SEED STORAGE AND VIABILITY OF *Toona ciliata* M. Roem. AND *Shorea robusta* Gaertn. f.

THESIS

BY

GURDEV CHAND

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Dr YASHWANT SINGH PARMAR
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DEDICATED

TO

MY

RESPECTED PARENTS

Dr S D Bhardwaj
Scientist (Forestry)

Deptt of Silviculture &
Agroforestry,
Dr YS Parmar University of
Horticulture and Forestry,
Solan 173 230 (HP) India

CERTIFICATE-I

This is to certify that the thesis entitled **"Seed Storage and Viability of *Toona ciliata* M. Roem. and *Shorea robusta* Gaertn. f."**, submitted in partial fulfilment of the requirements for the award of the degree of **MASTER OF SCIENCE** in **FORESTRY (Silviculture)** of Dr YS Parmar University of Horticulture and Forestry is a bonafide record of research work carried out by **Mr Gurdev Chand (F-92-2-M)** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of investigations have been fully acknowledged.

IS Bhardwaj 31.X.94

(**S D Bhardwaj**)
Major Advisor

Solan

Dated 31st October, 1994

CERTIFICATE-II

This is to certify that the thesis entitled "**Seed Storage and Viability of *Toona ciliata* M. Roem. and *Shorea robusta* Gaertn. f.**", submitted by **Mr Gurdev Chand (F-92-2-M)** to Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan in partial fulfilment of the requirements for the award of the degree of **MASTER OF SCIENCE** in **FORESTRY (Silviculture)**, has been approved by the Student's Advisory Committee after an oral examination of the same in collaboration with the Representative of the Dean.

S Bhardwaj 3.2.95

(S D Bhardwaj)
Chairman
Advisory Committee

3.2.95

(Representative of the Dean)

3/2/95

(Head of the Department)

6.2.95

(Dean of the College)

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(Gurdev Chand)

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INTRODUCTION

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INTRODUCTION

Forests are a very valuable natural yet renewable resource of a nation. Besides innumerable material benefits they confer on mankind, they make the environment of human beings pure, healthy and beautiful. The launching of people or environment oriented programmes such as social forestry and wasteland development has added new dimensions to plantation forestry. From the limited use of hardly a dozen species of high commercial or industrial value, recourse has been taken to the wide use of large number of species. This has brought about what may appropriately be called as "Seed Revolution".

Social forestry species such as *Toona ciliata, Shorea robusta, Azadirachta indica* and *Ulmus laevigata* etc. have low seed longevity.

Meliaceae

Toona ciliata M. Roem is cultivated for its timber and fuelwood values and is commonly called toon, is a large deciduous tree. It is distributed in the forests of sub-himalayan tracts and the valleys of the outer himalayas upto an elevation of 1200m. Luna (1989) pointed out that seeds of *Toona ciliata* M. Roem remain viable for one month. Seeds are very small in size and winged. Seeds of *Toona ciliata* behave as recalcitrant seeds (Nautiyal and Thapliyal, 1993).

Dipterocarpaceae

Shorea robusta Gaertn. f. is a typical dipterocarp, a dominant tree found in tropical rain forest.

The seeds are inseparable from the fruit and germinate as such. They become germinable 3 weeks before natural fall and loose viability within 10 days after maturity under ordinary conditions. Seeds of *Shorea robusta* Gaertn. f. have been put into the category of tropical recalcitrant seeds. (Bonner, 1990).

Objectives of seed storage are primarily either short-term for forestry operations or long-term for germplasm conservation. Even though seeds may be collected and used for sowing in the same year, a short period of storage cannot be avoided, and much damage can be done during this period especially if seed source has not been documented properly and seed storage has been done in a careless manner. Seeds of both these species i.e., *Toona ciliata* and *Shorea robusta* ripen in the month of June in North India, i.e., before the commencement of the monsoon. During the commencement of the monsoon, the rainfall is erratic. Development of techniques are therefore urgently required for storing seed, at least upto the time of onset of monsoon, so that seedling mortality due to drought can be checked.

To fulfill the conservation roles, seed storage life must exceed the natural interval between germination and seed production for the next generation. Most true-orthodox and many sub-orthodox seeds offer no problem, but neither recalcitrant seed class (i.e., tropical as well as temperate

recalcitrant) can meet this criterion with present technology. However, even short gains in viability retention of recalcitrant species can be useful (e.g., in transporting seed collections from remote areas to nurseries or laboratories).

Any measure which reduces the rate of respiration without otherwise damaging the seed are likely to be effective in extending longevity during storage. This is possible through the control of temperature and moisture content. The interaction between temperature and moisture is very important in storage. As a general rule, it may be said that when the temperature is low, the critical moisture content is high than when the temperature is high. Temperature also influences the absorption of moisture by the seed during storage. The respiratory process depends naturally on the moisture content in the seed. The purpose of lowering temperature during storage is precisely that of lowering respiratory activity, since this is the only way of ensuring that the seed maintains its germinative capacity for a long time.

In recent years, packaging seeds in moisture resistant containers for storage has been explored. The purpose of such containers is to maintain seed at safe storage moisture levels.

There is no available record on influence of interrelated effects of temperature and containers on the longevity of the seeds of *Toona ciliata* and *Shorea robusta*. Present investigation entitled, 'Seed Storage and Viability of *Toona ciliata* M.Roem. And *Shorea robusta* Gaertn. f.' was therefore taken up with the following objectives:

i) Evolve storage methods to prolong seed longevity

ii) To study the rate of seed deterioration with the passage of time

iii) To observe the effect of temperature on seed viability

iv) To find out suitable storage container.

It is hoped that the optimum conditions determined to prolong viability will be of immense importance in handling the seed of both the species after collection and during transportation.

Chapter-2

REVIEW OF LITERATURE

Chapter-2

REVIEW OF LITERATURE

The literature relevant to the present investigation has been reviewed under the following heads:

2.1 Storage of tree seeds

2.2 Seed storage classes

2.3 Factors affecting longevity in storage

2.3.1 Storage temperature, moisture and containers

2.3.2 Storage medium

2.1 Storage of tree seeds

Storage may be defined as the preservation of viable seeds from the time of collection, until they are required for sowing. Seed Storage is a practical necessity associated with artificial regeneration programmes which require regular and sustained seed supply. Ideally, seeds should not be stored at all, but sown in fresh condition immediately after collection. In practice, however, irregular and often infrequent seed production by many of the major forest species necessitates storage, sometimes for several years, in order to maintain supply through years of poor seed production. For general account of forest tree seed storage, there are a number of useful references (Holmes and Buszewics, 1958; Magini, 1962; Stein, Seabaugh and Plummer, 1974; Wang, 1974; Barner, 1975; Vivekanandan, 1978; Yap, 1981; Purohit, Sharma, Thapliyal, 1982; Tompsett, 1985; Maithani *et al.*, 1989).

2.2 Seed storage classes

Plant species have been divided into four groups for seed storage purposes (Bonner, 1990):

* True orthodox
* Sub-orthodox
* Temperate recalcitrant
* Tropical recalcitrant

True orthodox seeds can be stored for relatively long periods at sub-freezing temperatures, if their moisture contents are reduced to below 10 per cent. For short term storage of 5 years or less, temperatures of 0-5°C are satisfactory; for longer storage, -15°C is commonly used. Most species of economically valuable tree genera of the temperate zones are classified as orthodox: *Abies*, *Alnus*, *Betula*, *Fraxinus*, *Larix*, *Picea*, *Pinus*, *Prunus* etc. True-orthodox genera of great economic importance in the tropics include *Acacias* and many other leguminosae, *Eucalyptus*, *Casuarina* and *Gmelina*. Eliason and Heit (1973) reported 80 per cent germination in *Pinus resinosa* samples stored for 42 years. Barnett and Vozzo (1985) found that germination of *Pinus elliottii* was still 66 per cent after 50 years of storage at 4°C.

Sub-orthodox species seeds are those that can be stored under the same conditions as true-orthodox seeds but for shorter periods. Sub-orthodox species include seeds with

high lipid content (*Juglans nigra* and *Carya* species) and small seeds with thin seed coats (*Populus, Salix*). *Fagus silvatica* seeds can be stored at -10°C for 5 years with viability loss of 34 per cent (Suszka, 1975).

Temperate-recalcitrant species such as *Quercus* and *Aesculus* have seeds that cannot be dried at all, but they can be stored for several years at near-freezing temperature. 'North American species' seeds do best at 0-2°C (Bonner, 1973), while some European species can tolerate -3°C (Suszka and Tylkowski, 1980 and 1982). Because of their high moisture content, seeds in this class are very active metabolically. Even at low temperatures, germination is common during storage. By maintaining high seed moisture contents (35-40 %) and a certain amount of gas exchange, seeds of some *Quercus* species can be stored for 3-5 years at or near freezing with only moderate losses of viability (Bonner, 1973; Suszka and Tylkowski, 1980).

Seeds of Tropical-recalcitrant species have the same moisture and gas exchange requirements as the temperate recalcitrant species, but they are sensitive to low temperatures. Even short periods below 10°C will cause loss of viability (Chin and Roberts, 1980). Included in this group are many *Shorea* species, *Hopea* species and several tropical fruit trees.

2.3 Factors affecting longevity in storage

Longevity is determined by a complex of physiological and environmental factors. A seed contains an embryonic plant in a resting condition and germination is its resumption of growth. Throughout this resting stage, life processes cannot cease entirely (Barton, 1953). The loss of seed viability is largely governed by the rate of catabolism, since unlike growing plants, seeds have no means of replenishing the reserve material consumed in respiration (Anderson, 1973). Chernik (1983) reported that endosperm is apparently absent from the seeds of the Ulmaceae which could be one of the reason that can be ascribed to its extremely short viability. Anatomical studies showed that the endosperm is not absent but reduced to a single layer of cells lining the seed coat. Bewley'and Black, 1985 reported that respiration resulting in energy release and production of CO_2 and water through oxidation of carbohydrates and fats, is common to all living seeds, irrespective of their state of activity. Continuing respiration results in a decrease in dry matter content and gradual exhaustion of reserve materials. The respiration rate increases with increased moisture content and temperature and the rate of seed exhaustion is largely determined by these factors (Woodstock, Furman and Solomos, 1984).

The various factors that affect seed metabolic rate and longevity have been the subject of considerable study in

recent years and marked progress has resulted in developing efficient practical storage methods. According to Roberts (1972) most important factors for efficient storage are type of seed, its pre-storage treatment, stage of maturity, viability and moisture content when stored, the air temperature and humidity of the storage chamber and the extent of infection by fungi and bacteria. Anyone, or a combination of two or more, of these factors, may be of primary importance in determining seed longevity in a given species. Provided seed is mature and sound and of high initial viability, its life span is largely determined by environmental factors, notably temperature, humidity and storage containers (Allen, 1958).

2.3.1 Storage temperature, moisture and containers

Choice of storage temperature varies considerably according to species and the period for which the seed is to be stored. Purohit, Sharma and Thapliyal (1982), while studying the effect of storage temperatures on the viability of *Shorea robusta* seeds reported that seeds, stored at 33-36°C (Room temperature) nearly lost all viability within 11 days but at 13.5°C and 23.5°C, viability was maintained for longer. It is suggested that rapid loss of water at higher temperature (33-36°C) and near freezing (5°C) is the primary cause of loss in viability.

Tylkowski (1984) while studying the effect of storing silver maple samaras on the germinative capacity of seeds and seedling growth observed that germinative capacity of seeds is normally lost rapidly but can be maintained almost unchanged for 18 months by packing samaras into sealed bottles at an initial moisture content of 50 per cent and storing at -1°C.

Within certain limits, the effect of temperature on seed longevity of temperate recalcitrant species is similar to that of orthodox species. Some tropical species are killed by temperatures above freezing, for example, dipterocarps at temperature less than 14°C (Gordon, 1981). Tang and Tamari (1973) reported that seeds of *Hopea helferi* stored at 15°C, with high moisture content in unsealed polythene bags retained 98 per cent of viability after 37 days and 80 per cent after 60 days. Germination was much reduced if temperature was dropped to 10°C or raised to 25-28°C.

Corbineau and Come (1986) reported that in *Shorea roxburghii* seeds, there was total loss of viability after 10 days of storage at 20°C. Storage of seeds in a wet medium was difficult because of their germinating ability at low temperature. At the minimal permissible temperature seedling growth was not reduced enough to allow prolonged storage. Seeds of *Shorea Javanica* are best kept at 20°C (in an air conditioned room) at 60-66 per cent RH, or at 27°C (room

temperature) at 67 per cent RH, but not at lower RH (Umboh, 1987). Labeke and Degeyter (1989) found that seeds of *Quercus rubra* having 39.6 per cent moisture content can be stored successfully at 5°C, with only 6 per cent loss in germination percentage after 7 months.

Storage at near 40 per cent moisture content in ventilated containers at 16°C enabled survival of *Shorea roxburghii* seed for 9 months with over 50 per cent viability, whereas *Shorea almon* and *Shorea robusta* declined in viability to near 20 per cent within 14 days. A sudden loss of viability within 24 hours was observed for seed of *Shorea robusta* placed in 11 or 6°C, in the subsequent few days, little further loss of viability occurred. With 40 per cent moisture content, seed of all the species at 21°C stores as well as or better than those at lower temperature. Retention for short periods in closed containers quickly reduced germination of *Shorea robusta* and *Shorea almon* (Tompsett, 1985). *Shorea talura* retained over 50 per cent germination after storage in a closed bag at 4°C for 5 months and at 21°C for nearly 10 months (Sasaki, 1980). Panochit, Wasuwanich and Hellum, 1986 reported that seeds of *Shorea roxburghii* maintained 90 per cent germination when kept at 15°C for 56 days. Storage at 23°C did not give such good results and after storage at 2°C for 56 days, germination was only 2 percent. *Shorea ovalis* is another species which does not

withstand low temperatures (Tang and Tamari, 1973). Success has been achieved in storing *Quercus* seeds in U.S.A. by maintaining them at 35-45 percent moisture content and -1 and 3°C temperature (Bonner, 1978).

Maithani *et al.* (1989) stored *Azadirachta indica* seeds at room temperature and at 15 or 5°C in sealed and perforated polythene bags, perforated cardboard boxes and over silica gel in desiccators. Both sealed containers and low temperature (5°C) caused rapid deterioration of seeds (complete loss of germination capacity in 1-4 months), while the use of aerated containers at room temperature or 15°C inhibited deterioration so that some seeds still germinated after 6 months storage. Bonner (1973) reported that *Quercus falcata, Quercus shumardii* and *Quercus nigra* can be stored for 3 years or longer if kept at a moisture content of at least 30 per cent of fresh weight and at a temperature of 37°F. Polythene bags are good containers. Not a single acorn survived storage at 14°F. Apparently, the cloth bags failed because the acorns lost excessive moisture in low-humidity coolers. The 4-mil polythene prevented moisture loss but allowed limited gas exchange. Seeds of *Shorea siamensis* could be stored for more than 56 days in sealed plastic bags at 15°C or in folded plastic bags at 2°C (Panochit, Wasuwanich and Hellum, 1984) Chaisurisri, Ponoy and Wasuwanich (1986) obtained success in storing *Azadirachta indica* seeds in a

cotton bag at 15°C. Seeds were dried down to a moisture content of 46.18 per cent before storing. Under these conditions seeds retained viability for more than 4 months. Germination of seeds stored for 16 weeks was 62 per cent.

