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# Seed source and habitat variation affect seed germination in *Oroxylum indicum* (L.) Benth. ex Kurz: An important threatened medicinal tree

Chandrima Debi[1] and Vipin Parkash[2*]

[1] Ph. D. Scholar, [2] Scientist-D, Rain Forest Research Institute, AT Road, Sotai, Post Box No. 136, Jorhat-785001, Assam, INDIA

chandrimasl2011@gmail.com, bhardwajvpnpark@rediffmail.com

**ABSTRACT:**

*Oroxylum indicum* is an important medicinal plant of Indian Ayurvedic medicine system. The natural population of the plant is nearing to its threshold of extinction. Therefore, its conservation is must and on this aspect an experiment was performed to see the effect of different seed sources and habitats under a single eco-region of Brahmaputra Valley *i.e.* semi- evergreen forests of Assam on its seed germination by common and feasible natural germination methods. It is found that number of seeds per gram were more (25.66±1.45) in Nalbari seed source than rest of the locations but the seed germination percentage was low or minimum (25-50%) in this seed source and even the seeds were infected with intact seed fungus like *Curvularia* species while the seed source of North Lakhimpur had maximum seed germination percentage (70-100%) in all the studied treatments followed by Guwahati seed source. The Seedling Emergence Index (SEI) was high (1.0±0.45) in Nalbari seed source whereas minimum (0.00058±0.047) in North Lakhimpur seed source. The more the Seedling Emergence index value, the poorer is the seed germination percentage.

**Key words:** Conservation, habitat, *Oroxylum indicum*, seed germination, seed sources

## INTRODUCTION

*Oroxylum indicum* (L.) Benth. ex Kurz vernacularly known as *'Shyonaka'* or *'Sonpatha'*, '*Bhatghila'* in Assamese, belonging to the family *Bignoniaceae* is a small to medium size deciduous tree with large, flat, sword shape capsular fruits of many flat and papery seeds with broad silver wings [1]. The plant is used in many Ayurvedic preparations like, *Shyonakapatpak and Bruhatpanchamulayadikwath*, *Dashmula* and *Chyawanprash, Rasayana, Amratarista, Dantyarista, Dhanwantara, Ghrita, Narayana Taila* etc., [2],[3]. *O. indicum* is an indigenous tree of the Indian subcontinent, distributed throughout the country up to an altitude of 1200m [4]. It is distributed in Himalayan foothills, Eastern and Western Ghats and North East India [5]. It is located mainly in ravines, in damp region and moist places in the forests [6].

The plant usually flowers in the month of June-July and bears fruits in November-December. This tree has long pods that dangle from the branches. When the pod bursts open the seeds flutter to the ground, often travelling some distance, looking like butterflies [7]. The seeds are propagated by wind, which germinate by the beginning of the rainy season. The seeds can easily be recognized as the rather small, kidney shaped seeds are surrounded by a light brown, papery wing up to 5 cm in diameter [8]. The seeds are flat and winged with exalbuminous capsules which are arranged in sheets inside the pods. The seeds *of Oroxylum indicum* have immense therapeutical and ethno botanical uses. Dried seed powder is used by women to induce conception in ethnic communities. Seeds of *O. indicum* are used as purgative [9].

The germination of the seeds is a complex process where several reactions and individual factors are involved [10]. According to the literature review it was found that the seeds of *Oroxylum indicum* have poor seed setting and low seed viability [11], [12]. Destructive and non-sustainable collection methods coupled with low regeneration and habitat destruction have caused serious threat to the survival and availability of this highly useful tree [13]. Seed germination studies on *O. indicum* have been carried out by some of the following researchers. Tiwari *et al.* [14] developed a method to regenerate plant seedlings from callus cultures of nodal segments. Gokhale and Bansal [15] developed a protocol for micro propagation of *O. indicum* where seeds were germinated *in vitro* and the apical and axillary buds were inoculated under aseptic conditions on MS sterile culture medium. Pande and Gupta [16] studied on the role seed mycoflora on seed germination of *O. indicum* and impact of osmotic stress on the seed germination and seedling growth of *O.indicum*. Effect of temperature and plant growth regulators on seed germination response of *O. indicum* was studied by Singh *et al.* [17].

