 31.64 ± 0.00 | 30.32 ± 0.00 | 41.43 ± 2.01 | 38.73± 2.07 |
| P10 | 26.82± 1.00 | 32.23 ± 0.00 | 31.29 ± 0.00 | 29.56 ± 0.00 | 42.22 ± 1.39 | 38.81± 2.00 |
| P11 | 26.94± 1.00 | 33.41 ± 0.00 | 30.37 ± 0.00 | 28.72 ± 0.00 | 41.56 ± 1.73 | 37.49± 2.13 |
| P12 | 25.89± 1.00 | 32.79 ± 0.00 | 31.30 ± 0.00 | 29.99 ± 0.00 | 40.41 ± 1.59 | 37.15± 2.17 |
| Significance | *** | *** | *** | *** | *** | *** |

NS=Non Significant, ***=Significant at 0.5%.

**Table 7 :** Total germination period (days) of *T. chebula* seeds under different pre-sowing treatments.

| Accessions | Treatments | | | | | |
|---|---|---|---|---|---|---|
| | $T_0$ | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ |
| P1 | 76.0 ± 0.0 | 53.66± 1.67 | 64.10± 0.0 | 67.00± 3.0 | 84.00 ± 5.0 | 76.0± 0.0 |
| P2 | 66.0 ± 0.0 | 51.33± 1.62 | 54.50± 0.0 | 68.75± 1.02 | 79.00± 5.0 | 75.0± 0.0 |
| P3 | 56.0 ± 0.0 | 47.66± 1.67 | 61.20± 0.0 | 57.15± 1.01 | 81.00± 5.0 | 76.0± 0.0 |
| P4 | 78.0 ± 0.0 | 59.67± 1.61 | 67.10± 0.0 | 77.05± 1.01 | 86.00 ± 5.0 | 77.0± 0.0 |
| P5 | 61.0 ± 0.0 | 50.66± 1.67 | 60.50± 0.0 | 58.65± 1.02 | 74.00 ± 5.0 | 67.0± 0.0 |
| P6 | 58.0 ± 0.0 | 52.33± 1.63 | 58.10± 0.0 | 57.32± 1.01 | 78.00 ± 5.0 | 66.0± 0.0 |
| P7 | 77.0 ± 0.0 | 53.66± 1.67 | 51.50± 0.0 | 67.33± 1.01 | 79.00 ± 5.0 | 63.0± 0.0 |
| P8 | 69.0 ± 0.0 | 45.58± 1.64 | 57.10± 0.0 | 56.41± 1.00 | 71.00 ± 5.0 | 68.0± 0.0 |
| P9 | 68.0 ± 0.0 | 49.66± 1.67 | 59.20± 0.0 | 57.65± 1.00 | 73.00 ± 5.0 | 69.0± 0.0 |
| P10 | 65.0 ± 0.0 | 47.33± 1.53 | 62.50± 0.0 | 56.68± 1.00 | 75.00 ± 5.0 | 61.0± 0.0 |
| P11 | 61.0 ± 0.0 | 43.45± 1.67 | 61.30± 0.0 | 56.82± 1.00 | 64.00 ± 5.0 | 67.0± 0.0 |
| P12 | 51.0 ± 0.0 | 41.66± 1.61 | 56.50± 0.0 | 56.94± 1.00 | 62.00 ± 5.0 | 59.0± 0.0 |
| Significance | *** | *** | *** | *** | *** | *** |

NS = Non Significant, *** = Significant at 0.5%.

effect of various pre-sowing treatments was highly significant with relation to germination period in all the accessions (table 7). Maximum values (germination period) were recorded in $T_4$ treatment (fruits were depulped and soaked in cold water for 48 hours) in all accessions followed by $T_5$ (fruits were depulped and soaked in hot water (80°C to 100°C) for 2 minutes and were immediately washed in cold water treatment) and minimum values were recorded in $T_0$ (control (intact fruits without depulping and soaking). As regards to individual accessions maximum value of (86.00) was recorded in P4 (seeds collected from Uttarakhand) followed by (84.00) in P1 (seeds collected from Himachal Pradesh) and minimum (41.66) values were recorded in P12 (seeds collected from West Bengal).

Olmez (2011), Gupta *et al*. (1997), Bhuse *et al*. (2001) reported in *Hippophae rhamnoides*, *Glycyrrhiza glabra*, *Cassia angustifolia*, respectively the effect of pre-treatments for decreasing germination period. On the other hand, Bharatkumar *et al*. (1985) could not find any improvement in germination of *Catharanthus roseus* seeds due to pre-soaking treatments for different periods.