Maithani *et al.* (1987) recorded a fall in the germination per cent and value of *Holoptelia integrifolia* seeds to zero within 2 months of storage in open containers at room temperature or within 4-5 months in perforated polybags at room temperature or 30°C. In seeds from sealed polybags at room temperature, germination capacity remained high (85 %) for 15 months. At 5°C, deterioration in germination capacity of seeds stored in polybags was slow until 12 months and then dropped rapidly. Nautiyal and Thapliyal (1993) reported that seeds of *Toona ciliata* can be stored at 5-8°C in the polythene bags for one year with 90 per cent germination. Whereas the seeds lost viability after 3 months at room temperature in the wooden box. The rapid loss of moisture content at room temperature was the main cause for the loss in the seed viability.

Triplochiton species seed is naturally short-lived but can be stored for upto 22 months at a temperature of around 6°C and a moisture content of between 12 and 25 per cent (Bowen and Jones, 1975). Tylkowski (1984) found that *Acer saccharinum* seed lost only 8 per cent viability after 18

months storage at -3°C with initial moisture content of 50 per cent.

2.3.2 Storage medium

Blomme and Degeyter (1986) stored *Quercus robur* acorns with a moisture content of 43.2 per cent by mixing with dry peat or not at -5°C, 2°C or 10-15°C for upto 16 weeks. With seeds stored at 2°C or higher, the percentage moisture content declined by upto 6 per cent during the first six weeks, with little change thereafter, at -5°C, moisture loss declined gradually over the whole period, the total loss amounting to 3 per cent. Average germinability after 12 weeks declined from 78 per cent to 63.5 per cent at -5°C, 44 per cent at 2°C and 46.5 per cent at 10°C. Mixing with peat made little difference. Seeds of *Podocarpus milanjinus* were kept in a cold store for upto 1 year in perforated polybags either without any medium (control), or in damp sawdust or peat. Under these conditions, moisture content of the control sample was stable at 42-45 per cent, while seeds in peat lost moisture to 38 per cent, and those in sawdust gained moisture of 58 per cent. After 1 year, germination decreased from 69 per cent in fresh seeds to 50 per cent in control and peat-stored seeds, but increased to 72 per cent in sawdust- stored seeds. Storage of seed in sawdust in a cold store gave better results (Schaefer, 1990). Maury-Lechon, Hassan and Bravo (1981) found that the optimum storage conditions for *Shorea*

parvifolia and *Dipterocarpus humeratus* are at half initial moisture content and 15°C under N_2 or air/ silica gel. The maximum storage period was 2 weeks for *Shorea parvifolia* and 8 weeks for *Dipterocarpus humeratus*. Barnard (1950) reported that storage of seeds of *Shorea leprosula, S. Parvifolia, S. acuminata* and *S. resinanigra* in fresh sawdust did not delay development of the radicle, but kept it alive for 7-14 days, after which deterioration was rapid; all fruits were dead after 28 days storage. Kurniaty and Syamsuwida (1988) successfully stored *Shorea pinanga* seed in small wooden boxes sealed with wax, or coating the seeds with wax in unsealed boxes, resulting in 62.5 per cent and 45.8 per cent germination respectively after 4 weeks, at which time seeds stored in open metal containers had lost their viability.

Chapter-3

MATERIAL AND METHODS

MATERIAL AND METHODS

The present investigation entitled, 'Seed Storage and Viability of *Toona ciliata* M. Roem. and *Shorea robusta* Gaertn. f.' was conducted during 1993 and 1994 in the laboratory of the Department of Silviculture and Agroforestry, Dr. Y.S. Parmar University of Horticulture and Forestry, Solan (H.P.). The materials and methods employed during the course of investigation are detailed as under:

3.1 EXPERIMENTAL METHODOLOGY

3.1.1 Storage of *Toona ciliata* seeds

3.1.1.1 Seed collection and extraction

Seeds of *Toona ciliata* were collected from the area of the Dr. Y.S. Parmar University of Horticulture and Forestry, Solan (H.P.) on June 16, 1993. For the extraction of seeds, capsules were kept in the sun for one day. Thereafter, the seeds were stored as per the treatments.

3.1.1.2 Germination testing in seed germinator.

A sample of 400 seeds was drawn from seed lot. These seeds were then sown on blotter papers in germinating trays.

Plate 1. A view of ungerminated seeds of *Toona ciliata*

Plate 2. A view of ungerminated seeds of *Shorea robusta*

4 replicates of 100 seeds each were sown in germinating trays as per the rules laid down by ISTA (1976). The seeds were gently watered and germinating trays were then stacked in the germinator. The temperature of germinator was set at 25° ± 1°C. Daily count of germinated seeds was made for 14 days. Emergence of radicle was taken as criterion for germination. Initial germination per cent before storage was 99.75 per cent. Germination testing was done at one month interval upto one year.

3.1.1.3 Outline of Treatments

		Symbol
A.	**Storage temperatures**	
1.	Room temperature	T_1
2.	-10° ± 1°C	T_2
3.	0° ± 1°C	T_3
4.	10° ± 1°C	T_4
B.	**Storage containers**	
1.	Earthen pot	C_1
2.	Canvass bag	C_2
3.	Polythene bag	C_3
4.	Plastic bin	C_4
C.	**Storage durations**	
1.	One month	D_1
2.	Two months	D_2
3.	Three months	D_3

4.	Four months	D_4
5.	Five months	D_5
6.	Six months	D_6
7.	Seven months	D_7
8.	Eight months	D_8
9.	Nine months	D_9
10.	Ten months	D_{10}
11.	Eleven months	D_{11}
12.	Twelve months	D_{12}

Design	:	Split split plot
Main Plot factor	:	Storage temperature
Sub-plot factor	:	Storage container
Sub-sub plot factor	:	Storage duration

3.1.1.4 Storage containers and store temperatures

Two hundred grams seed was stored in each of the four different containers i.e., earthen pot, canvass bag, polythene bag and plastic bin. Under each storage temperature, 4 different types of containers were kept. After every month, seeds from four different containers stored under each storage temperature were tested for their viability as per the ISTA rules (1976). Seeds were stored for one year.

Plate 3. Different types of storage containers used for storing *Toona ciliata* seeds

Plate 4. Different types of storage containers used for storing *Shorea robusta* seeds

3.1.2 Storage of *Shorea robusta* seeds.

3.1.2.1 Seed Collection

Seeds of *Shorea robusta* were collected from the Bara Ban Forest of Nahan Forest Division on June 26, 1994 and were stored on June 27, 1994.

3.1.2.2 Germination testing in seed germinator

A sample of 400 seeds was drawn form seed lot. These seeds were then sown on sand in the germination trays. 4 replicates of 100 seeds each were sown in germinating trays as per the rules laid down by ISTA (1976). The seeds were gently watered and germinating trays were then stocked in the germinator. The temperature of the germinator was set at 25° ± 1°C. Daily count of germinated seeds was made and germination testing was done at one week interval upto six weeks.

3.1.2.3 Outline of Treatments.

Shorea robusta seeds were stored in two ways. For the first experiment, the outline of treatments is as follows:

	A. Storage temperatures	Symbol
1.	Room temperature	T_1
2.	5° ± 1°C	T_2
3.	10° ± 1°C	T_3

4.	$15^{o} \pm 1^{o}C$	T_4

B. Storage containers

1.	Earthen pot	C_1
2.	Plastic bin	C_2
3.	Glass pot	C_3

C. Storage durations

1.	One Week	D_1
2.	Two Weeks	D_2
3.	Three Weeks	D_3
4.	Four Weeks	D_4
5.	Five Weeks	D_5
6.	Six Weeks	D_6

Design	:	Split split plot
Main Plot factor	:	Storage temperature
Sub-plot factor	:	Storage container
Sub-sub plot factor	:	Storage duration

3.1.2.4 Storage containers and storage temperatures.

Two kg of seeds were stored in each of the three types of containers i.e., earthen pots, plastic bins and glass pots. Under each storage temperature, two each of the three different types of container were kept. After every week, seeds from three different types of containers stored under each storage temperature were tested for their viability as

per the ISTA rules (1976). Initial germination per cent before storage was 99 per cent. Seeds were stored for one and half a month.

3.1.2.5 Outline of Treatments for the second experiment on *Shorea robusta* seed are as follows:

		Symbol
A.	**Storage temperatures**	
1.	Room temperature	T_1
2.	$15^{o} \pm 1^{o}C$	T_2
B.	**Seed Treatments**	
1.	Storage of seed after coating with gum	t_1
2.	Storage of seed after packaging in lime	t_2
3.	Storage of seed in saw dust	t_3
4.	Storage of seed after coating with clay	t_4
5.	Storage of seed after coating with paraffin wax	t_5
6.	Control	t_6
C.	**Storage durations**	
1.	One Week	D_1
2.	Two Weeks	D_2
3.	Three Weeks	D_3
4.	Four Weeks	D_4
5.	Five Weeks	D_5
6.	Six Weeks	D_6

Design	:	Split split plot
Main Plot factor	:	Storage temperature and different seed treatments
Sub-plot factor	:	Storage duration

3.1.2.6 Storage temperatures and different seed treatments

Dewinging of the seeds of *Shorea robusta* which were to be given different treatments was done. Then the seeds were given different treatments i.e., coating the seeds with gum paste, coating the seeds with clay after dipping in clay suspension, coating the seeds with paraffin wax. Seeds which were dipped in gum paste and clay suspension were dried in shade for 24 hours. Seeds which were stored in lime and saw dust were not dewinged. Including control, there were six treatments. Under each storage temperature, seeds with six different types of treatments were stored in the open trays. After every week, seeds from six different treatments stored under each storage temperature were tested for their viability as per the rules laid down by ISTA (1976). Seeds were stored for one and half a month.

3.2 OBSERVATIONS RECORDED

The observations recorded for *Toona ciliata* as well as for both the experiments of *Shorea robusta* are as follows:

3.2.1 Germination percentage:

Germination percentage was calculated by counting the number of seeds germinated.

3.2.2 Germination energy:

The percentage of number of seeds that germinate upto the time when germination reaches its peak was worked out.

3.2.3 Germination Value:

Germination value was worked out following the method developed by Czabator (1962).

3.2.4 Germination speed:

Germination speed was worked out following the method developed by Maguire (1962).

Speed of germination = $\Sigma(n/t)$

where,

n = number of seeds newly germinating at time 't'
t = number of days from sowing

3.2.5 Viability per cent:

At the end of the germination test period, all the remaining ungerminated seeds were cut and examined and the number of fresh, firm and possible viable seeds were

recorded. Viability per cent was worked out by summation of percentage of germinated seeds and the percentage of ungerminated but apparently sound seeds (FAO, 1985).

3.2.6 Per cent Moisture Content:

Per cent moisture content on fresh weight basis was determined by the following formula.

$$\text{Moisture content (\%)} = \frac{\text{Original weight - oven dry weight}}{\text{Original weight}} \times 100$$

Seeds were dried in the oven at 105°C temperature for 16 hours.

3.3 STATISTICAL ANALYSIS:

The data were analysed following the procedures described by Gomez and Gomez (1984).

Chapter-4

EXPERIMENTAL RESULTS

EXPERIMENTAL RESULTS

The results of the present investigation are presented under the following heads:

4.1 Storage of *Toona ciliata* seeds

4.2 Storage of *Shorea robusta* seeds (Experiment I)

4.3 Storage of *Shorea robusta* seeds (Experiment II)

4.1 STORAGE OF *Toona ciliata* SEEDS

4.1.1 Determination of germination, viability and moisture content of freshly collected seeds of *Toona ciliata*

As evident from the Table 4.1, germination percentage of freshly collected *Toona ciliata* seeds was found to be 99.75 per cent. Germination energy, viability and moisture content were found to be 95.25, 99.75 and 24.88 per cent respectively. Germination value and germination speed were recorded to be 1323.69 and 56.25 respectively.

Table 4.1 Germination of freshly collected *Toona ciliata* seeds

Germination				Viability (%)	Moisture content (%)
Per cent	Energy (%)	Value	Speed		
99.75	95.25	1323.69	56.25	99.75	24.88

4.1.2 Effect of storage temperatures on germination, viability and moisture content of *Toona ciliata* seeds

Seeds of *Toona ciliata* were stored under four different storage temperatures namely, room temperature,

-10°±1°C, 0°±1°C and 10°±1°C. Storage temperature of 0°±1°C resulted highest germination percentage of 95.59 and was followed by 83.75 per cent at 10°±1°C. The lowest germination percentage of 17.21 per cent was recorded in seed stored at room temperature (Table 4.2). Similarly, germination energy, value, speed and viability per cent were recorded highest at 0°±1°C followed by 10°±1°C and minimum at room temperature. But highest per cent moisture content of 25.68 was recorded at -10°±1°C followed by 19.39 at 0°±1°C and 17.62 per cent at 10°±1°C. Minimum per cent moisture content of 11.05 per cent was noted at room temperature.

4.1.3 Effect of storage containers on germination, viability and moisture content of *Toona ciliata* seeds

Four types of storage containers namely earthen pot (C_1), canvass bag (C_2), polythene bag (C_3) and plastic bin (C_4) were assessed for their influence on germination, viability and moisture content of *Toona ciliata* seeds in storage. Maximum germination of 73.94 per cent was recorded in seeds stored in polythene bag, followed by 73.70 per cent in the plastic bin stored seeds (Table 4.2). The lowest germination of 47.47 per cent was recorded in earthen pot container. Highest germination energy of 68.97 per cent was recorded in plastic bin container which is on a par with the polythene bag container (67.96%) and lowest germination energy of 41.04 per cent was registered in earthen pot.

Plate 5. Germinated seeds of *Toona ciliata*

Plate 6. Germinated seeds of *Shorea robusta*

Table 4.2 Effect of storage temperature and containers on germination, viability and moisture content of *Toona ciliata* seeds in storage

Treatments	Germination				Viability per cent	Per cent moisture content
	Per cent	Energy (%)	Value	Speed		
A. Storage temperatures (°C)						
T_1: Room temp.	17.21 (15.06)	14.80 (13.24)	63.27	5.26	20.41 (19.55)	11.05
T_2: -10°±1	52.69 (44.12)	45.88 (38.61)	156.31	14.78	54.71 (46.39)	25.68
T_3: 0°1±1	95.59 (78.45)	89.94 (72.10)	332.22	27.33	96.98 (80.96)	19.39
T_4: 10±1	83.75 (68.45)	75.69 (62.21)	254.36	23.50	86.49 (71.30)	17.62
S.Ed.	0.16	0.15	1.08	0.05	0.22	0.04
$LSD_{0.05}$	0.36	0.34	2.45	0.12	0.50	0.12
B. Storage containers						
C_1: Earthen pot	47.47 (39.35)	41.04 (34.42)	143.97	13.45	49.70 (42.22)	17.10
C_2: Canvass bags	54.13 (44.64)	48.34 (39.94)	170.10	15.22	57.02 (48.01)	17.46
C_3: Polythene bags	73.94 (61.33)	67.96 (55.83)	250.93	21.06	75.65 (63.82)	19.63
C_4: Plastic bin	73.70 (60.76)	68.97 (55.98)	241.16	21.14	76.21 (64.15	19.54
S.Ed.	0.22	0.12	1.48	0.08	0.24	0.03
$LSD_{0.05}$	0.45	0.39	3.01	0.17	0.48	0.07

*Figures within parentheses indicate transformed values

Germination value and per cent moisture content followed a trend parallel to that by germination per cent whereas the germination speed and viability per cent followed the same trend to that of germination energy.