Studies on the effect of different seed sources on germination parameters have been studied by various researchers on various tree species like *Pinus wallachiana*, *Santalum album*, *Tamarindus indica*, *Hippophae salicifolia*, *Vateria indica* L., *Acacia catechu* and *Elaeocarpus floribundus* species etc. [18], [19], [20], [21], [22], [23]. However, the study of different seed sources effect on the germination of *O. indicum* has not been studied so far by any researcher. Bhat and Chauhan [24] and Mamo *et al.* [25] have also reported that seed source variation tests are necessary to select dominant seed source for plantation for higher productivity. So the present study was taken on this objective to see the effect of source variation on seed germination of *O. indicum* and simultaneously developing economic, cost effective and feasible method to attain quality seedling stock for the farmers interested in cultivation of *O. indicum*.

## MATERIALS AND METHODS

The pods of *Oroxylum indicum* were collected from trees showing fruiting from five different collection sites of a single eco-region (Brahmaputra Valley semi-evergreen forests), *i.e.* Jorhat, Nalbari, Guwahati, Itanagar and North Lakhimpur (see Fig.1). The location, GPS coordinates and habitat are mentioned in

Table 1. Mature pods of *O. indicum* were collected during the month of December, 2013- January, 2014 from the above mentioned study sites. Three trees from each collection site were selected randomly, where the tree is growing in its natural habitat. Three best ripen pods were collected from each tree. Seeds of *O. indicum* were selected by sorting out the healthy, uninfected seeds of almost uniform size and were stored air-tight container for further use in BOD at 27˚C ± 2˚C. The variation in external morphology of the seeds from different sources was studied (see Table 2 in Results and Discussion section). The seeds were subjected to different seed treatments to understand the variation in germinability along different seed sources. About 36 seeds from each study site were tested for their germinability test. The seeds were treated with Normal Water treatment (NW), Hot water (HW) treatment and Alcohol (Alc.) treatment and sown separately in a randomized manner in three replication in 1:1:1 ratio of sand: soil: FYM in root trainers. The root trainers were kept under shade and timely watered. The germination of the seedlings was studied *ex situ*. *In vitro* study for the germinability of seeds, radicle and plumule length were studied separately in Moist chambers as it is difficult to study the increment in radicle length in *ex situ* condition. On the basis of literature available (Food and Agriculture Association), the following seed tests were performed on seeds of each site and germination parameters were analysed.

**Normal Water Treatment (NWT)**

The seeds were treated with normal tap water for different treatment periods *viz.*, 12 hour, 24 hour and 48 hour for each treatment. The seeds were placed in glass beakers that constantly held the water at the room temperature (20-25˚C). The excess water was drained by the help of cotton rolls just before sowing of the seeds. The germination percent was determined performing the germination test [26], [27] and www.fao.org [28] (accessed during the experiment).

**Hot Water Treatment (HWT)**

The seeds were treated with hot water *i.e.* .boiling water at 100˚C for different treatment periods, *viz.*, 1 min., 5 min. and 10 min. for each treatment. The seeds were placed in a water bath that constantly held the water at the recommended temperature. After treatment, the seeds were placed immediately in cold tap water for 5 minutes to stop heating action.

**Alcohol Treatment (Alc.T)**

For Alcohol treatment the seeds were dipped in 70% alcohol for 5, 10, and 15 minutes followed by washing with running water. Before sowing, seeds were washed with running water four to five times [29].

**Moist chamber tests**

The seeds were studied for growth parameters like length of radicle and plumule. The seeds were thoroughly cleaned in distilled water and were again treated with 70% alcohol in order to sterilize seed surface followed by washing with distilled water again. The seeds were patted dry and finally placed in moist chambers for germination in BOD at temperature of 27˚C±2˚C. Moist chambers were created by placing filter papers inside petriplates and moistened with distilled water.

**Statistical analysis**

The data obtained in this study was analyzed for standard deviation and standard error of mean using the SPSS (version 18) and for figures the Microsoft Office Excel (2007) was used.

Seed germination percentage was calculated using the following formula according to ISTA rules [30]:

Germination % =Number of germinated seeds / Total number of seeds × 100

Germination associate parameters were calculated by using following formulae of Gairola *et al.* [31].

Speed of germination:-

Speed of germination was calculated by the following formula given by Czabator, [32].

Speed of germination= n1/d1+n2/d2+n3/d3+----------

Where, n = number of germinated seeds,
d= number of days.