Meyer *et al*. (1989) also documented correlation variation of germination rate for *Artimisia tridantata* and

**Table 8 :** Germination percentage of *T. chebula* seeds under different pre-sowing treatments.

| Accessions | Treatments | | | | | |
|---|---|---|---|---|---|---|
| | $T_0$ | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ |
| P1 | 48.90± 2.22 | 56.17± 5.77 | 58.90± 4.0 | 60.10± 1.92 | 66.70± 2.02 | 50.10± 6.75 |
| P2 | 46.39± 2.22 | 55.70± 5.77 | 59.79± 4.0 | 58.00± 1.92 | 65.50± 2.02 | 48.10± 6.75 |
| P3 | 45.15± 2.22 | 53.27± 5.77 | 58.19± 4.0 | 60.30± 1.92 | 62.30± 2.02 | 46.10± 6.75 |
| P4 | 52.21± 2.22 | 58.78± 5.77 | 61.29± 4.0 | 63.10± 1.92 | 68.70± 2.02 | 53.10± 6.75 |
| P5 | 44.26± 2.22 | 50.71± 5.77 | 56.39± 4.0 | 57.60± 1.92 | 65.40± 2.02 | 46.10± 6.75 |
| P6 | 41.28± 2.22 | 55.76± 5.77 | 55.90± 4.0 | 55.00± 1.92 | 61.30± 2.02 | 45.10± 6.75 |
| P7 | 37.19± 2.22 | 51.37± 5.77 | 53.45± 4.0 | 51.50± 1.92 | 65.10± 2.02 | 42.10± 6.75 |
| P8 | 37.90± 2.22 | 50.74± 5.77 | 51.51± 4.0 | 56.00± 1.92 | 63.50± 2.02 | 41.10± 6.75 |
| P9 | 38.69± 2.22 | 46.37± 5.77 | 50.59± 4.0 | 54.20± 1.92 | 63.20± 2.02 | 45.10± 6.75 |
| P10 | 40.19± 2.22 | 49.87± 5.77 | 49.38± 4.0 | 59.10± 1.92 | 61.50± 2.02 | 47.10± 6.75 |
| P11 | 39.45± 2.22 | 48.71± 5.77 | 47.32± 4.0 | 53.00± 1.92 | 59.10± 2.02 | 40.10± 6.75 |
| P12 | 38.63± 2.22 | 46.75± 5.77 | 45.41± 4.0 | 52.50± 1.92 | 56.40± 2.02 | 39.10± 6.75 |
| Significance | *** | *** | *** | *** | *** | *** |

NS=Non Significant, ***=Significant at 0.5%.

**Table 9 :** Germination value of *T. chebula* seeds under different pre-sowing treatments.

| Accessions | Treatments | | | | | |
|---|---|---|---|---|---|---|
| | $T_0$ | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ |
| P1 | 1.65 | 4.21 | 4.18 | 3.98 | 4.41 | 0.9 |
| P2 | 1.56 | 4.16 | 4.14 | 3.78 | 4.21 | 0.8 |
| P3 | 1.44 | 4.11 | 4.10 | 3.81 | 4.11 | 0.8 |
| P4 | 1.48 | 4.05 | 4.09 | 3.76 | 4.34 | 0.7 |
| P5 | 1.52 | 4.01 | 4.16 | 3.54 | 4.21 | 0.7 |
| P6 | 1.58 | 4.13 | 4.11 | 3.35 | 4.34 | 0.8 |
| P7 | 1.39 | 4.19 | 3.65 | 3.21 | 4.05 | 0.6 |
| P8 | 1.46 | 3.89 | 3.84 | 3.14 | 4.23 | 0.7 |
| P9 | 1.39 | 3.67 | 3.51 | 3.11 | 4.22 | 0.6 |
| P10 | 1.37 | 3.54 | 3.32 | 3.04 | 3.61 | 0.5 |
| P11 | 1.32 | 3.49 | 3.24 | 3.01 | 3.85 | 0.5 |
| P12 | 1.21 | 3.41 | 3.11 | 2.99 | 3.87 | 0.4 |
| Significance | *** | *** | NS | *** | *** | *** |

NS=Non Significant, ***=Significant at 0.5%

*Chrysothamus nauseosus* and Uniyal (1998) revealed that germination parameters of *Grewia optiva* may change from provenance to provenance and it may be due to the variation in seed size and weight among the seed source. However, Mugasha and Msanga (1987) recorded highest germination value (0.82) on the germination of seed of *Maesopsis eminii* Engl.

**Germination percentage**

Maximum values of germination percentage were recorded in $T_4$ treatment (fruits were depulped and soaked in cold water for 48 hours) in all accessions followed by $T_3$ (fruits were depulped and soaked in hot water (80°C to 100°C) for 2 minutes and were immediately washed in cold water) and minimum values were recorded in $T_0$ (control) [intact fruits without depulping and soaking]. As regards to individual accessions same trend was observed in germination percentage as found in imbibition period and germination period. Maximum germination percentage of (68.70) were recorded in P4 (seeds collected from Uttarakhand) followed by (66.70) in P1 (seeds collected from Himachal Pradesh) and minimum (37.19) germination percentage was recorded in P7 (that is seeds collected from Uttar Pradesh).