4.1.4 Effect of different storage durations on the germination, viability and moisture content of *Toona ciliata* seeds in storage

Twelve storage durations namely, 1 month (D_1), 2 months (D_2), 3 months (D_3), 4 months (D_4), 5 months (D_5), 6 months (D_6), 7 months (D_7), 8 months (D_8), 9 months (D_9), 10 months (D_{10}), 11 months (D_{11}), 12 months (D_{12}) were subjected to comparison in the light of their impact on germination, viability and moisture content of *Toona ciliata* seeds.

Storage durations recorded significant differences in all the parameters. Germination percentage showed declining trend from D_1 (one month) to D_{12} (12 months) with D_1 registering maximum value of 96.03 per cent and D_{12}, minimum value of 40.87 per cent of germination. Germination energy, value, speed, viability and moisture content showed similar trend to that of germination per cent (Table 4.3).

4.1.5 Interaction effects of storage temperatures, containers and durations on the germination, viability and moisture content of *Toona ciliata* seeds in storage

Comparison of storage temperatures at individual container level (TxC) revealed that $0^{o}\pm1^{o}C$ was the best

Table 4.3 Effect of storage durations on germination, viability and moisture content of *Toona ciliata* seeds in storage

Treatments	Germination				Viability per cent	Per cent moisture content
	Per cent	Energy (%)	Value	Speed		
Durations						
D_1	96.03 (79.80)	89.06 (71.63)	465.62	39.10	97.31 (83.39)	24.10
D_2	84.36 (71.44)	79.37 (66.00)	283.98	23.35	86.19 (73.75)	23.44
D_3	74.76 (61.74)	67.78 (55.89)	231.88	20.46	79.36 (67.70)	22.19
D_4	65.75 (55.18)	61.26 (50.76)	202.56	18.07	69.67 (60.92)	20.66
D_5	62.28 (52.22)	59.03 (48.97)	196.30	17.11	65.39 (56.82)	19.83
D_6	58.89 (48.51)	55.14 (44.79)	188.04	16.27	61.44 (52.22)	18.54
D_7	56.94 (46.00)	52.00 (41.71)	178.22	15.55	58.50 (48.12)	17.49
D_8	55.39 (44.67)	50.36 (40.47)	167.41	15.08	57.28 (46.44)	16.52
D_9	54.91 (44.21)	45.80 (37.53)	150.03	14.42	56.37 (45.72)	15.72
D_{10}	52.78 (42.57)	44.44 (36.61)	142.87	13.87	54.25 (44.01)	14.79
D_{11}	44.78 (37.52)	40.53 (34.18)	113.93	11.78	46.76 (39.01)	14.20
D_{12}	40.87 (34.68)	34.17 (29.93)	97.65	10.56	43.23 (36.52)	13.70
S.Ed.	0.36	0.31	2.13	0.10	0.46	0.06
$LSD_{0.05}$	0.70	0.61	4.17	0.20	0.90	0.12

*Figures within parentheses indicate transformed values

storage temperature which gave the highest germination per cent for all the containers (Table 4.4). On the other hand, while comparing storage containers at individual temperature level (CxT), polythene bag stored seeds gave the maximum germination per cent of 85.21 at -10°±1°C storage temperature and germination of 96.62 per cent at 0°±1°C storage temperature. At room temperature plastic bin registered maximum germination per cent which is at a par with the polythene bag. At 10°±1°C storage temperature, also plastic bin registered maximum germination of 92.02 per cent. Polythene bag containers stored at 0°±1°C gave the highest germination per cent of 96.62. Germination per cent was found to be least for all the temperatures when seeds were stored in earthen pot except at room temperature. For germination energy, value, speed and viability per cent, comparison of storage temperatures at individual container level followed same trend to that of germination per cent, but per cent moisture content was maximum at -10°±1°C temperature for all the containers. For germination energy, value, speed and viability per cent, comparing storage container at individual temperature level, it was noted that polythene bag at 0°±1°C and plastic bin at 10°±1°C storage temperature were the most suited storage containers. Highest per cent moisture content of 29.56 was recorded at -10°±1°C in the canvass bag and lowest per cent moisture content of 7.17 was found at room temperature in the earthen pot (Table 4.5).

Table 4.4 Effect of storage temperature and container interactions on the germination per cent, germination energy and germination value of *Toona ciliata* seeds in storage

Storage temperatures (°C)	Storage containers											
	Per cent germination				Germination energy (%)				Germination value			
	C_1	C_2	C_3	C_4	C_1	C_2	C_3	C_4	C_1	C_2	C_3	C_4
T_1	10.27 (8.48)	9.58 (8.40)	24.06 (21.19)	24.94 (21.65)	19.42 (8.37)	8.79 (7.82)	20.02 (18.15)	20.96 (18.63)	40.93	58.22	79.03	74.90
T_2	11.75 (10.77)	31.39 (26.59)	85.21 (70.43)	82.42 (68.69)	8.29 (8.32)	25.81 (22.85)	72.42 (60.19)	77.02 (63.07)	33.74	76.41	252.03	263.07
T_3	94.83 (77.26)	95.46 (78.15)	96.62 (80.16)	95.44 (78.22)	86.87 (69.42)	88.94 (71.09)	93.56 (75.57)	90.39 (72.31)	309.52	318.97	377.28	323.13
T_4	73.04 (60.38)	80.08 (65.43)	89.87 (73.54)	92.02 (74.47)	59.58 (51.57)	69.83 (57.99)	85.85 (69.39)	87.50 (69.89)	191.72	226.81	295.37	303.54
		S.Ed.	$LSD_{0.05}$			S.Ed.	$LSD_{0.05}$			S.Ed.	$LSD_{0.05}$	
For storage containers at same or different temperature level		.45	0.91			0.39	0.79			2.96	6.01	
For storage temperatures at same or different storage container level		.42	0.87			0.37	0.76			2.78	5.74	

*Figures within parentheses are transformed values

Table 4.5 Effect of storage temperature and container interactions on the germination speed, viability per cent and per cent moisture content of *Toona ciliata* seeds in storage

Storage temperatures (°C)	Storage containers											
	Germination speed				Viability per cent				Per cent moisture content			
	C_1	C_2	C_3	C_4	C_1	C_2	C_3	C_4	C_1	C_2	C_3	C_4
T_1	3.60	3.22	7.05	7.18	14.25 (14.75)	13.81 (14.25)	25.69 (23.50)	27.89 (25.72)	7.17	7.24	14.75	15.03
T_2	3.65	9.06	23.08	23.36	12.75 (12.41)	33.35 (28.06)	87.21 (72.77)	85.52 (72.33)	29.27	29.56	21.62	21.86
T_3	26.86	27.04	28.01	27.42	96.00 (79.19)	97.17 (81.30)	97.64 (82.41)	97.10 (80.92)	16.92	17.24	21.62	21.78
T_4	19.69	21.59	26.10	26.62	75.81 (62.53)	83.75 (68.45)	92.06 (76.59)	94.33 (77.63)	15.06	15.39	20.55	19.47
	S.Ed.		$LSD_{0.05}$		S.Ed.		$LSD_{0.05}$		S.Ed.		$LSD_{0.05}$	
For storage containers at same or different storage temperature level	0.17		0.34		0.48		0.97		0.06		0.13	
For storage temperatures at same or different storage container level	0.15		0.31		0.47		0.74		0.07		0.18	

*Figures within parentheses are transformed values

Comparing storage durations at individual temperature level (DxT) showed that storage for one month yielded maximum per cent germination which was found to be declining thereafter. The rate of decline was significantly different at different temperatures (Table 4.6). At room temperature, germination per cent of 92.50 came down to zero after six months of storage. At $-10^{o}\pm1^{o}C$ storage temperature, the per cent loss in the germinability after one year was 79.87 per cent. But at $0^{o}\pm1^{o}C$ storage temperature, the rate of loss of germinability was very low. At $0^{o}\pm1^{o}C$, the loss in the germinability after one year of storage was 7.69 per cent. At $10^{o}\pm1^{o}C$, rate of decline of germination per cent was comparatively faster than at $0^{o}\pm1^{o}C$ i.e. the loss in germination per cent after one year was 40.57 per cent. Trend parallel to that of per cent germination emerged for germination energy, germination value, germination speed and viability per cent (Table 4.7 & 4.8). There was a sharp decline in the per cent moisture content at room temperature. At $0^{o}\pm1^{o}C$, the loss in moisture content after one year of storage was 10.99 per cent. At $10^{o}\pm1^{o}C$, the per cent moisture content came down to 10.09 after one year from 24.60 after one month of storage. At $-10^{o}\pm1^{o}C$ storage temperature, there was slight gain in per cent moisture content upto 3 months of storage and then a slight decline leading to the lowest value of 23.78 per cent after one year from 25.29 per cent after one month of storage (Table 4.8). Comparing storage

Table 4.6 Effect of storage temperature and duration interactions on the germination per cent and germination energy of *Toona ciliata* seeds in storage

Storage duration	Storage temperature							
	Germination per cent				Germination energy (%)			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
D_1	92.50 (71.51)	94.87 (78.03)	98.56 (84.15)	98.19 (82.51)	87.56 (69.57)	82.06 (66.54)	93.87 (75.88)	92.75 (74.52)
D_2	61.56 (54.29)	81.12 (68.44)	97.64 (81.40)	97.06 (80.30)	54.31 (48.50)	72.81 (60.68)	95.25 (77.49)	95.12 (77.33)
D_3	37.81 (30.25)	69.81 (59.47)	97.44 (80.92)	94.00 (76.32)	24.06 (21.96)	62.37 (53.04)	93.81 (75.79)	90.87 (72.78)
D_4	11.12 (14.01)	63.62 (52.66)	97.00 (80.23)	91.25 (73.80)	8.94 (12.34)	57.12 (46.80)	92.87 (74.87)	86.12 (69.02)
D_5	3.56 (7.62)	58.94 (49.24)	96.12 (79.04)	90.25 (72.98)	2.69 (6.53)	54.44 (45.56)	93.19 (75.15)	85.81 (68.65)
D_6	0.00 (0.002)	51.19 (44.16)	95.87 (78.50)	88.50 (71.38)	0.00 (0.002)	47.25 (40.18)	91.44 (73.23)	81.87 (65.77)
D_7	0.00 (0.002)	46.25 (37.07)	95.37 (77.86)	86.12 (69.09)	0.00 (0.002)	42.00 (33.29)	89.81 (71.79)	76.19 (61.76)
D_8	0.00 (0.002)	45.37 (36.18)	94.75 (76.93)	81.44 (65.59)	0.00 (0.002)	40.87 (32.43)	88.19 (70.09)	72.37 (59.37)
D_9	0.00 (0.002)	43.87 (34.83)	94.35 (76.93)	81.00 (65.08)	0.00 (0.002)	32.62 (27.23)	87.19 (69.12)	63.37 (53.79)
D_{10}	0.00 (0.002)	41.00 (32.53)	94.50 (76.63)	75.62 (61.12)	0.00 (0.002)	31.37 (26.30)	87.31 (69.26)	59.06 (50.91)
D_{11}	0.00 (0.002)	21.25 (20.33)	94.12 (76.21)	63.75 (53.53)	0.00 (0.002)	19.25 (19.16)	86.25 (68.59)	56.62 (48.95)
D_{12}	0.00 (0.002)	15.00 (16.47)	90.87 (72.56)	57.62 (49.70)	0.00 (0.002)	8.44 (12.12)	80.92 (63.92)	48.12 (43.69)
			S.Ed.	$LSD_{0.05}$	S.Ed.	$LSD_{0.05}$		
For storage temperatures at same or different durations level			0.70	1.38	0.61	1.20		
For storage durations at individual temperature level			0.71	1.39	0.61	1.19		

*Figures within parentheses indicate transformed values

Table 4.7 Effect of storage temperature and duration interactions on the germination value and germination speed of *Toona ciliata* seeds in storage

Storage durations	Storage temperatures							
	Germination value				Germination speed			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
D_1	436.16	425.20	513.38	487.75	34.54	34.90	37.63	37.33
D_2	234.95	234.73	335.75	330.48	16.25	22.21	27.61	27.33
D_3	81.20	200.50	340.36	305.48	9.24	18.99	27.38	26.22
D_4	6.26	186.20	335.29	282.51	2.41	17.35	27.22	25.30
D_5	0.68	169.02	332.72	282.79	0.71	15.91	26.79	25.04
D_6	0.00	150.87	328.00	273.30	0.00	13.91	26.60	24.59
D_7	0.00	138.77	319.62	254.48	0.00	12.49	26.34	23.39
D_8	0.00	132.47	311.55	225.63	0.00	12.19	26.18	21.95
D_9	0.00	108.57	293.81	197.72	0.00	10.85	26.08	20.74
D_{10}	0.00	94.48	306.47	170.52	0.00	10.20	26.01	19.25
D_{11}	0.00	24.19	300.03	131.50	0.00	5.09	25.70	16.31
D_{12}	0.00	10.75	269.71	110.16	0.00	3.32	24.39	14.54

	S.Ed.	$LSD_{0.05}$	S.Ed.	$LSD_{0.05}$
For storage temperatures at same or different durations level	4.22	8.35	0.19	0.38
For storage durations at individual temperature level	4.26	8.35	0.21	0.41

Table 4.8 Effect of storage temperature and duration interactions on the viability and moisture content of *Toona ciliata* seeds in storage

Storage durations	Storage temperatures							
	Viability per cent				Per cent moisture content			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
D_1	94.87	96.25	99.19	98.94	21.71	25.29	24.81	24.60
D_2	65.06	82.81	98.62	98.25	18.07	27.44	24.34	23.93
D_3	50.69	72.25	98.56	95.94	13.81	27.86	23.70	23.38
D_4	19.56	67.12	97.94	94.06	11.11	27.12	22.47	21.94
D_5	9.94	60.75	97.50	93.37	10.39	26.41	21.51	21.02
D_6	3.62	53.06	96.81	92.25	9.25	26.07	20.19	18.66
D_7	1.19	47.31	96.37	89.12	9.21	25.52	18.49	16.73
D_8	0.00	46.56	96.44	86.12	8.79	25.52	17.07	14.41
D_9	0.00	45.62	96.37	83.50	8.12	25.10	16.27	13.40
D_{10}	0.00	43.06	96.37	77.56	7.73	23.76	15.47	12.21
D_{11}	0.00	23.87	95.75	67.44	7.27	23.95	14.56	11.03
D_{12}	0.00	17.81	93.81	61.31	7.09	23.78	13.82	10.09

	S.Ed.	$LSD_{0.05}$	S.Ed.	$LSD_{0.05}$
For storage temperatures at same or different durations level	0.90	1.78	0.12	0.25
For storage durations at individual temperature level	0.92	1.80	0.12	0.23

temperatures at individual duration level (TxD) it was noted that the highest germination per cent was recorded at $0^{o}\pm1^{o}C$ storage temperature and lowest at room temperature for all the durations (Table 4.6). Similar trend to that of per cent germination was recorded in germination energy, germination value, germination speed and viability per cent (Table 1.7 & 1.8). Per cent moisture content was highest at $-10^{o}\pm1^{o}C$ storage temperature and lowest at room temperature for all the durations (Table 4.8).