Mean germination Time (MGT):-

Mean germination time was calculated by the formula given by Ellis and Roberts [33].

MGT = n1 x d1 + n2 x d2 + n3 x d3 + --------/ Total number of days

Where, n= number of germinated seed
d = number of days

Mean daily germination (MDG):-

Mean daily germination can be calculated by the following formula given by Czabator [32].

MDG = Total number of germinated seeds/ Total number of days

Peak Value (PV):-

Peak value was calculated by the following formula given by Czabator [32].

PV = Highest seed germinated/ Number of days

Germination Value (GV):-

Germination value was calculated by the following formula given by Czabator [32].

GV = PV × MDG

**RESULTS AND DISCUSSION**

The mature pods of *Oroxylum indicum* were collected from Jorhat (OI/JRT/01), 26˚47′05″N and 94˚17’15”E from roadside habitat, Nalbari (OI/NLB/02), 26˚27′14″N and 91˚27′30″E from riverside habitat, Guwahati (OI/GHY/03), 26˚05′52″N and 91˚47′17″E from forest fringe habitat, Itanagar, (OI/ITA/04), 27˚05′59″N and 93˚36′16″E from hill slope and North

Lakhimpur (OI/LKP/05), 26˚57′63″N and 93˚51′40″E from paddy field (see Table1).

The seeds when studied for the variation in morphological characters in different seed sources the average size varied along different seed sources. Jorhat seeds have maximum average size (29.49±1.111) while it was minimum for Nalbari seeds (17.19±1.100). Number of seeds per gram was maximum (23.66±1.453) for Nalbari seeds while it was minimum (8.33±0.881) for Itanagar seeds. The Jorhat, Guwahati and North Lakhimpur seeds do not have large variation in number of seeds per gram. The seed source from Itanagar has elongated papery wing extension. The Jorhat seed source has broad papery wing extension. The Nalbari seed source has intermediate papery wing extension with comparatively smaller cotyledon size. The Guwahati and North Lakhimpur seed sources have proportional cotyledon and wing size. (Table 2 and see Fig. 2A).

**Effect of different treatments on seed germination of *O. indicum* in Jorhat seed source**

The effect of different treatments on seed germination of *O. indicum* in Jorhat seed source (Table 3) shows that the germination parameters of the seeds of each site showed significant difference when compared with each other. When the Jorhat seed source was analysed for germination test, maximum germination percentage (100%) was found when the seeds were treated with normal water for 24 hours and hot water for 1 minute, while minimum germination percentage (50 %) was found in hot water treatment for 10 minutes and Alcohol treatment for 15 minutes. The mean germination time was maximum (13.81±0.432) for normal water 24 hours, while it was minimum (6.14±0.447) for seeds treated with alcohol for 10 minutes. The speed of germination varied between alcohol treatment 10 min (0.228±0.0088) and normal water 48 hours (0.896±0.02894). The mean daily germination varied between hot water 10 minutes (0.04±0.004) and normal water 24 hours (0.081±0.006) and hot water 1 minute (0.081±0.006). The peak value varied between (0.020±0.002) to (0.006±0.002). The germination value varied between (0.0008±0.0001) to (0.00499±0.0002).

**Effect of different treatments on seed germination of *O. indicum* in Nalbari seed source**

Nalbari seed source shows maximum germination percentage (75%) in Normal water treatment for 48 hours while minimum germination percentage 0% was found in Hot water treatment for 5 minute, 10 minutes and Alcohol treatment for 5 minutes and 15 minutes. The mean germination time was maximum (8.28±0.487) for normal water 48 hours, while it was minimum (2± 0.338) for seeds treated with hot water for 1 minute. Zero germination percentage was found in hot water treatment and Alcohol treatment for 10 minutes. The speed of germination was maximum (0.04±0.007) for hot water for 1 minute while it was minimum (0.156±0.0.018) for normal water 24 hours. The mean daily germination varied between normal water 12 hours (0.02±0.009) to and Alcohol treatment for 10 minutes (0.061±0.011). The peak value varied between (0.020±0.004) to (0.006±0.009). The germination value varied between (0.0004±0.0004) to (0.00372±0.0005) (see Table 4).