Geetika and Chauhan (2013) studied the effects of a number of pre-sowing treatments in improving the germination of *Cassia tora* and observed highly significant differences between the different germination treatments. Meyer *et al*. (1989) also documented correlation variation germination rate for *Artimisia tridantata* and *Chrysothamus nauseosus* and Mugasha and Msanga (1987) recorded highest germination per cent (77%) and germination value (0.82) on the germination of seeds of *Maesopsis eminii* Engl. In addition, Al-Menaie *et al.* (2010) who observed that treated seeds of *Cassia fistula* with $H_2SO_4$ scarification followed by dropping in hot water at 50°C resulted in higher germination percentage. On other hand, Aduradola and Adejomo (2005) reported that reduced germination percentage for *Erythronphleum suaveolens* seeds soaked in concentrated $H_2SO_4$ and attributed it to probable destruction of the embryo by the acid.

**Table 10 :** Germination energy of *T. chebula* seeds under different pre-sowing treatments.

| Accessions | Treatments | | | | | |
|---|---|---|---|---|---|---|
| | $T_0$ | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ |
| P1 | 48.9 | 53.9 | 53.6 | 50.7 | 58.9 | 41.1 |
| P2 | 47.2 | 52.0 | 52.2 | 48.4 | 56.0 | 40.8 |
| P3 | 47.8 | 50.0 | 51.3 | 47.0 | 57.4 | 37.1 |
| P4 | 46.1 | 51.2 | 52.7 | 44.7 | 58.6 | 37.8 |
| P5 | 44.6 | 53.0 | 52.3 | 50.3 | 55.4 | 34.1 |
| P6 | 45.5 | 52.0 | 50.0 | 49.0 | 58.3 | 32.3 |
| P7 | 45.3 | 51.5 | 50.6 | 50.1 | 53.0 | 30.1 |
| P8 | 44.2 | 50.0 | 51.3 | 49.5 | 58.1 | 31.0 |
| P9 | 43.4 | 51.1 | 52.2 | 47.0 | 54.0 | 32.1 |
| P10 | 42.5 | 48.0 | 50.30 | 50.6 | 53.1 | 34.3 |
| P11 | 40.3 | 45.0 | 48.3 | 45.0 | 51.6 | 37.1 |
| P12 | 40.8 | 42.4 | 45.9 | 43.2 | 50.0 | 35.8 |
| Significance | -*** | *** | *** | *** | *** | *** |

NS=Non Significant, ***=Significant at 0.5%

### Germination value

Maximum germination values were recorded in $T_4$ treatment (fruits were depulped and soaked in cold water for 48 hours) in all accessions followed by $T_1$ (fruits were depulped, but were not soaked in water) and minimum values were recorded in $T_5$ (fruits were depulped and soaked in hot water (80°C to 100°C) for 2 minutes and were immediately washed in cold water). As regards to individual accessions, maximum value (4.41) were recorded in P1 (Himachal Pradesh) when fruits were depulped and soaked in cold water for 48 hours followed by (4.34) in P4 and P6 (Uttarakhand) from the same treatment and minimum (0.4) value was recorded in P12 in $T_5$ (fruits were depulped and soaked in hot water (80°C to 100°C) for 2 minutes and were immediately washed in cold water). Germination value is a further expression of germination energy and has been used as an integrated measure of seed quality in *Acacia nilotica* (Ginwal and Gera, 2000) and *Terminalia ivorensis* (Okoro, 1976). Mahendru (1936) concluded that coniferous seed had the poorest germination capacity (about 25%).

### Germination energy

Maximum values were recorded in $T_4$ treatment (fruits were depulped and soaked in cold water for 48 hours) in all accessions followed by $T_1$ (fruits were depulped, but were not soaked in water) and minimum values were recorded in $T_5$ [fruits were depulped and soaked in hot water (80°C to 100°C) for 2 minutes and were immediately washed in cold water]. As regards to individual accessions, maximum value (58.9) was recorded in P1 (seeds collected from Himachal Pradesh) when treated with $T_4$ (fruits were depulped and soaked in cold water for 48 hours) followed by (58.6) in P4 (seeds collected from Uttarakhand) from the same treatment and minimum (30.1) values were recorded in P7 (seeds collected from Uttar Pradesh) in $T_5$ (fruits were depulped and soaked in hot water (80°C to 100°C) for 2 minutes and were immediately washed in cold water). The interest in germination energy is based on the theory that only those seeds which germinate rapidly and vigorously under favourable conditions are likely to be capable of producing vigorous seedling in field conditions, whereas weak or delayed germination is often fatal and the result of the present study strongly supports it. Germination values varied considerably among seed sources and exhibited a random pattern, which is an index of combining speed and completeness of germination and itself is a function of seed size and weight (Czabator, 1962) and (Dunlop and Barnett, 1983).

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