Comparison of storage duration at individual container level (DxC) revealed that the rate of decline of germination per cent was more or less similar for earthen pot and canvass bag for all the durations (Table 4.9). The loss in germinability was 67.50 per cent for earthen pot and 65.13 per cent for convass bag stored seeds after one year of storage. Similarly, the loss in the germination was 51.0 per cent for polythene bag and 51.88 per cent for plastic bin after one year of storage i.e. the rate of decline of germination per cent was almost similar for polythene bag and plastic bin containers. Comparing storage containers at individual duration level (CxD), germination per cent in polythene bag stored seeds was statistically at par with the plastic bin for all the durations. Germination per cent in earthen pot stored seeds was statistically at par with the canvass bag stored seeds for all the durations. More or less

Table 4.9 Effect of storage container and duration interactions on the germination per cent and germination energy of *Toona ciliata* seeds in storage

Storage durations	Storage containers							
	Germination per cent				Germination energy (%)			
	C_1	C_2	C_3	C_4	C_1	C_2	C_3	C_4
D_1	95.37 (78.25)	93.25 (76.37)	97.94 (82.98)	97.56 (81.61)	85.56 (69.13)	85.50 (68.40)	93.81 (75.76)	91.37 (73.22)
D_2	66.50 (58.27)	77.19 (65.42)	97.62 (81.42)	96.12 (79.34)	60.25 (53.54)	72.44 (61.02)	94.37 (76.56)	90.44 (72.89)
D_3	48.25 (41.40)	67.19 (54.46)	91.56 (75.55)	92.06 (75.55)	45.69 (38.56)	61.00 (49.72)	81.00 (67.32)	83.44 (67.97)
D_4	44.19 (35.62)	62.69 (51.52)	77.25 (66.45)	78.87 (67.11)	40.75 (32.67)	56.87 (46.62)	72.56 (61.14)	74.87 (62.50)
D_5	44.00 (35.48)	57.94 (48.09)	73.62 (62.83)	73.56 (62.47)	41.87 (33.68)	52.56 (43.88)	71.00 (59.41)	70.69 (58.93)
D_6	42.87 (34.64)	49.56 (42.51)	72.25 (59.39)	70.87 (57.51)	39.25 (31.60)	45.00 (38.49)	69.56 (56.02)	66.75 (53.06)
D_7	42.37 (34.28)	44.37 (35.63)	70.75 (57.42)	70.25 (56.60)	34.00 (28.17)	41.37 (32.97)	65.94 (52.66)	66.69 (53.04)
D_8	40.50 (32.90)	41.87 (33.82)	69.69 (56.06)	69.50 (55.90)	32.50 (27.31)	38.50 (30.92)	64.44 (51.29)	66.00 (52.37)
D_9	40.62 (32.96)	42.50 (34.46)	68.12 (54.60)	68.37 (54.82)	32.50 (27.41)	30.87 (26.37)	55.94 (45.73)	63.87 (50.63)
D_{10}	39.37 (32.13)	40.62 (33.12)	65.12 (52.56)	65.50 (52.47)	31.00 (26.53)	30.50 (26.17)	54.87 (44.97)	61.37 (48.79)
D_{11}	33.37 (28.64)	37.75 (31.26)	54.12 (45.18)	53.87 (44.98)	27.00 (23.85)	34.62 (28.55)	50.94 (42.80)	49.56 (41.50)
D_{12}	32.25 (27.58)	34.62 (29.05)	48.75 (41.49)	47.87 (40.62)	22.12 (20.59)	30.87 (26.20)	41.12 (36.25)	42.56 (36.70)

	S.Ed.	$LSD_{0.05}$	S.Ed.	$LSD_{0.05}$
For storage containers at same or different duration level	0.72	1.41	0.62	1.21
For storage duration at individual containers level	0.71	1.39	0.62	1.21

similar trend was also recorded for germination energy germination value, germination speed, viability per cent and per cent moisture content (Table 4.10 & 4.11).

Comparison of storage temperatures at the same combination of storage container and duration (TxCxD) revealed that $0^{o}\pm1^{o}C$ storage temperature outperformed all the others (Table 4.12). Comparing the storage containers at similar storage temperature and duration level, it was found that polythene bag recorded invariably higher values for germination per cent at $-10^{o}\pm1^{o}C$ and $0^{o}\pm1^{o}C$ storage temperature whereas plastic bin recorded higher values for germination per cent at room temperature and at $10^{o}\pm1^{o}C$ storage temperature. A clear pattern showing fall in per cent germination emerged when the twelve storage durations were compared amongst themselves. Germination per cent was highest after one month storage and lowest after one year of storage. The fall in the per cent germination was maximum in the canvass bag and earthen pot seeds stored at room temperature where the germination per cent came down to zero after 3 months of storage. Further scrutiny of the data led to the inference that decline in per cent germination was least in polythene bag seeds stored at $0^{o}\pm1^{o}C$ temperature for various storage durations. Polythene bag seeds stored at $0^{o}\pm1^{o}C$ temperature recorded 99.25 per cent germination after one month and 93 per cent after one year of storage.

Table 4.10 Effect of storage container and duration interactions on the germination value and germination speed of *Toona ciliata* seeds in storage

Storage durations	Storage containers							
	Germination value				Germination speed			
	C_1	C_2	C_3	C_4	C_1	C_2	C_3	C_4
D_1	439.06	417.69	510.51	495.22	35.46	34.80	37.47	36.67
D_2	187.39	308.50	328.46	311.56	18.19	21.08	27.42	26.71
D_3	148.37	203.75	292.70	282.71	13.24	18.35	24.94	25.30
D_4	129.35	182.51	256.98	241.42	12.11	17.08	21.31	21.78
D_5	134.94	159.68	256.12	234.48	11.94	15.70	20.41	20.40
D_6	133.63	138.65	254.22	225.67	11.73	13.55	20.17	19.64
D_7	115.56	138.18	235.94	223.20	11.21	11.95	19.56	19.50
D_8	107.09	116.88	227.16	218.51	10.66	11.23	19.18	19.25
D_9	98.44	104.37	188.91	208.38	10.36	10.64	17.78	18.87
D_{10}	94.39	97.18	189.22	190.68	10.00	10.21	17.27	17.92
D_{11}	76.74	90.20	146.69	142.09	8.61	9.41	14.29	14.19
D_{12}	62.77	83.83	124.22	120.00	7.83	8.69	12.88	12.85
			S.Ed.	$LSD_{0.05}$	S.Ed.		$LSD_{0.05}$	
For storage containers at same or different duration level			4.34	8.51	0.21		0.41	
For storage durations at individual containers level			4.26	8.35	0.20		0.39	

Table 4.11 Effect of storage container and duration interaction on the viability and moisture content of *Toona ciliata* seeds in storage

Storage durations	Storage containers							
	Viability per cent				Per cent moisture content			
	C_1	C_2	C_3	C_4	C_1	C_2	C_3	C_4
D_1	96.44 (79.77)	95.31 (79.51)	98.81 (87.22)	98.69 (87.07)	23.37	23.52	24.76	24.76
D_2	68.56 (60.24)	80.25 (68.34)	98.50 (83.99)	97.44 (82.43)	23.07	23.00	23.78	23.93
D_3	55.69 (50.77)	74.50 (63.40)	93.06 (78.38)	94.19 (78.25)	21.30	21.53	22.97	22.96
D_4	50.31 (45.65)	68.19 (59.75)	79.00 (68.68)	81.19 (69.61)	19.78	19.73	21.52	21.61
D_5	47.50 (41.85)	61.56 (53.69)	75.87 (65.97)	76.62 (65.77)	18.44	18.97	20.93	21.00
D_6	44.25 (35.47)	52.31 (45.25)	74.43 (64.18)	74.75 (63.99)	16.71	17.28	19.93	20.24
D_7	43.19 (34.64)	46.06 (37.30)	71.69 (58.63)	73.06 (61.90)	15.43	15.66	19.36	19.51
D_8	43.00 (34.71)	43.94 (35.50)	71.06 (57.77)	71.12 (57.80)	15.13	15.10	18.00	17.87
D_9	40.94 (33.31)	43.87 (35.76)	70.19 (56.75)	70.50 (57.04)	14.14	14.78	17.00	16.95
D_{10}	38.56 (32.05)	42.50 (34.70)	67.69 (54.41)	68.25 (54.88)	13.12	13.50	16.20	16.35
D_{11}	34.81 (29.73)	39.25 (32.52)	56.00 (46.41)	57.00 (47.38)	12.72	13.18	15.84	15.08
D_{12}	33.19 (28.46)	36.50 (30.47)	51.50 (43.45)	51.75 (43.69)	12.03	13.26	15.31	14.18

	S.Ed.	$LSD_{0.05}$	S.Ed.	$LSD_{0.05}$
For storage containers at same or different duration level	0.91	1.78	0.08	0.16
For storage duration at individual containers level	0.92	1.80	0.12	0.23

*Figures within parentheses are transformed values

Table 4.12 Effect of TxCxD (storage temperature x container x duration) interactions on germination per centage of Toona ciliata seeds during storage

Temperatures x containers	Storage durations											
	D_1	D_2	D_3	D_4	D_5	D_6	D_7	D_8	D_9	D_{10}	D_{11}	D_{12}
T_1C_1	92.50	30.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_1C_2	87.00	28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_1C_3	96.00	96.00	74.00	17.75	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_1C_4	94.50	91.50	77.25	26.75	9.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_2C_1	93.25	42.00	5.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_2C_2	89.25	85.75	79.00	61.25	45.75	15.75	0.00	0.00	0.00	0.00	0.00	0.00
T_2C_3	98.25	98.50	96.75	96.50	95.00	95.00	92.50	91.50	88.50	85.00	47.00	38.00
T_2C_4	98.75	98.25	97.75	96.75	95.00	94.00	92.50	90.00	87.00	79.00	38.00	22.00
T_3C_1	98.00	96.50	96.75	95.75	95.50	95.50	95.00	94.00	94.00	93.50	93.50	90.00
T_3C_2	98.75	97.75	97.50	97.00	95.00	94.50	95.00	94.50	95.50	95.00	94.00	91.00
T_3C_3	99.25	98.25	98.25	97.75	97.50	97.50	96.50	95.50	95.00	95.50	95.50	93.00
T_3C_4	98.25	98.25	97.25	97.50	96.50	96.00	95.00	95.00	94.50	94.00	93.50	89.50
T_4C_1	97.75	96.75	90.50	91.00	80.50	76.00	74.50	68.00	68.50	64.00	40.00	39.00
T_4C_2	98.00	97.25	92.25	92.50	91.00	90.50	82.50	73.00	74.50	67.50	57.00	47.50
T_4C_3	98.25	97.75	97.25	97.00	97.00	96.50	94.00	91.75	89.00	82.00	74.00	64.00
T_4C_4	98.75	96.50	96.00	94.50	93.50	93.50	93.50	93.00	92.00	89.00	84.00	80.00

	S.Ed.	$LSD_{0.0.5}$
For two storage temperatures at the same combination of storage duration and container	1.47	3.32
For two containers at the same combination of temperature and duration	1.49	3.02
For two durations at the same combination of temperature and container	1.45	2.84

4.2 STORAGE OF *Shorea robusta* SEEDS (Experiment I)

4.2.1 Determination of germination, viability and moisture content of freshly collected seeds of *Shorea robusta*

As evident from the Table 4.13, germination percentage of freshly collected *Shorea robusta* seeds was found to be 99 per cent. Germination energy, viability and moisture content were found to be 96, 99 and 40.79 per cent respectively. Germination value and germination speed were recorded to be 1584.66 and 48.99 respectively.

Table 4.13 Germination of freshly collected *Shorea robusta* seeds

Germination				Viability (%)	Moisture content (%)
Per cent	Energy (%)	Value	Speed		
99.00	96.00	1584.66	48.99	99.00	40.79

4.2.2 Effect of storage temperatures on germination, viability and moisture content of *Shorea robusta* seeds in storage

Seeds of *Shorea robusta* were stored under four storage temperatures namely, room temperature, $5^{o}\pm1^{o}C$, $10^{o}\pm1^{o}C$, $15^{o}\pm1^{o}C$. Storage temperature of $10^{o}\pm1^{o}C$ resulted in highest germination percentage of 48.72 per cent followed by 43.36 per cent at $15^{o}\pm1^{o}C$ storage temperature. The lowest germination percentage of 6.50 per cent was found at $5^{o}\pm1^{o}C$ storage temperature. A similar trend on the lines of

germination per cent was recorded for germination energy, germination value, germination speed, viability per cent and per cent moisture content (Table 4.14).

4.2.3 Effect of storage containers on germination, viability and moisture content of *Shorea robusta* seeds in storage

Three types of storage containers namely, earthen pot, plastic bin and glass pot were assessed for their influence on germination, viability and moisture content of *Shorea robusta* seeds in storage (Table 4.14). Maximum germination per cent of 34.17 was recorded in seeds stored in plastic bin followed by glass pot (26.92%) which is on a par with the earthen pot (26.83%). Maximum germination energy of 27.52 per cent was recorded in the plastic bin followed by 22.33 per cent in the glass pot stored seeds. The lowest germination energy of 21.27 per cent was recorded in the earthen pot container. Viability per cent followed a trend parallel to that by germination per cent whereas the germination value, germination speed and per cent moisture content followed a trend parallel to that by germination energy.

4.2.4 Effect of different storage durations on the germination, viability and moisture content of *Shorea robusta* seeds in storage

Six storage durations namely, 1 week (D_1), 2 weeks (D_2), 3 weeks (D_3), 4 weeks (D_4), 5 weeks (D_5) and 6 weeks (D_6) were subjected to comparison in the light of their

Table 4.14 Effect of storage temperatures and containers on germination, viability and moisture content of *Shorea robusta* seeds in storage

Treatments	Germination				Viability per cent	Moisture content (%)
	Per cent	Energy (%)	Value	Speed		
A. Storage temperatures (°C)						
T_1: Room temp.	18.64 (16.24)	15.94 (14.47)	331.47	14.08	21.99 (21.68)	29.47
T_2: 5°±1	6.50 (8.46)	5.61 (7.77)	16.66	2.58	8.58 (11.52)	29.35
T_3:10°1±1	48.72 (44.31)	37.69 (35.84)	505.34	28.32	52.15 (47.57)	35.24
T_4:15±1	43.36 (39.59)	35.58 (33.73)	454.11	26.30	47.40 (43.65)	34.73
S.Ed.	0.41	0.26	5.70	0.34	0.31	0.04
$LSD_{0.05}$	0.93	0.59	12.89	0.54	0.70	0.13
B. Storage containers						
C_1: Earthen pot	26.83 (25.11)	21.27 (20.83)	200.92	13.07	29.64 (28.99)	25.51
C_2: Plastic bin	34.17 (30.83)	27.52 (26.04)	493.56	24.05	37.23 (34.29)	35.82
C_3: Glass pot	26.92 (25.52)	22.33 (21.99)	286.20	16.35	30.72 (30.03)	36.02
S.Ed.	0.29	0.31	6.59	0.25	0.28	0.06
$LSD_{0.05}$	0.60	0.64	13.60	0.52	0.58	0.14

*Figures within the parentheses are transformed values

impact on germination, viability and moisture content of *Shorea robusta* seeds in storage.