**Effect of different treatments on seed germination of *O. indicum* in Guwahati seed source**

Maximum germination percentage (100%) was found in Normal water treatment for 12 hours, 24 hours, 48 hours and Hot water treatment for 1 minute while minimum germination percentage (75%) was found in rest other treatments. The mean germination time was maximum (15.28±0.127) for normal water 24 hours, while it was minimum (7.28±0.267) for seeds treated with alcohol for 10 minutes. The speed of germination varied between Alcohol treatment for 15 minutes (0.254±0.014) and normal water 24 hours (0.981±0.018). The mean daily germination varied between Alcohol treatment for 15 minutes (0.061±0.018) and normal water 24 hours (0.081± 0.009). The peak value varied between (0.04±0) and (0.061±0.009). The germination value varied between (0.0024±0) and (0.00494±0.001) (see Table-5).

**Effect of different treatments on seed germination of *O. indicum* in Itanagar seed source**

Itanagar seed source shows maximum germination percentage (100%) in Hot water treatment for 1 minute. While minimum germination percentage (25%) was found in Hot water treatment for 10 minutes and Alcohol treatment for 15 minutes. The mean germination time was maximum (11± 0.061) in Hot water treatment for 1 minute, while it was minimum (3.57±0.057) for seeds treated with Hot water treatment for 10 minutes. The speed of germination was maximum (0.67±0.063) for normal water 24 hours while it was minimum (0.156±0.0453) for Hot water treatment for 10 minutes. The mean daily germination was minimum (0.02±0.019) in hot water for 10 minutes while it was maximum (0.081±0.021) in hot water for 1 minute. The peak value varied between (0.020±0.004) to (0.006±0.006). The germination value varied between (0.00012±0.001) to (0.00499±0.0002) (see Table 6).

**Effect of different treatments on seed germination of *O. indicum* in North Lakhimpur seed source**

North Lakhimpur seed source shows maximum germination percentage (100%) in Normal water treatment for 12 hours, 24 hours, 48 hours and Hot water treatment for 1 minute, 5 minutes and 10 minutes while minimum germination percentage (75%) was found in rest other treatments. The mean germination time was maximum (15±1.097) for normal water 48 hours, while it was minimum (6.71±0.787) for seeds treated with Alcohol for 5 minutes. The speed of germination was minimum (0.201±0.059) for Alcohol treatment for 5 minutes and maximum

(0.91±0.087) for normal water 48 hours. The mean daily germination varied from (0.081±0.011) hot water for 10 minutes to Alcohol treatment for 5 minutes (0.061±0.010). The peak value varied between (0.061±0.010) to (0.04±0). The germination value varied between (0.0024±0.0004) to (0.00494±0.001) (see Table 7).

**Moist Chamber tests**

In a separate set of experiment, the seed sources were observed under moist chambers for germinability and plumule and radicle length and data were recorded. The average plumule to radicle ratio varied along different seed sources.

The Seedling Emergence Index was derived for each seed source. The Seedling Emergence Index can be calculated by dividing the plumule to radicle ratio by plumule length. From the observation below it was found that, North Lakhimpur seed source has minimum Seedling Emergence index (0.00058±0.047), while Nalbari seed source has maximum Seedling Emergence index (1±1.452) (see Table 8). The more the Seedling Emergence index value, the poorer is the seed germination percentage.

The viability aspect did not affect on germination parameters in the experiment as the pods were freshly harvested and experimented, which has also been discussed by Brand *et al*., [34]. The time taken for the germination to complete is also variable in different cases [35-37].

The variability of seed germination depends on microclimate, local environmental conditions and plant population in the growing area, the age of mother tree and its habitat which may influence in the production of fertile seeds [38], [39], [40].

The *ex situ* germination test showed that North Lakhimpur seed source had higher seed germination percentage followed by Guwahati seed source. Quality seedlings can be produced from quality seed stock. Seed germination tests are considered essential for increasing production and survival and seedling growth [41].There are many factors controlling the germinability of the seeds. The differences in the germination parameters could be due to the geographically distinct local environmental conditions, diversity of edapho-climatic conditions, altitude, precipitation etc which otherwise, effect the genetic constitution of the species of the seed sources [42-46].

During the study it was found that there was variation in external morphology of the seeds of *Oroxylum indicum* collected from each study site (see Fig. 2A). The flaky flattened seeds are arranged in the form of sheets longitudinally inside the pods. The cotyledons are enclosed inside thin capsules which extend to form broad papery wings. There is a suture line which runs along the middle of the cotyledons. The size of the cotyledons also varies, it was found through observation that bigger the cotyledon size higher is the germination percentage. Proportional size of the cotyledon and winged extension showed higher germination percentage. The suture line present in the seed runs along sides.

There are various other factors effecting the germination of *O. indicum*. As reported by Shankar and Tripathi [47] *O. indicum* is sparsely distributed in nature. The pollination in this tree species is naturally carried by bat species viz. *Eonycteris spelaea* and *Leschenault's rousette* [48]. Due to the sparse population the lack of pollen germination, reduced fertilization, difference in time of fertilization and competition for maternal resources within a pod [49], [50] may result in seed abortion [51]. Seed abortion and fungal decay may be the factors affecting the germination percentage of Nalbari seed source (Figs. 2B&C).

When the seeds were planted in nature they showed zero germination percentage. Similar report has been given by Shankar and Tripathi [52], where, new seedlings in nature are very rarely found. The reason may be due to longer duration of rainy season causing water logging and rotting of seeds.

During seed germination tests it was found that the Nalbari seed source showed minimum germination percentage when kept for observation under moist chambers. The seeds were infected by *Curvularia* species which is found intact inside the seed system and might be the causable agent for hindering the seed germination. The ecological and geographical location of the seed sources of *Oroxylum indicum* might be responsible for the fungus to thrive. Pande and Gupta [16] also reported that seeds and seedlings of *O. indicum* are highly susceptible to fungal decay which may be the causable agent to cause decay of the seed.

During study, it was also found that the juvenile seedlings require sufficient water supply for their survival. *O. indicum* belongs to moist deciduous climate region. High rate of transpiration and profound root system are collectively responsible for creating stress in the seedlings if not watered adequately. The seedlings should be kept under shade to attain maturity. Quality seedling stocks should be first raised in nursery and further transplanted in the field.

*Oroxylum indicum* is a valuable medicinal tree species of immense importance. In order to meet the increasing market demands, overexploitation of the tree as a whole has created the danger of extinction of this valuable tree species. Large scale plantation of this tree is the need of the hour to protect this tree from further extinction.

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**Table 1. Location, GPS coordinates and habitat of different seed sources of *Oroxylum indicum***

| Accession Number | Location (seed source) | GPS coordinates | Habitat |
|---|---|---|---|
| OI/JRT/01 | Jorhat (Assam) | 26°47′05″N; 94°17′15″E | Roadside |
| OI/NLB/02 | Nalbari (Assam) | 26°27′14″N; 91°27′30″E | Riverside |
| OI/GHY/03 | Guwahati (Assam) | 26°05′52″N; 91°47′17″E | Forest Fringe |
| OI/ITA/04 | Itanagar (Arunachal Pradesh) | 27°05′59″N; 93°36′16”E | Hill Slope |
| OI/LKP/05 | North Lakhimpur (Assam) | 26°57′63″N; 93°51′40″E | Paddy Field |

**Table 2. Variation in morphological characters of *O.indicum* seeds in different seed sources**

| Seed source | Average length(cm) | Average breadth(cm) | Average length × breadth | Colour | Shape | No. of seeds per gram |
|---|---|---|---|---|---|---|
| Jorhat | 6.86 ± 0.1568 | 4.3 ± 0.0949 | 29.49 ± 1.111 | Pearly white | Broad flattened | 12.1±0.577 |
| Nalbari | 5.18 ± 0.102 | 3.32 ± 0.159 | 17.19 ± 1.100 | Dirty white | Round Flattened | 23.66± 1.453 |
| Guwahati | 6.58 ± 0.201 | 3.36 ± 0.092 | 22.1 ± 1.062 | Silky white | Round Flattened | 11.33±1.201 |
| Itanagar | 6.84 ± 0.124 | 3.62 ± 0.037 | 24.7 ± 0.556 | Creamish white | Elongated Flattened | 8.33±0.881 |
| North Lakhimpur | 5.54 ± 0.074 | 3.6 ± 0.104 | 19.9 ± 0.670 | Silky white | Round Flattened | 14±1.154 |