Germination per cent showed declining trend from one week of storage to six weeks of storage duration. The maximum value of 73.79 was recorded for germination per cent after one week of storage and the minimum value of 2.67 was recorded for germination per cent after six weeks of storage (Table 4.15). Germination energy, germination value, germination speed, viability per cent and per cent moisture content showed a similar trend to that of germination per cent.

4.2.5 Interaction effects of storage temperatures, containers and durations on the germination, viability and moisture content of *Shorea robusta* seeds in storage

Comparison of storage temperatures at individual container level (TxC) revealed that earthen pot and glass pot containers gave the maximum germination per cent of 49.00 and 44.17 per cent respectively at $10^{o}\pm1^{o}C$ storage temperature whereas the plastic bin stored seeds registered the highest germination per cent of 56.58 per cent at $15^{o}\pm1^{o}C$ storage temperature (Table 4.16). The lowest germination per cent was recorded at $5^{o}\pm1^{o}C$ for all the containers. Germination energy, germination value, germination speed, viability per cent and per cent moisture content followed a trend parallel to that by germination per cent (Tables 4.16 & 4.17). On the

Table 4.15 Effect of storage durations on the germination, viability and moisture content of *Shorea robusta* seeds in storage (Experiment I)

Treatments	Germination				Viability per cent	Per cent moisture content
	Per cent	Energy (%)	Value	Speed		
Durations						
D_1: One week	73.79 (61.91)	60.50 (51.28)	924.63	38.03	76.50 (64.36)	39.10
D_2: Two weeks	51.50 (46.02)	46.58 (42.16)	578.92	31.92	54.89 (48.75)	35.51
D_3: Three weeks	24.54 (22.28)	17.62 (17.99)	296.61	17.75	30.67 (31.50)	32.86
D_4: Four weeks	14.29 (15.91)	9.54 (12.60)	94.35	9.79	17.06 (19.60)	30.89
D_5: Five weeks	9.04 (11.35)	6.17 (9.19)	61.03	7.42	11.42 (13.95)	29.22
D_6: Six weeks	2.67 (5.44)	1.83 (4.47)	5.83	2.02	4.64 (8.48)	27.12
S.Ed.	0.34	0.35	9.75	0.33	0.32	0.08
$LSD_{0.05}$	0.67	0.69	19.11	0.65	0.63	0.16

*Figures within parentheses are transformed values

Table 4.16 Effect of storage temperature and container interactions on the germination per cent, germination energy and germination value of *Shorea robusta* seeds in storage

Storage temperatures (^{o}C)	Storage containers								
	Germination per cent			Germination energy (%)			Germination value		
	C_1	C_2	C_3	C_1	C_2	C_3	C_1	C_2	C_3
T_1	15.08 (13.87)	20.08 (17.29)	20.75 (17.56)	12.67 (12.27)	16.08 (14.65)	19.08 (16.47)	144.36	533.92	316.14
T_2	4.17 (6.65)	7.00 (8.91)	8.33 (9.82)	3.00 (5.66)	6.42 (8.48)	7.42 (9.17)	3.86	11.57	34.54
T_3	49.00 (45.32)	53.00 (47.67)	44.17 (39.95)	36.83 (36.06)	41.00 (38.63)	35.25 (32.83)	335.63	639.98	540.41
T_4	39.08 (34.60)	56.58 (49.45)	34.42 (34.72)	32.58 (29.30)	46.58 (42.40)	27.58 (29.48)	319.84	788.76	253.72
	S.Ed.	$LSD_{0.05}$		S.Ed.	$LSD_{0.05}$		S.Ed.	$LSD_{0.05}$	
For storage containers at individual temperature level	0.53	1.09		0.63	1.30		13.17	27.18	
For storage temperatures at same or different storage container level	0.59	1.27		0.59	1.24		12.17	25.65	

*Figures within parentheses are transformed values

Table 4.17 Effect of storage temperature and container interactions on the germination speed, viability and moisture content of Shorea robusta seeds in storage

Storage temperatures (°C)	Storage containers								
	Germination speed			Viability per cent			Per cent moisture content		
	C_1	C_2	C_3	C_1	C_2	C_3	C_1	C_2	C_3
T_1	10.32	18.12	13.79	17.04 (17.89)	23.29 (22.59)	25.62 (24.58)	18.06	35.29	35.05
T_2	1.29	2.80	3.66	6.54 (10.01)	9.04 (11.85)	10.17 (12.69)	22.04	32.41	33.62
T_3	22.99	34.70	27.28	52.21 (47.80)	56.29 (50.34)	47.96 (44.58)	33.41	37.71	37.62
T_4	17.66	40.57	20.68	42.79 (40.28)	60.29 (52.40)	39.12 (38.28)	28.54	37.87	37.79
	S.Ed.	$LSD_{0.05}$		S.Ed.	$LSD_{0.05}$		S.Ed.	$LSD_{0.05}$	
For storage containers at individual temperature level	0.50	1.03		0.56	1.15		0.13	0.30	
For storage temperatures at same or different storage container level	0.53	1.14		0.56	1.19		0.11	0.27	

*Figures within parentheses are transformed values

other hand, while comparing storage containers at individual temperature level, (CxT) revealed that the highest germination of 56.58 per cent was obtained in the seeds stored in the plastic bin at $15^{o}\pm1^{o}C$ followed by 53.0 per cent in the plastic bin at $10^{o}\pm1^{o}C$ temperature. The lowest germination per cent of 4.17 per cent was obtained in the earthen pot stored seeds at $5^{o}\pm1^{o}C$ storage temperature. Results obtained for germination energy, germination value, germination speed and viability per cent were comparable to that of germination per cent. Maximum moisture content of 37.87 per cent was recorded in the plastic bin stored seeds at $15^{o}\pm1^{o}C$ which is statistically at par with the 37.79 per cent in the seeds stored in glass pot at $15^{o}\pm1^{o}C$. The lowest moisture content of 18.06 per cent was recorded at the room temperature in the earthen pot container (Table 4.17).

Comparing storage durations at individual temperature level (DxT) showed that storage for one week yielded maximum germination of 80.0 per cent which was found to be declining thereafter (Table 4.18). The rate of decline of germination per cent was almost same at $10^{o}\pm1^{o}C$ and $15^{o}\pm1^{o}C$. The loss in the germinability after 6 weeks of storage at $10^{o}\pm1^{o}C$ storage temperature was 93.67 per cent where as at $15^{o}\pm1^{o}C$ storage temperature, it was 93.67 per cent. At room temperature and at $5^{o}\pm1^{o}C$, germination per cent came down to zero after three weeks of storage whereas at $10^{o}\pm1^{o}C$ and $15^{o}\pm1^{o}C$ storage

Table 4.18 Effect of storage temperature and duration interaction on the germination per cent and germination energy of *Shorea robusta* seeds

Storage durations	Storage temperatures							
	Germination per cent				Germination energy (%)			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
D_1	80.00 (63.58)	28.17 (31.87)	96.17 (78.97)	90.83 (73.21)	65.33 (54.02)	24.33 (29.14)	76.50 (61.20)	75.83 (60.76)
D_2	31.83 (33.86)	10.83 (18.88)	88.17 (70.17)	75.17 (61.18)	30.33 (32.77)	9.33 (17.48)	78.00 (62.16)	68.67 (56.22)
D_3	0.00 (0.002)	0.00 (0.002)	51.00 (45.58)	47.17 (43.53)	0.00 (0.002)	0.00 (0.002)	36.50 (37.04)	34.00 (34.93)
D_4	0.00 (0.002)	0.00 (0.002)	28.50 (32.00)	28.67 (31.65)	0.00 (0.002)	0.00 (0.002)	17.33 (24.16)	20.83 (26.27)
D_5	0.00 (0.002)	0.00 (0.002)	23.17 (28.24)	13.00 (17.14)	0.00 (0.002)	0.00 (0.002)	14.83 (22.32)	9.83 (14.42)
D_6	0.00 (0.002)	0.00 (0.002)	5.33 (10.90)	5.33 (10.85)	0.00 (0.002)	0.00 (0.002)	3.00 (8.13)	4.33 (9.76)

	S.Ed.	$LSD_{0.05}$	S.Ed.	$LSD_{0.05}$
For storage durations at same temperature level	0.48	0.94	0.49	0.96
For storage temperatures at same or different duration level	0.74	1.52	0.70	1.41

*Figures within parentheses are transformed values

temperature, germination per cent after three weeks of storage was 51.0 and 47.17 per cent respectively. Trend parallel to that of germination per cent emerged for germination energy, germination value, and germination speed (Table 4.19). Viability per cent came down to zero after five weeks of storage at room temperature. The rate of decline in the viability per cent was almost similar at $10^{o}\pm1^{o}C$ and $15^{o}\pm1^{o}C$ storage temperature. The loss in the viability per cent after six weeks of storage was 88.83 per cent at $10^{o}\pm1^{o}C$ and 90.58 per cent at $15^{o}\pm1^{o}C$ storage temperature. The rate of decline of per cent moisture content was highest at room temperature i.e. the loss in the moisture content was 18.81 per cent after six weeks of storage at room temperature. The rate of decline of per cent moisture content was minimum at $10^{o}\pm1^{o}C$ storage temperature i.e. the loss in the moisture content was 7.36 per cent after six weeks in storage (Table 4.20). Comparison of storage temperatures at individual duration level (TxD) indicated that highest germination per cent of 96.17 per cent was obtained after one week of storage for the seeds stored at $10^{o}\pm1^{o}C$ (Table 4.18). $10^{o}\pm1^{o}C$ storage temperature gave better results than other temperatures for all the durations. Germination energy, and viability showed a similar trend. Highest germination value of 1421.83 was obtained at room temperature after one week of storage. Maximum germination speed of 53.22 was recorded after the one week of storage at room temperature. Highest per cent

Table 4.19 Effect of storage temperature and duration interactions on the germination value and germination speed of *Shorea robusta* seeds in storage

Storage durations	Storage temperatures							
	Germination value				Germination speed			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
D_1	1421.83	90.47	1139.51	1046.72	53.22	11.99	44.07	42.84
D_2	567.00	9.47	1051.84	687.36	31.25	3.52	50.49	42.41
D_3	0.00	0.00	594.77	591.68	0.00	0.00	37.12	33.90
D_4	0.00	0.00	112.83	264.55	0.00	0.00	16.48	22.66
D_5	0.00	0.00	126.44	117.67	0.00	0.00	18.27	11.42
D_6	0.00	0.00	6.66	16.67	0.00	0.00	3.51	4.58

	S.Ed.	$LSD_{0.05}$	S.Ed.	$LSD_{0.05}$
For storage durations at individual temperature level	13.79	27.03	0.46	0.90
For storage temperatures at same or different duration level	18.70	37.18	0.69	1.40

Table 4.20 Effect of storage temperature and duration interactions on the viability per cent and per cent moisture content of *Shorea robusta* seeds in storage

Storage durations	Storage temperatures							
	Viability per cent				Per cent moisture content			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
D_1	82.25 (65.38)	32.75 (34.81)	97.25 (80.75)	93.75 (76.50)	38.42	37.39	39.86	40.73
D_2	35.83 (36.39)	14.08 (21.93)	91.00 (72.82)	78.67 (63.87)	33.98	33.30	37.71	37.06
D_3	10.83 (18.96)	4.67 (12.37)	55.42 (48.21)	51.75 (46.47)	30.50	29.09	36.59	35.25
D_4	3.00 (9.36)	0.00 (0.002)	32.17 (34.41)	33.08 (34.63)	27.13	27.25	35.20	33.99
D_5	0.00 (0.002)	0.00 (0.002)	26.92 (30.91)	18.75 (24.88)	24.82	25.61	34.68	31.79
D_6	0.00 (0.002)	0.00 (0.002)	10.17 (18.33)	8.42 (15.57)	21.98	23.52	33.43	29.57
			S.Ed.	$LSD_{0.05}$	S.Ed.		$LSD_{0.05}$	
For storage durations at individual temperature level			0.45	0.88	0.11		0.21	
For storage temperatures at same or different duration level			0.66	1.34	0.15		0.31	

*Figures within parentheses are transformed values

moisture content of 40.73 per cent was obtained at $15^{o}\pm1^{o}C$ storage temperature after one week of storage duration followed by 39.86 per cent at $10^{o}\pm1^{o}C$ storage temperature after the same storage duration (Table 4.20).

Comparing the storage duration at the individual container level (DxC) revealed that the loss of germinability after six weeks of storage was 94.75 per cent and 97.38 per cent respectively for plastic bin and glass pot stored seeds. Whereas it was 96.88 per cent for the seeds stored in the earthen pot (Table 4.21). Trend parallel to that of per cent germination emerged for germination energy, germination value, germination speed and viability per cent. In case of earthen pot stored seeds, the moisture content decreased down to 17.73 per cent after six weeks of storage from 36.95 per cent after one week of storage duration. The loss in the moisture content from one week of storage upto the six weeks of storage was 9.71 per cent and 8.23 per cent for plastic bin and glass pot stored seeds, respectively. Comparison of storage containers at individual duration level (CxD) indicated highest values of germination per cent for the seeds stored in the plastic bin for all the durations. Trend parallel to that of per cent germination was obtained for germination energy, germination value, germination speed and viability per cent. Per cent moisture content was higher for the seeds stored in the plastic bin and glass pot for all the

Table 4.21 Effect of storage container and duration interactions on the germination per cent and germination energy of *Shorea robusta* seeds in storage

Storage durations	Storage containers					
	Germination per cent			Germination energy (%)		
	C_1	C_2	C_3	C_1	C_2	C_3
D_1	70.87 (59.93)	76.50 (64.20)	74.00 (61.59)	56.62 (48.65)	61.50 (52.10)	63.37 (53.09)
D_2	50.87 (45.63)	53.62 (47.31)	50.00 (45.13)	42.37 (38.75)	51.00 (45.31)	46.37 (42.41)
D_3	17.62 (18.21)	36.00 (29.11)	20.00 (19.52)	13.62 (15.73)	26.25 (23.23)	13.00 (15.03)
D_4	12.50 (14.71)	20.25 (19.71)	10.12 (13.32)	9.37 (12.50)	13.00 (15.03)	6.25 (10.30)
D_5	7.00 (7.98)	14.37 (16.20)	5.75 (9.86)	4.50 (6.27)	10.25 (13.42)	3.75 (7.87)
D_6	2.12 (4.21)	4.25 (8.44)	1.62 (3.66)	1.12 (3.05)	3.12 (7.16)	1.25 (3.22)
	S.Ed.	$LSD_{0.05}$		S.Ed.	$LSD_{0.05}$	
For storage durations at individual container level	0.59	1.16		0.60	1.78	
For storage containers at same or different duration level	0.59	1.16		0.63	1.23	

*Figures within parentheses are transformed values

durations (Table 4.22 & 4.23). Per cent moisture content was lowest in the seeds stored in the earthen pot for all the durations (Table 4.23).