**Table 3. Effect of different treatments on seed germination of *O. indicum* in Jorhat seed sources**

| Treatment | Speed of Germination | MGT | MDG | Peak Value | Germination Value | Germination Percentage |
|---|---|---|---|---|---|---|
| NWT-12hrs. | 0.487±.0131 | 8.42±0.406 | 0.061±0.006 | 0.040±0.002 | 0.00249±0.0002 | 75±2.525 |
| NWT-24hrs. | 0.779±0.0090 | 13.81±0.432 | 0.081±0.006 | 0.006±0.002 | 0.00499±0.0002 | 100±2.699 |
| NWT-48hrs. | 0.896±0.02894 | 11.5±0.386 | 0.061±0.005 | 0.040±0.002 | 0.00244±0.0002 | 75±2.464 |
| HWT-1min. | 0.529±0.0138 | 12.57±0.376 | 0.081±0.006 | 0.061±0.002 | 0.0049±0.0002 | 100±2.688 |
| HWT-5min. | 0.312±0.0133 | 7.14±0.257 | 0.061±0.004 | 0.040±0.001 | 0.0016±0.0001 | 75±1.956 |
| HWT-10min. | 0.27±0.0115 | 6.28±0.295 | 0.04±0.004 | 0.020±0.0001 | 0.0008±0.0001 | 50±2.061 |
| Alc.T- 5min | 0.249±0.0096 | 7.14±0.331 | 0.061±0.004 | 0.040±0.0001 | 0.0024±0.0001 | 75±2.061 |
| Alc.T- 10min. | 0.228±0.0088 | 6.14±0.447 | 0.04±0.005 | 0.020±0.002 | 0.0008±0.0001 | 50±2.525 |
| Alc.T-15min. | 0.492±0.0131 | 10.57±0.111 | 0.061±0.006 | 0.040±0.002 | 0.0024±0.0002 | 75±2.525 |

**Table 4. Effect of different treatments on seed germination of *O. indicum* in Nalbari seed source**

| Treatment | Speed of Germination | MGT* | MDG* | Peak Value | Germination Value | Germination Percentage |
|---|---|---|---|---|---|---|
| NWT-12hrs. | 0.156± 0.018 | 3.57±0.429 | 0.02±0.009 | 0.02±0.008 | 0.0004±0.0004 | 25±3.764 |
| NWT-24hrs. | 0.156±0.0.018 | 3.57±0.455 | 0.02±0.010 | 0.02±0.008 | 0.0004±0.0005 | 25±4.021 |
| NWT-48hrs. | 0.32±0.0389 | 8.28±0.487 | 0.061±0.011 | 0.061±0.009 | 0.00372±0.0005 | 50±4.339 |
| HWT-1min. | 0.04±0.007 | 2± 0.338 | 0.04±0.010 | 0.04±0.006 | 0.0016±0.0002 | 50±2.988 |
| HWT-5min. | 0 | 0 | 0 | 0 | 0 | 0 |
| HWT-10min. | 0 | 0 | 0 | 0 | 0 | 0 |
| Alc.T- 5min | 0 | 0 | 0 | 0 | 0 | 0 |
| Alc.T- 10min. | 0.156±0.031 | 5.85±0591 | 0.061±0.011 | 0.02±0.004 | 0.0012±0.0002 | 25±2.061 |
| Alc.T-15min. | 0 | 0 | 0 | 0 | 0 | 0 |

**Table 5. Effect of different treatments on seed germination of *O. indicum* in Guwahati seed source**

| Treatment | Speed of Germination | MGT | MDG | Peak Value | Germination Value | Germination Percentage |
|---|---|---|---|---|---|---|
| NWT-12hrs. | 0.527±0.013 | 12.57±1.092 | 0.081± 0.010 | 0.061±0.010 | 0.00494±0.001 | 100±4.981 |
| NWT-24hrs. | 0.981±0.018 | 15.28±0.127 | 0.081± 0.009 | 0.061±0.010 | 0.00494±0.001 | 100±4.891 |
| NWT-48hrs. | 0.826±0.009 | 14± 0.886 | 0.081± 0.007 | 0.061±0.009 | 0.00494±0.001 | 100±4.612 |
| HWT-1min. | 0.527±0.016 | 11.14±0.521 | 0.081± 0.019 | 0.061±0.008 | 0.0049±0.001 | 100±3.858 |
| HWT-5min. | 0.332±40.013 | 8.14±0.310 | 0.061±0.025 | 0.04±0 | 0.0024±0 | 75±0 |
| HWT-10min. | 0.332±0.013 | 8.14±0.356 | 0.061±0.027 | 0.04±0 | 0.0024±0 | 75±0 |
| Alc.T- 5min | 0.408±0.010 | 9.57±0.433 | 0.061±0.0267 | 0.04±0 | 0.0024±0 | 75±0 |
| Alc.T- 10min. | 0.301±0.016 | 7.28±0.267 | 0.061± 0.023 | 0.04±0 | 0.0024±0 | 75±0 |
| Alc.T-15min. | 0.254±0.014 | 8.28±1.092 | 0.061± 0.018 | 0.04±0 | 0.0024±0 | 75± 0 |