Comparison of storage temperatures at the same combination of storage container and duration (TxCxD) revealed that $10^{o}\pm1^{o}C$ storage temperature outperformed all the others (Table 4.24). Comparing the storage containers at similar storage temperature and duration level, it was found that glass pot recorded higher values for germination per cent at room temperature and $5^{o}\pm1^{o}C$ storage temperature. Whereas plastic bin recorded higher values for germination per cent at $10^{o}\pm1^{o}C$ and $15^{o}\pm1^{o}C$ storage temperatures. A clear pattern showing the fall in the per cent germination emerged when the six storage durations were compared amongst themselves. Germination per cent was highest after one week storage and lowest after six weeks of storage. The fall in per cent germination was maximum in the earthen pot seeds stored at $5^{o}\pm1^{o}C$ temperature. Further scrutiny of the data led to the inference that decline in per cent germination was least in the plastic bin seeds stored at $15^{o}\pm1^{o}C$ temperature for various storage durations. Plastic bin seeds stored at $15^{o}\pm1^{o}C$ temperature recorded 94.5 per cent germination after one week, 49.5 per cent germination after one month and 9.5 per cent germination after six weeks of storage.

Table 4.22 Effect of storage container and duration interactions on the germination value and germination speed of *Shorea robusta* seeds in storage

Storage durations	Storage containers					
	Germination value			Germination speed		
	C_1	C_2	C_3	C_1	C_2	C_3
D_1	642.84	1276.52	854.54	35.27	43.77	35.06
D_2	456.43	718.10	562.23	25.35	37.58	32.83
D_3	40.12	637.39	212.33	6.31	30.78	16.16
D_4	24.08	194.08	64.87	4.61	16.56	8.19
D_5	39.66	124.16	19.25	5.60	12.16	4.50
D_6	2.42	11.08	4.00	1.26	3.44	1.37

	S.Ed.	$LSD_{0.05}$	S.Ed.	$LSD_{0.05}$
For storage durations at individual container level	16.89	33.10	0.56	1.10
For storage containers at same or different duration level	16.77	32.87	0.57	1.12

Table 4.23 Effect of storage container and duration interactions on the viability and per cent moisture content of *Shorea robusta* seeds in storage

Storage durations	Storage containers					
	Viability per cent			Per cent moisture content		
	C_1	C_2	C_3	C_1	C_2	C_3
D_1	79.19 (62.10)	79.12 (66.79)	77.19 (64.19)	36.95	40.25	40.09
D_2	54.06 (48.76)	57.00 (49.88)	53.62 (47.62)	29.89	38.52	38.12
D_3	22.69 (26.17)	42.00 (38.43)	27.31 (29.90)	25.05	37.04	36.48
D_4	14.50 (17.49)	22.56 (22.78)	14.12 (18.54)	22.93	34.72	35.03
D_5	9.94 (12.64)	16.25 (17.37)	8.06 (11.82)	20.53	33.31	33.83
D_6	3.50 (6.81)	6.44 (10.50)	4.00 (8.11)	17.73	31.08	32.56
		S.Ed.	$LSD_{0.05}$	S.Ed.	$LSD_{0.05}$	
For storage durations at individual container level		0.55	1.08	0.13	0.25	
For storage containers at same or different duration level		0.77	1.51	0.10	0.20	

*Figures within parentheses are transformed values

Table 4.24 Effect of TxCxD (temperature x container x duration) internations on germination percentage of *Shorea robusta* seeds in storage

Temperature x container	Storage durations					
	D_1	D_2	D_3	D_4	D_5	D_6
T_1C_1	75.00	15.50	0.00	0.00	0.00	0.00
T_1C_2	84.50	36.00	0.00	0.00	0.00	0.00
T_1C_3	80.50	44.00	0.00	0.00	0.00	0.00
T_2C_1	19.00	6.00	0.00	0.00	0.00	0.00
T_2C_2	30.00	12.00	0.00	0.00	0.00	0.00
T_2C_3	35.50	14.50	0.00	0.00	0.00	0.00
T_3C_1	94.50	91.50	36.00	35.50	28.00	8.50
T_3C_2	97.00	86.00	65.50	31.50	31.00	7.50
T_3C_3	97.00	87.00	51.50	18.50	11.00	0.00
T_4C_1	95.00	90.50	34.50	14.50	0.00	0.00
T_4C_2	94.50	80.50	78.50	49.50	27.00	9.50
T_4C_3	83.00	54.50	28.50	22.00	12.00	6.50

	S.Ed.	$LSD_{0.05}$
For two storage temperatures at the same combination of treatments and duration	1.60	3.62
For two treatments at the same combination of temperature and duration	1.52	3.14
For two storage durations at the same combination of temperature and treatments	1.50	2.94

4.3 STORAGE OF *Shorea robusta* SEEDS (Experiment II)

4.3.1 Effect of storage temperatures on the germination, viability and moisture content of *Shorea robusta* seeds in storage

In the second experiment, *Shorea robusta* seeds were stored under two storage temperatures, namely room temperature and 15°±1°C. Storage temperature of 15°±1°C resulted in 26.0 per cent germination whereas room temperature resulted in 11.29 per cent germination. Results similar to that of germination per cent were obtained for germination energy, germination value, germination speed, viability per cent and per cent moisture content (Table 4.25).

4.3.2 Effect of different seed treatments on the germination, viability and moisture content of *Shorea robusta* seeds in storage

Six different types of treatments namely coating the seed with gum (t_1), storage of seed in lime (t_2), storage of seed in saw dust (t_3), coating the seed with clay (t_4), coating the seed with paraffin wax (t_5) and control (t_6) were assessed for their influence on germination of *Shorea robusta* seeds in storage. Highest germination per cent of 31 per cent was recorded in the seeds coated with paraffin wax, whereas the lowest germination per cent of 9.08 per cent was recorded in the seeds coated with the gum. Trend parallel to that of germination per cent was obtained for the germination energy,

Table 4.25 Effect of storage temperatures and different treatments on germination, viability and moisture content of *Shorea robusta* seeds in storage

Treatments	Germination				Viability per cent	Per cent moisture content
	Per cent	Energy (%)	Value	Speed		
A. Storage temperatures (°C)						
T_1: Room temp.	11.29 (10.08)	9.29 (8.83)	42.12	4.13	14.87 (15.60)	14.32
T_2: 15°±1	26.00 (23.58)	20.69 (20.17)	132.90	10.27	30.04 (28.43)	22.03
S.Ed.	0.22	0.26	3.61	0.09	0.21	0.07
$LSD_{0.05}$	0.45	0.53	7.35	0.18	0.43	0.15
B. Treatments						
t_1: Gum paste	9.08 (8.71)	8.50 (8.37)	17.06	2.67	12.37 (13.50)	20.56
t_2: Lime	22.17 (19.51)	16.54 (15.75)	119.02	7.84	26.10 (25.03)	15.51
t_3: Saw dust	24.46 (22.21)	19.00 (18.83)	97.41	8.91	28.54 (27.47)	22.29
t_4: Clay suspension	10.71 (8.92)	6.92 (6.68)	48.16	4.14	14.67 (15.21)	14.06
t_5: Paraffin wax	31.00 (28.31)	29.69 (27.27)	185.86	14.62	35.50 (33.02)	17.29
t_6: Control	14.46 (13.30)	9.31 (10.02)	57.56	5.02	17.54 (17.86)	19.35
S.Ed.	0.39	0.45	6.26	0.15	0.37	0.12
$LSD_{0.05}$	0.79	0.92	12.75	0.30	0.75	0.26

*Figures within parentheses are transformed values

germination speed, germination value and viability per cent. Maximum moisture content of 22.29 per cent was recorded in the seeds stored in the sawdust whereas the minimum moisture content of 14.06 per cent was recorded on the seeds stored by coating with clay (Table 4.25).

4.3.3 Effect of storage durations on the germination, viability and moisture content of *Shorea robusta* seeds in storage

Six storage durations namely, one week (D_1), 2 weeks (D_2), 3 weeks (D_3), 4 weeks (D_4), 5 weeks (D_5) and 6 weeks (D_6) were subjected to comparison in the light of their impact on the germination of *Shorea robusta* seeds in storage. Germination percentage showed declining trend from one week of storage to the six weeks of storage duration with maximum value of 69.06 per cent after one week of storage and minimum value of 0.58 per cent after six weeks of storage. Germination energy, germination value, germination speed, viability per cent and per cent moisture content showed similar trend to that of germination per cent (Table 4.26).

4.3.4 Interaction effects of storage temperatures, seed treatments and storage durations on the germination, viability and moisture content of *Shorea robusta* seeds

Comparison of treatments at individual temperature level (txT) revealed that germination per cent of 17.25 per cent and 44.75 per cent were recorded both at room temperature and $15^{o}\pm1^{o}C$ respectively, for the seeds coated

Table 4.26 Effect of storage durations on the germination, viability and moisture content of *Shorea robusta* seeds in storage(Experiment II)

Treatments	Germination				Viability per cent	Per cent moisture content
	Per cent	Energy (%)	Value	Speed		
Durations						
D_1: One week	69.06 (57.09)	56.85 (49.53)	362.76	27.81	73.35 (59.98)	27.47
D_2: Two weeks	23.98 (22.53)	16.67 (17.91)	120.37	9.32	33.27 (34.31)	21.07
D_3: Three weeks	11.08 (11.29)	9.33 (10.04)	97.41	3.66	15.75 (20.53)	18.15
D_4: Four weeks	5.00 (6.24)	4.58 (5.96)	48.16	1.36	7.02 (9.16)	15.96
D_5: Five weeks	2.17 (2.55)	2.17 (2.55)	185.86	0.87	3.92 (5.50)	14.24
D_6: Six weeks	0.58 (1.28)	0.35 (0.99)	57.56	0.17	1.42 (2.62)	12.16
S.Ed.	0.22	0.45	26.08	1.21	1.15	1.14
$LSD_{0.05}$	0.43	0.88	51.12	2.37	2.25	2.28

*Figures within parentheses are transformed values

with paraffin wax and germination of 7.83 per cent and 10.33 per cent in the seeds coated with gum at room and 15°±1°C temperatures, respectively (Table 4.27). Maximum per cent moisture content of 19.21 per cent at room temperature was recorded in the seeds treated with gum paste and at 15°±1°C, maximum moisture content was 31.65 per cent was recorded in the seeds stored in the sawdust and moisture content of 11.50 per cent and 16.62 per cent for the seeds treated with clay suspension at the room temperature and 15°±1°C respectively (Table 4.28). Trend parallel to that of germination per cent emerged for germination energy, germination value, germination speed and viability per cent. Comparing storage temperatures at individual treatment level (Txt) indicated that seeds stored at 15°±1°C storage temperature gave better results as compared to the seeds stored at room temperature. Per cent moisture content was also higher for the seeds stored at 15°±1°C storage temperature for all the treatments.

Comparison of storage durations at the individual temperature level (DxT) revealed that per cent germination came down to zero after three weeks of storage from 62.0 per cent after one week of storage at room temperature whereas at 15°±1°C, germination per cent after one week was 76.12 per cent and came down to 1.17 per cent after six weeks of storage (Table 4.29). Trend parallel to that of germination per cent emerged for germination energy, germination value,

Table 4.27 *Effect of storage temperature and treatment interactions on the germination per cent, germination energy and germination value of* ***Shorea robusta*** *seeds in storage*

Storage treatments	Storage temperatures (°C)					
	Per cent germination		Germination energy (%)		Germination value	
	T_1	T_2	T_1	T_2	T_1	T_2
t_1	7.83 (7.21)	10.33 (10.21)	7.83 (7.21)	9.17 (9.53)	11.44	22.67
t_2	13.17 (10.46)	31.17 (28.57)	9.25 (8.03)	23.83 (23.48)	60.80	117.23
t_3	10.92 (11.23)	38.00 (33.21)	7.58 (9.16)	30.42 (28.50)	28.02	166.81
t_4	8.83 (7.79)	12.58 (10.06)	7.25 (6.88)	6.58 (6.49)	32.06	64.25
t_5	17.25 (15.47)	44.75 (41.15)	15.92 (14.46)	43.46 (40.08)	96.61	275.12
t_6	9.75 (8.32)	19.17 (18.29)	7.92 (7.25)	10.71 (12.93)	23.79	91.32
	S.Ed.	$LSD_{0.05}$	S.Ed.	$LSD_{0.05}$	S.Ed.	$LSD_{0.05}$
For storage temperature at same or different treatment level	0.55	1.12	0.63	1.28	8.45	17.21
For treatments at individual storage temperature level	0.55	1.12	0.63	1.28	8.85	18.03

*Figures within parentheses are transformed values

Table 4.28 Effect of storage temperature and treatment interactions on the germination speed, viability per cent and moisture content of Shorea robusta seeds in storage

Storage treatments	Storage temperatures (°C)					
	Germination speed		Viability per cent		Per cent moisture content	
	T_1	T_2	T_1	T_2	T_1	T_2
t_1	2.20	3.14	11.25 (12.75)	13.50 (14.25)	19.21	21.91
t_2	4.06	11.62	17.92 (17.23)	34.29 (32.82)	12.53	18.48
t_3	3.38	14.43	13.42 (14.52)	43.67 (40.41)	12.93	31.65
t_4	3.20	5.08	12.50 (13.84)	16.83 (16.59)	11.50	16.62
t_5	9.07	20.17	20.83 (21.13)	50.17 (44.90)	13.55	21.02
t_6	2.85	7.20	13.29 (14.12)	21.79 (21.61)	16.18	22.51
	S.Ed.	$LSD_{0.05}$	S.Ed.	$LSD_{0.05}$	S.Ed.	$LSD_{0.05}$
For storage temperatures at same or different treatment level	0.22	0.45	0.52	1.06	0.17	0.35
For treatments at individual storage temperature level	0.22	0.45	0.52	1.06	0.17	0.37

*Figures within parentheses are transformed values

Table 4.29 Effect of storage temperature and duration interactions on the germination per cent, germination energy and germination value of *Shorea robusta* seeds in storage (Experiment II)

Durations	Storage temperatures					
	Germination per cent		Germination energy (%)		Germination value	
	T_1	T_2	T_1	T_2	T_1	T_2
D_1	62.00 (52.37)	76.12 (61.81)	51.75 (46.27)	61.96 (52.80)	246.66	478.85
D_2	5.75 (8.10)	42.21 (36.95)	4.00 (6.72)	29.33 (29.10)	6.05	234.68
D_3	0.00 (0.003)	22.17 (22.57)	0.00 (0.003)	18.67 (20.08)	0.00	63.74
D_4	0.00 (0.003)	10.00 (12.48)	0.00 (0.003)	9.17 (11.92)	0.00	11.73
D_5	0.00 (0.003)	4.33 (5.10)	0.00 (0.003)	4.33 (5.10)	0.00	8.00
D_6	0.00 (0.003)	1.17 (2.56)	0.00 (0.003)	0.71 (1.98)	0.00	0.41
	S.Ed.	$LSD_{0.05}$	S.Ed.	$LSD_{0.05}$	S.Ed.	$LSD_{0.05}$
For storage temperatures at same or different duration level	2.51	4.92	2.02	3.96	33.86	66.39
For storage durations at individual temperature level	2.73	5.35	2.19	4.29	36.88	72.28

*Figures within parentheses are transformed values

germination speed and viability per cent. At room temperature, the moisture content after one week storage was 24.49 per cent which came down to 9.33 per cent after six weeks of storage whereas at $15^{o}\pm1^{o}C$, the moisture content after one week storage was 30.45 per cent which came down to 14.99 per cent after six weeks of storage (Table 4.30). Comparing storage temperatures at individual duration level (TxD) indicated better results at $15^{o}\pm1^{o}C$ storage temperature for all the durations. Per cent moisture content was higher in the seeds stored at $15^{o}\pm1^{o}C$ for all the durations.