**Table 6. Effect of different treatments on seed germination of** *O.indicum* in Itanagar seed source

| Treatment | Speed of Germination | MGT | MDG | Peak Value | Germination Value | Germination Percentage |
|---|---|---|---|---|---|---|
| NWT-12hrs. | 0.225±0.062 | 7.57±0.055 | 0.061±0.017 | 0.061±0.006 | 0.00372±0.0014 | 75±3.620 |
| NWT-24hrs. | 0.67±0.063 | 10.42±0.059 | 0.061±0.018 | 0.061±0.005 | 0.00372±0.0014 | 75± 3.788 |
| NWT-48hrs. | 0.38±0.046 | 9.71±0.059 | 0.061±0.019 | 0.04±0.005 | 0.0024±0.0014 | 75±3.973 |
| HWT-1min. | 0.476±0.050 | 11± 0.061 | 0.081±0.021 | 0.061±0.005 | 0.0049±0.00158 | 100±4.175 |
| HWT-5min. | 0.176±0.0450 | 4.57±0.053 | 0.04±0.017 | 0.04±0.004 | 0.0016±0.0007 | 50±2.988 |
| HWT-10min. | 0.156±0.0453 | 3.57±0.057 | 0.02±0.019 | 0.02±0.004 | 0.004±0.0008 | 25±3.419 |
| Alc.T- 5min | 0.383±0.030 | 7.42±0.045 | 0.04±0.011 | 0.04±0.004 | 0.0016±0.0006 | 50±3.571 |
| Alc.T- 10min. | 0.420±0.040 | 10.28±0.063 | 0.061±0.018 | 0.04±0.005 | 0.0024±0.0008 | 75±5.050 |
| Alc.T-15min. | 0.268±0.143 | 5.85±0.0246 | 0.061±0.017 | 0.02±0.004 | 0.00012±0.001 | 25±3.149 |

**Table 7. Effect of different treatments on seed germination of *O. indicum* in North Lakhimpur seed source**

| Treatment | Speed of Germination | MGT | MDG | Peak Value | Germination Value | Germination Percentage |
|---|---|---|---|---|---|---|
| NWT-12hrs. | 0.767±0.085 | 14.85±1.093 | 0.081±0.009 | 0.061±0.010 | 0.00494±0.001 | 100±4.725 |
| NWT-24hrs. | 0.767±0.086 | 14.85± 1.105 | 0.081±0.010 | 0.061±0.010 | 0.00494±0.001 | 100±4.891 |
| NWT-48hrs. | 0.91±0.087 | 15±1.097 | 0.081±0.010 | 0.061±0.010 | 0.00494±0.001 | 100±5.052 |
| HWT-1min. | 0.767±0.068 | 14.8±1.031 | 0.081±0.010 | 0.061±0.011 | 0.0049±0.001 | 100±5.176 |
| HWT-5min. | 0.529±0.0486 | 9.14±0.841 | 0.081±0.011 | 0.061±0.011 | 0.0049±0.001 | 100±5.176 |
| HWT-10min. | 0.429±0.0496 | 11.57±0.795 | 0.081±0.011 | 0.061±0.010 | 0.0049±0.001 | 100±4.725 |
| Alc.T- 5min | 0.201±0.059 | 6.71±0.787 | 0.061±0.010 | 0.04±0 | 0.0024±0.0004 | 75±0 |
| Alc.T- 10min. | 0.456±0.009 | 10± 0.152 | 0.061±0 | 0.04±0 | 0.0024±0.00004 | 75±0 |
| Alc.T-15min. | 0.492±0.047 | 10.57±0.214 | 0.061±0 | 0.04±0 | 0.0024±0.0004 | 75±0 |

*Where MGT represents Mean Germination Time, MGD represents Mean Daily Germination

**Table 8. Seedling Emergence Index (SEI) of *O. indicum* in moist chamber test for different seed sources**

| Location/Seed source | Plumule length (cm) | Radicle length (cm) | Plumule length: Radicle length Ratio (x) | Seedling Emergence Index (x/ Plumule length ) |
|---|---|---|---|---|
| Jorhat | 1.18±0.443 | 2.24±0.390 | 0.526±0.467 | 0.277±0.209 |
| Nalbari | 0.16±0.040 | 0.16±0.040 | 1±0.452 | 1±0.452 |
| Guwahati | 2.82±0.114 | 6.02±1.050 | 0.468±0.025 | 0.219±0.025 |
| Itanagar | 2.78±0.346 | 3.12±0.307 | 0.891±0.151 | 0.795±0.032 |
| North Lakhimpur | 0.1±0.031 | 4.12±0.381 | 0.024±0.006 | 0.00058±0.047 |

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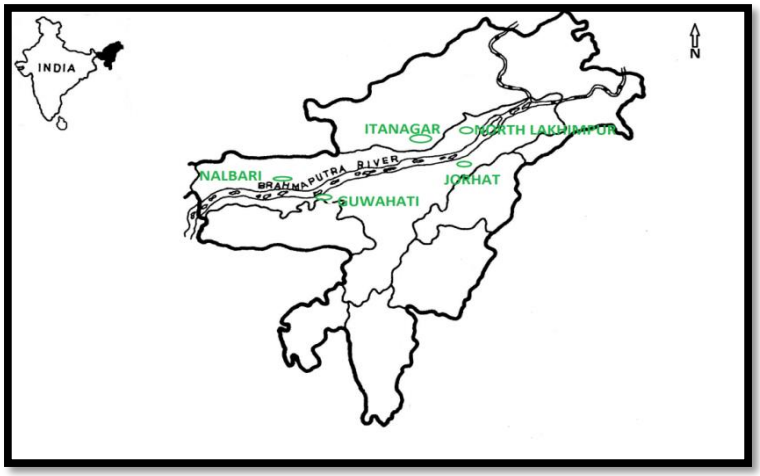


Fig. 1: Map of North-east India showing collection sites/seed sources of *Oroxylum indicum* (green circles and fonts) along the Brahmaputra Valley (semi- evergreen forests eco-region), (source: internet free public domain)

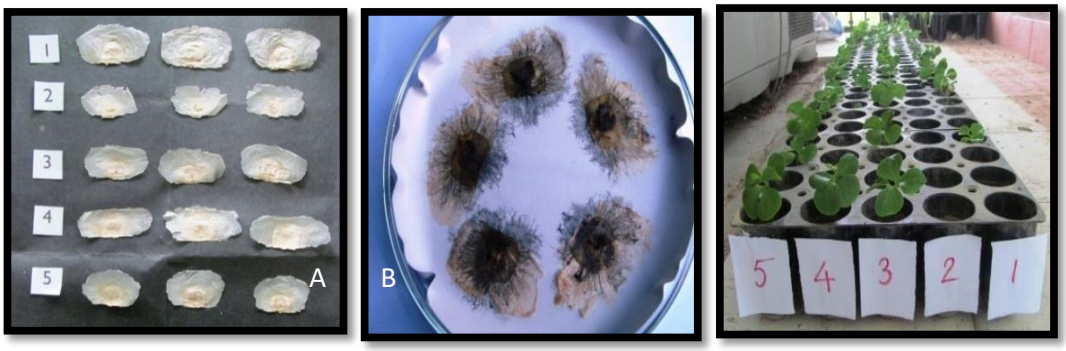


Fig. 2: A . Variation in seed morphology of *Oroxylum indicum* from different seed sources (1 –Jorhat, 2 – Nalbari, 3 – Guwahati, 4 – Itanagar, 5 - North Lakhimpur); C. Seed source variation in seed germination of *O. indicum* in root trainers; B. *Curvularia* sp. on seeds of *O. indicum* in Nalbari seed source.

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