Comparison of storage durations at the individual treatment level (Dxt) revealed that in case of seeds coated with gum, germination per cent came down to zero after three weeks of storage from 52.25 per cent after one week of storage (Table 4.31). In case of seeds stored in the lime and sawdust, zero per cent germination was recorded after the five weeks of storage. In case of seeds coated with clay, the germination per cent after one week of storage was 64.25 per cent and it came down to zero per cent after two weeks of storage. In the control, zero germination per cent was recorded after 4 weeks of storage. Coating of seeds with paraffin wax was the most effective treatment giving 75.25 per cent germination after one week and 3.5 per cent after six weeks of storage. Trend similar to that of germination per cent was recorded for germination energy, germination

Table 4.30 Effect of storage temperature and duration interaction on the germination speed, viability and moisture content of *Shorea robusta* seeds in storage (Experiment II)

Durations	Storage temperatures					
	Germination speed		Viability per cent		Per cent moisture content	
	T_1	T_2	T_1	T_2	T_1	T_2
D_1	23.14	32.48	66.54 (55.23)	80.17 (64.73)	24.49	30.45
D_2	1.62	17.02	17.37 (24.34)	49.17 (44.27)	16.57	25.56
D_3	0.00	7.32	4.79 (12.36)	26.71 (28.69)	13.41	22.89
D_4	0.00	2.73	0.50 (1.65)	13.54 (16.66)	11.77	20.14
D_5	0.00	1.75	0.00 (0.003)	7.83 (10.99)	10.33	18.15
D_6	0.00	0.34	0.00 (0.003)	2.83 (5.24)	9.33	14.99
	S.Ed.	$LSD_{0.05}$	S.Ed.	$LSD_{0.05}$	S.Ed.	$LSD_{0.05}$
For storage temperatures at same or different duration level	2.53	4.96	1.50	2.94	1.47	2.88
For storage durations at individual temperature level	2.77	5.43	1.63	3.19	1.61	3.22

*Figures within parentheses are transformed values

Table 4.31 *Effect of treatment and storage duration interactions on the germination per cent and germination energy of Shorea robusta seeds in storage*

Durations	Treatments											
	Germination per cent						Germination energy (%)					
	t_1	t_2	t_3	t_4	t_5	t_6	t_1	t_2	t_3	t_4	t_5	t_6
D_1	52.25 (46.30)	86.75 (69.81)	70.25 (58.15)	64.25 (53.54)	75.25 (60.53)	65.62 (54.23)	48.75 (44.26)	70.75 (58.12)	61.50 (53.07)	41.50 (40.08)	75.25 (60.53)	43.37 (41.14)
D_2	2.25 (5.96)	30.50 (25.69)	47.25 (42.78)	0.00 (0.002)	45.75 (42.22)	18.12 (18.51)	2.25 (5.96)	17.75 (18.28)	27.75 (30.40)	0.00 (0.002)	41.75 (39.21)	10.50 (13.64)
D_3	0.00 (0.002)	13.50 (15.63)	19.75 (19.46)	0.00 (0.002)	30.25 (25.54)	3.00 (7.08)	0.00 (0.002)	8.50 (12.16)	16.50 (17.53)	0.00 (0.002)	29.00 (24.81)	2.00 (5.75)
D_4	0.00 (0.002)	2.25 (5.96)	9.50 (12.91)	0.00 (0.002)	18.25 (18.58)	0.00 (0.002)	0.00 (0.002)	2.25 (5.96)	8.25 (11.96)	0.00 (0.002)	17.00 (17.83)	0.00 (0.002)
D_5	0.00 (0.002)	0.00 (0.002)	0.00 (0.002)	0.00 (0.002)	13.00 (15.30)	0.00 (0.002)	0.00 (0.002)	0.00 (0.002)	0.00 (0.002)	0.00 (0.002)	13.00 (15.31)	0.00 (0.002)
D_6	0.00 (0.002)	0.00 (0.002)	0.00 (0.002)	0.00 (0.002)	3.5 (7.66)	0.00 (0.002)	0.00 (0.002)	0.00 (0.002)	0.00 (0.002)	0.00 (0.002)	2.12 (5.94)	0.00 (0.002)
	S.Ed.	$LSD_{0.05}$					S.Ed.	$LSD_{0.05}$				
For treatments at at same or different duration level	4.34	8.51					3.49	6.84				
For storage durations at individual treatment level	4.74	9.29					3.79	7.43				

*Figures within parentheses are transformed values

value, germination speed, and viability per cent (Tables 4.31, 4.32 & 4.33). Per cent moisture content declined with the increase in the storage time for all the treatments. For the seeds coated with gum, moisture content was 23.06 per cent after one week of storage and 18.65 per cent after six weeks of storage. Seeds stored in the lime and sawdust recorded the highest moisture content of 24.53 and 30.59 per cent respectively after one week of storage and minimum of 10.32 and 14.82 per cent for lime and sawdust respectively after six weeks of storage. The highest value of moisture content for seeds coated with clay and paraffin wax was 20.41 and 28.66 per cent after one week of storage and these came down to 9.54 and 11.01 per cent respectively, after six weeks of storage. The rate of loss of moisture content was faster in the control.

Comparing treatments at individual duration level (txD) indicated that highest per cent germination was obtained in case of seeds coated with paraffin wax and lowest for the seeds coated with the gum for all the durations. Trend parallel to that of per cent germination was also obtained for germination energy, germination value, germination speed and viability per cent. Highest per cent moisture content was recorded in the control after one week of storage and lowest in the seeds coated with the clay after six weeks of storage.

Table 4.32 Effect of treatment and storage duration interactions on the germination value and germination speed of *Shorea robusta* seeds in storage

Durations	Treatments											
	Germination value						Germination speed					
	t_1	t_2	t_3	t_4	t_5	t_6	t_1	t_2	t_3	t_4	t_5	t_6
D_1	99.21	521.04	228.64	288.95	729.50	309.22	14.91	30.04	25.64	24.83	47.50	23.94
D_2	3.12	181.19	316.33	0.00	186.45	35.10	1.12	13.12	19.48	0.00	16.91	5.28
D_3	0.00	10.93	32.77	0.00	146.49	1.02	0.00	3.31	5.79	0.00	11.94	0.91
D_4	0.00	0.94	6.74	0.00	27.50	0.00	0.00	0.56	2.51	0.00	5.10	0.00
D_5	0.00	0.00	0.00	0.00	24.00	0.00	0.00	0.00	0.00	0.00	5.25	0.00
D_6	0.00	0.00	0.00	0.00	1.24	0.00	0.00	0.00	0.00	0.00	1.02	0.00
		S.Ed.	$LSD_{0.05}$					S.Ed.	$LSD_{0.05}$			
For treatments at same or different duration level		58.48	116.58					4.38	8.58			
For storage durations at individual treatment level		63.87	125.18					4.79	9.39			

Table 4.33 Effect of treatment and storage duration interactions on the viability and moisture content of *Shorea robusta* seeds in storage

Durations	Treatments											
	Viability per cent						Per cent moisture content					
	t_1	t_2	t_3	t_4	t_5	t_6	t_1	t_2	t_3	t_4	t_5	t_6
D_1	58.75 (50.10)	89.37 (72.31)	74.00 (60.79)	67.62 (55.65)	80.12 (63.93)	70.25 (57.08)	23.06	24.53	30.59	20.41	28.66	37.57
D_2	12.00 (20.23)	42.87 (40.46)	51.87 (46.48)	15.87 (23.41)	50.87 (45.56)	26.12 (29.70)	22.53	18.54	26.66	15.78	20.45	22.45
D_3	8.50 (10.66)	16.87 (21.90)	25.12 (27.48)	4.50 (12.21)	37.25 (35.68)	7.25 (15.24)	20.10	15.87	23.56	14.74	15.97	18.64
D_4	0.00 (0.002)	5.37 (9.55)	12.75 (15.16)	0.00 (0.002)	22.37 (25.08)	1.62 (5.15)	19.69	13.02	19.69	12.99	14.68	15.67
D_5	0.00 (0.002)	2.12 (5.94)	6.25 (10.35	0.00 (0.002)	15.12 (16.67)	0.00 (0.002)	19.34	10.73	18.40	10.89	12.96	13.12
D_6	0.00 (0.002)	0.00 (0.002)	1.25 (4.53)	0.00 (0.002)	7.25 (11.19)	0.00 (0.002)	18.65	10.33	14.82	9.54	11.01	8.62
	S.Ed.	$LSD_{0.05}$					S.Ed.	$LSD_{0.05}$				
For treatments at same or different duration level	2.60	5.10					1.80	3.53				
For storage durations at individual treatment level	2.82	5.53					2.79	5.47				

*Figures within parentheses are transformed values

Comparison of storage temperatures at the same combination of treatment and duration (TxtxD) revealed that $15^{o}\pm1^{o}C$ storage temperature gave better results than room temperature (Table 4.34). Comparing the different seed treatments at similar storage temperature and duration level, it was found that seeds coated with paraffin wax recorded invariably higher values for germination per cent at both the temperatures. A clear pattern showing the fall in per cent germination emerged when the six storage durations were compared amongst themselves. The fall in the per cent germination was maximum in the seeds coated with gum and stored at room temperature. Further scrutiny of the data led to the inference that decline in per cent germination was least in seeds coated with the paraffin wax and stored at $15^{o}\pm1^{o}C$ storage temperature. Seeds coated with paraffin wax and stored at $15^{o}\pm1^{o}C$ storage temperature recorded 69.0 per cent germination after one week of storage, 36.5 per cent germination after four weeks of storage and 7.0 per cent germination after six weeks of storage.

Table 4.34 Effect of TxtxD (temperature x treatment x duration) interactions on germination percentage of *Shorea robusta* seeds in storage

Temperature x treatment	Storage durations					
	D_1	D_2	D_3	D_4	D_5	D_6
T_1t_1	42.00	0.00	0.00	0.00	0.00	0.00
T_1t_2	79.00	0.00	0.00	0.00	0.00	0.00
T_1t_3	53.00	12.50	0.00	0.00	0.00	0.00
T_1t_4	53.00	0.00	0.00	0.00	0.00	0.00
T_1t_5	81.50	22.00	0.00	0.00	0.00	0.00
T_1t_6	58.50	0.00	0.00	0.00	0.00	0.00
T_2t_1	57.50	4.50	0.00	0.00	0.00	0.00
T_2t_2	94.50	61.00	27.00	4.50	0.00	0.00
T_2t_3	87.50	82.00	39.50	19.00	0.00	0.00
T_2t_4	75.50	0.00	0.00	0.00	0.00	0.00
T_2t_5	69.00	69.50	60.50	36.50	26.00	7.00
T_2t_6	72.75	31.25	6.00	0.00	0.00	0.00

	S.Ed.	$LSD_{0.05}$
For two storage temperatures at the same combination of containers and duration	5.40	10.96
For two containers at the same combination of temperature and duration	7.64	15.51
For two storage durations at the same combination of temperature and containers	5.89	11.54

Chapter-5

DISCUSSION

DISCUSSION

The results obtained from the present investigation have been discussed in this chapter, establishing a cause and effect relationship, wherever necessary or feasible, in the light of available literature, under the following heads:

5.1 Seed storage studies

5.1.1 Effect of storage temperature on seed longevity

5.1.2 Effect of storage container on seed longevity

5.1.3 Effect of storage medium on seed longevity

5.1.4 Effect of storage duration on seed longevity

5.1.5 Interaction effects of temperature, container, duration and medium on seed longevity

5.1 Seed storage studies

Seed storage studies were carried out on *Toona ciliata* and *Shorea robusta*. Seeds of both these species have low longevity. Seeds of *Toona ciliata* lose viability after about two months if kept open and behave in a recalcitrant manner. Seeds are very small in size and winged. Seeds of *Shorea robusta* loose viability within 10 days of collection and rapid loss of moisture content is the chief cause of loss in the seed viability. Loss in the seed viability within a few days after collection causes heavy loss to nurserymen and disturb the seedling production targets. Hence it adds to the production cost of seedlings. Seed storage was thus viewed as

a practical necessity associated with massive afforestation programmes.

5.1.1 Effect of storage temperature on seed longevity

Seed longevity is a function primarily of storage temperature and moisture content of the seed. Depending on the storage conditions, we are able to vary the longevity of seed from less than a day over a hundred years. For *Toona ciliata*, four storage temperatures namely, room temperature, $-10\pm1^{o}C$, $0^{o}\pm1^{o}C$ and $10^{o}\pm1^{o}C$ were investigated for their influence on seed longevity. $0^{o}\pm1^{o}C$ storage temperature proved most ideal and conducive for storage. Seeds stored at this temperature recorded 95.5 per cent average germination which was considerably greater as compared to other storage temperatures. Better retention of viability at $0^{o}\pm1^{o}C$ is possibly due to the reason that biological processes in seeds are slowed down at near freezing temperature, thus enhancing seed longevity. One main cause of loss of seed viability is the loss of moisture content from the seeds. Per cent moisture content was highest at $-10^{o}\pm1^{o}C$ storage temperature because seeds were stored in the freezer of refrigerator. At the time of power failure, ice melted and seeds gained moisture. Therefore one possible reason for high seed longevity at $0^{o}\pm1^{o}C$ is due to the higher per cent moisture content in case of seeds stored at this temperature as compared to the room temperature and $10^{o}\pm1^{o}C$. Rapid loss of

viability at -10°±1°C may be attributed to the chilling damage as the seeds contained relatively higher moisture content at the time of storage.

For *Shorea robusta*, four storage temperatures, namely room temperature, 5°±1°C, 10°±1°C and 15°±1°C were investigated for their influence on seed longevity. 10°±1°C storage temperature proved most ideal and conducive for storage. Seeds stored at this temperature recorded 48.7 per cent average germination. At 10°±1°C storage temperature, per cent moisture content was maximum (35.24%) and that is the one reason for higher germination per cent at this temperature. There was a rapid loss in the moisture content at room temperature and at 5°±1°C storage temperature. Rapid loss in the germination per cent at 5°±1°C is due to the chilling damage to the seeds as the seeds contained relatively higher moisture content at the time of storage.

These results are in agreement with the findings of Ezumah (1986) in Azadirachta indica and Purohit, Sharma and Thapliyal (1982) in Shorea robusta, Tompsett (1985) in *Shorea robusta* and Nautiyal and Thapliyal (1993) in *Toona ciliata*. Loss of viability in seeds stored at higher temperatures (20-30°C) may be ascribed to rapid loss of water from the seeds. These findings are in agreement with those of Purohit, Sharma and Thapliyal (1982) who, while studying the effect of temperature on viability of sal reported that seeds stored at

33-36°C (room temperature) lost nearly all viability within 11 days, but at 13.5°C, viability was maintained for longer. They suggested that rapid loss of water at higher temperatures (33-36°C) and near freezing temperature (±5°C) is the primary cause of the loss of viability.

The deterioration in viability and germination ability of seeds in storage in the present study, may be due to the changes in the physiological state of seeds particularly the respiratory metabolism. The changes in respiratory metabolism are reported as one of the major factors for seed deterioration and hence fall in viability (Abdul-Baki, 1980; Woodstock, Furman and Solomos, 1984).

5.1.2 Effect of storage container on seed longevity

In case of *Toona ciliata* seed, four storage containers were investigated for their influence on seed longevity. These containers include earthen pot, canvass bag, polythene bag and plastic bin. Polythene bag and plastic bin proved superior and equally good in comparison to earthen pot and convass bag. Per cent germination was 73.9 per cent in polythene bag and 73.7 per cent in plastic bin stored seeds. Maximum per cent moisture content of 19.6 per cent was recorded in the polythene bags followed by 19.5 per cent in the plastic bin stored seeds and that is probably the one

reason for the maintenance of higher germination per cent in the polythene bags and plastic bin containers.

Low viability of earthen pot and convass bag stored seeds is due to the reduction in the seed moisture during storage which reduced seed longevity.

Shorea robusta seeds were stored in three types of containers namely earthen pot, plastic bin and glass pot. Plastic bin proved to be superior than the earthen pot and glass pot. Plastic bin registered a maximum average germination of 34.2 per cent and 35.8 per cent moisture content. Per cent moisture content was maximum in the glass jar stored seeds (36.02%). Therefore moisture content alone cannot be made responsible for the loss of seed viability. *Shorea robusta* seed is tropical recalcitrant. So two reasons can be ascribed for the better results in the plastic bin stored seeds. One reason is the maintenance of higher moisture content. The second is that plastic bin is a type of container which is resistant to moisture and gases but not completely impermeable to moisture and gases. That means limited gas exchange will occur in the plastic bin and that is must for the recalcitrant type of seeds to survive. Active respiration is must for the survival of the recalcitrant seeds and if respiration is stopped, the seeds die. Glass jar container is completely impermeable to the moisture and gases. So there may be more accumulation of Co_2 in the

container as the exchange of gases with the outside environment is nil. So the seeds die off suffocation.

5.1.3 Effect of storage medium on the seed longevity

Shorea robusta seeds were stored in the different mediums also. These were by coating seeds with gum paste, storing in the lime, storing in the sawdust, covering the seeds with a layer of clay and coating the seed with paraffin wax. Coating the seeds with the paraffin wax was the best treatment which gave highest germination of 31 per cent. The possible reason for this can be that due to covering of the individual seeds with wax, the rate of respiration will be reduced and the problem of heating is reduced. Heating is the main problem in recalcitrant seeds which leads to the rapid deterioration of the seeds. Seeds stored in the sawdust also gave good results. It can be attributed to the better exchange of gases in the sawdust stored seeds. Gum paste was responsible for the rapid deterioration of the seeds. It may be due to the poor exchange of gases.

5.1.4 Effect of storage duration on seed longevity

Maximum viability of 99 per cent was recorded when the seeds of both the species were tested immediately after collection. A comprehensive view reveals sharp decline in seed viability with increase in period of storage.

Loss in seed viability with progressive increase in period of storage duration can be attributed to numerous factors. Harrington (1973) reported that loss of viability can be attributed to ageing of seeds. Researchers have reported that ageing is caused by the production of toxic end products. The loss of ability to produce the plant hormones, gibberellic acid, phytotoxin and ethylene necessary for triggering germination is the other cause of ageing of seed. The loss of ability to produce hormones may be caused by destruction of enzymes by protein denaturation, by activity of free radicals or by an inability to produce denovo, by a break-down of the DNA-RNA templating mechanism. A fair number of research workers feel that chromosome break-down is the main cause of senescence.

The other possible reason for the rapid loss of viability with time can be the depletion of food reserves of seed during storage.

Respiration resulting in energy release and production of Co_2 and water through oxidation of carbohydrates and fats is common to all living seeds irrespective of their state of activity. Continuing respiration results in gradual decrease in dry matter content and gradual exhaustion of reserve food material resulting ultimately in declining of viability with time.

5.1.5 Interaction effects of temperature, container, duration and media on seed longevity

Toona ciliata seeds in storage gave best results in case of polythene bag seeds stored at $0^{o}\pm1^{o}C$ storage temperature. Per cent germination after one year in case of polythene bag stored seeds at $0^{o}\pm1^{o}C$ storage temperature was 93.0 per cent. Better retention of viability in case of polythene bag stored seeds at $0^{o}\pm1^{o}C$ storage temperature is possibly due to the reason that biological processes in seeds are slowed down at near freezing temperature and also the percentage of moisture content in the polythene bag stored seeds was comparatively more than the other containers. The rate of loss of viability was faster in case of earthen pot and canvass bag seeds kept at room temperature. This is due to the fact that at higher temperature, rate of respiration is more and loss of moisture from the seed is faster and hence early deterioration of the seed. At $-10^{o}\pm1^{o}C$ storage temperature, earthen pot and canvass bag stored seeds showed a faster rate of decline of germination per cent. The reason for this is the susceptibility of the seeds with higher moisture content to the chilling injury. Chilling injury was less in the polythene bag and plastic bin containers because these containers are resistant to the exchange of gases. The rate of loss of viability was also comparatively faster at $10^{o}\pm1^{o}C$ than at $0^{o}\pm1^{o}C$ storage temperature for all the containers.

In the first experiment on *Shorea robusta*, seeds stored at 15°±1°C in the plastic bin outperformed all the others. The germination per cent after one month was 49.5 per cent, which came down to 27 per cent after 5 weeks of storage. The possible reason for retention of higher viability in plastic bin seeds stored at 15°±1°C storage temperature is that at this temperature, the rate of respiration is slowed down and also the rate of loss of moisture content from the seeds is less. Moreover plastic bin containers are resistant to exchange of gases, but not impermeable. So some amount of gas exchange is also there which is must for the recalcitrant seeds to survive. At room temperature, the rate of decline of per cent germination was comparatively lesser in the glass pot because glass pot containers retained higher moisture content in seeds. Seeds suffered the chilling injury at 5°±1°C storage temperature because of presence of higher moisture content in the seeds. At 10°±1°C storage temperature, earthen pot and plastic bin containers gave better results. At this temperature, earthen pot seeds gave 35.5 per cent germination after one month and plastic bin seeds gave 31.5 per cent germination after one month of storage. The probable reason for this is the slow down of physiological activities at lower temperature and rate of loss of moisture content is also lesser.

In the second experiment of *Shorea robusta*, seeds coated with paraffin wax and stored at $15^{o}\pm1^{o}C$ storage temperature, outperformed all the others, giving 36.5 per cent germination after one month of storage. The possible reason for this can be that due to coating of wax, the rate of respiration is slowed down and rate of loss of moisture content is also lesser, but some amount of gas exchange also takes place. At room temperature also, seeds coated with paraffin wax gave better results. Seeds stored in the sawdust and lime at $15^{o}\pm1^{o}C$ storage temperature also gave better results than seeds coated with gum and clay. The reason for this is that in case of sawdust and lime, some amount of gas exchange is possible which is must for the survival of recalcitrant seeds in storage.

Chapter-6

SUMMARY AND CONCLUSION

Chapter-6

SUMMARY AND CONCLUSION

The present investigations 'Seed Storage and Viability of *Toona ciliata* M. Roem. and *Shorea robusta* Gaertn.f.' were carried out during the years 1993 and 1994 in the laboratory of Department of Silviculture and Agroforestry, Dr YS Parmar University of Horticulture and Forestry, Solan. The experiments were planned with the following objectives:

6.1 Evolve storage methods to prolong seed longevity

6.2 To study the rate of seed deterioration with the passage of time

6.3 To observe the effect of temperature on seed viability

6.4 To find out suitable storage container

6.1 STORABILITY OF *Toona ciliata* SEEDS

Seed storage studies were initiated keeping in view that seed longevity is very low as the seeds of current year collection cannot be utilized for raising nursery stock in subsequent years. The freshly collected seeds are highly viable exhibiting viability as high 99 per cent.

Seeds were stored under four different storage temperatures so as to find out the optimum temperature for storage. Seeds stored at $0^{o}\pm1^{o}C$ gave average germination of 95.59 percent in 12 months of storage and this temperature proved to be most ideal one for prolonging seed viability. Since container exercise considerable influence in enhancing

viability, seeds were stored in different types of storage containers. Of the four storage containers evaluated, polythene bag and plastic bin recorded germination of 73.94 and 73.70 percent respectively and were superior to earthen pot and canvass bag type of storage containers.

Interaction studies revealed that seed stored in polythene bags at $0^{o} \pm 1^{o}C$ excelled all other combinations of storage temperatures and containers maintaining 93 percent germination after one year of storage.

6.2 STORABILITY OF *Shorea robusta* SEEDS

Shorea robusta is propagated through seeds which are short-lived i.e., loses viability within few days. It is therefore, frequently recommended that the seeds should be sown soon after collection. But in actual practice a gap often encounters between seed collection and sowing schedules. So the seed storage studies were conducted. The freshly collected seeds are highly viable exhibiting germination percentage as high as 99 per cent.

In the first experiment, seeds were stored under four different storage temperatures so as to find out the optimum temperature for storage. Seeds stored at $10^{o} \pm 1^{o}C$ exhibited the highest average germination of 48.72 per cent during six weeks of storage. Seeds were stored in different types of containers. Of the three storage containers evaluated,

plastic bin recorded germination per cent of 34.17 during the six weeks of storage and proved to be most ideal one for prolonging seed viability.

Interaction studies revealed that seed stored in plastic bin at $15^{o}\pm1^{o}C$ excelled all other combinations of storage temperatures and containers maintaining 49.5 per cent germination after one month of storage.

In the second experiment on *Shorea robusta* seeds, seeds coated with paraffin wax, stored at room temperature as well as at $15^{o}\pm1^{o}C$, excelled all the other combinations. At the room temperature, paraffin wax coated seeds maintained 22 per cent germination after 15 days and at $15^{o}\pm1^{o}C$, paraffin wax coated seeds maintained 36.5 per cent germination after one month of storage.

CONCLUSION

In the light of the results obtained from these investigations, following conclusions are arrived at:

1. *Toona ciliata* seeds loses viability rapidly after collection at room temperature.

2. Seeds of *Toona ciliata* stored in the polythene bags kept at $0^{o}\pm1^{o}C$ storage temperature maintained 93 per cent germination after one year in storage. Hence the

seeds of current year can be used for nursery raising of stock in subsequent years.

3. Polythene and plastic bin containers are equally effective at room temperature maintaining about 75 per cent germination of *Toona ciliata* seeds after 3 months in storage. Hence these containers can be used to transport the seeds to long distances.

4. Since the seeds of *Toona ciliata* can be stored for one year with 93 per cent germination, therefore, possibility of *Toona ciliata* seeds for long-term storage for germplasm conservation can be explored.

5. *Shorea robusta* seeds are short-lived, it is therefore frequently recommended that the seeds should be sown soon after collection.

6. *Shorea robusta* seeds stored in the plastic bin at $15^{o}\pm1^{o}C$ storage temperature maintained 49.5 per cent germination after one month in storage. The seeds of current year cannot be used for nursery raising of stock for subsequent years.

7. Plastic bin and glass pot containers are equally effective at room temperature maintaining nearly 40 per cent germination of *Shorea robusta* seeds after 2 weeks in storage. Hence these containers can be used to transport the seed to long distances.

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APPENDICES

APPENDIX-II

Analysis of variance for studies on seed storage and viability of *Toona ciliata*

Source of variation	Degree of freedom	Mean sum of square				
		Germination				Viability per cent
		Per cent	Energy	Value	Speed	
Replication (R)	3	5.54	6.89	144.0	0.50	14.44
Temperature (T) [Main plot factor]	3	153340.27*	132514.80*	2626095.30*	18530.55*	145207.67*
Error (a)	9	2.50	2.19	112.28	0.272	4.74
Container (C) [Sub plot factor]	3	24130.65*	23403.51*	531899.56*	3027.59*	23858.88*
T x C	9	8055.00*	6050.53*	113161.17*	848.14*	8702.44*
Error (b)	36	4.80	3.63	210.59	0.64	5.45
Duration (D) [Sub-sub-plot factor]	11	11644.21*	10418.97*	604733.81*	2930.14*	13308.79*
T x D	33	1884.58*	1511.14*	32854.98*	226.12*	1945.97*
C x D	33	274.59*	217.90*	6145.62*	31.32*	199.16*
T x C x D	99	409.10*	301.65*	7854.24*	52.90*	331.59*
Error (c)	528	4.06	3.05	145.28	0.32	6.72

*Significant at 5 per cent level of significance

APPENDIX-III

Analysis of variance for studies on seed storage and viability of *Shorea robusta* (Experiment I)

Source of variation	Degree of freedom	Mean sum of square				
		Germination				Viability per cent
		Per cent	Energy	Value	Speed	
Replication (R)	3	2.00	1.88	1401.18	1.43	0.59
Temperature (T) [Main plot factor]	3	22026.30*	14031.04*	3463128.00*	10282.11*	21624.18*
Error (a)	9	6.03	2.96	1171.65	4.22	3.59
Container (C) [Sub plot factor]	2	977.57*	719.79*	2174450.80*	3051.11*	757.21*
T x C	6	437.74*	341.54*	455485.28*	636.61*	390.08*
Error (b)	24	3.36	4.76	2082.15	2.99	3.79
Duration (D) [Sub-sub plot factor]	5	23380.58*	17606.15*	6235880.80*	9882.91*	22622.34*
T x D	15	968.27*	686.88*	889864.31*	1271.33*	489.80*
C x D	10	54.23*	54.33*	291205.84*	256.07*	61.79*
T x C x D	30	193.71*	135.14*	327431.31*	324.70*	138.90*
Error (c)	180	2.75	2.92	2282.53	2.55	2.40

*Significant at 5 per cent level of significance

APPENDIX-IV

Analysis of variance for studies on seed storage and viability of *Toona ciliata* (Experiment II)

Source of variation	Degree of freedom	Mean sum of square				
		Germination				Viability per cent
		Per cent	Energy	Value	Speed	
Replication (R)	3	15.22	11.66	1818.08	1.41	13.33
Temperature (T) [First main plot factor]	1	13122.76*	9247.69*	593388.50*	2720.80*	11856.40*
Treatments [Second main plot factor]	5	2964.71*	2894.84*	174469.25*	892.67*	2840.54*
T x t	5	1177.31*	1286.11*	50304.82*	238.07*	1335.86*
Error (I)	33	3.62	4.78	939.46	0.56	3.27
Duration (D) [Sub-plot factor]	5	21523.19*	15907.80*	971520.19*	5427.15*	23124.72*
T x D	5	1262.11*	835.97*	146395.34*	388.91*	335.24*
t x D	25	379.00*	218.82*	78680.35*	169.05*	147.22*
T x t x D	25	321.81*	250.75*	25133.86*	91.97*	164.79*
Error (II)	180	89.71	57.57	16320.30	35.21	31.88