

**ECOLOGICAL STUDIES ON SEED PRODUCTION,  
DISPERSAL, GERMINATION AND SEEDLING FITNESS  
OF RUDRAKSH (*Elaeocarpus ganitrus* Roxb.)**

By  
**PUTUL BHUYAN**



**THESIS SUBMITTED IN FULFILMENT OF THE DEGREE OF  
DOCTOR OF PHILOSOPHY IN BOTANY**

**DEPARTMENT OF BOTANY  
OF  
NORTH-EASTERN HILL UNIVERSITY  
SHILLONG-793022, INDIA  
2002**

# THE NORTH EASTERN HILL UNIVERSITY

SEPTEMBER, 2002

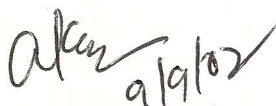
## DECLARATION

I, Putul Bhuyan, hereby declare that the subject matter of this thesis entitled “**Ecological studies on seed production, dispersal, germination and seedling fitness of Rudraksh (*Elaeocarpus ganitrus* Roxb.)**” is the record of work done by me, that the contents of this thesis did not form basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree in any other University/ Institute.

This is being submitted to the North-Eastern Hill University, Shillong for the award of the degree of Doctor of Philosophy in Botany.

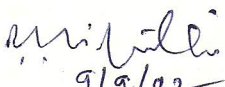


(Putul Bhuyan)



(Head of the Department)

Head  
Department of Botany  
School of Life Sciences  
N. E. H. U.  
Shillong-793008



(Supervisor)



(Joint Supervisor)

## ACKNOWLEDGEMENTS

I express my deep sense of gratitude and sincere appreciation to my Supervisor, Professor R. S. Tripathi FNA, FNASc., Department of Botany, NEHU, for his valuable suggestions, ingenious guidance and constant encouragement throughout the course of this study.

I express my deep sense of indebtedness to my joint supervisor Dr. M. L. Khan, Reader, Department of Forestry, NERIST, for his constant encouragement, keen interest and constructive criticism to complete the study. I am always grateful to him for his efforts that gave me a new dimension in the field of Forestry.

My grateful thanks to Professor H. N. Pandey, Dr. Uma Shankar and Dr. S. K. Barik Department of Botany, NEHU, for their constant support and suggestions throughout the study.

I sincerely thank the Head of the Department of Botany, NEHU for providing necessary facilities during the course of study.

I extend my gratitude to Professor A. L. Verma, Director, NERIST for providing facilities and encouragement.

I also like to express my sincere thanks to Head, Department of Forestry, Dr. (Mrs.) P. Rethy for providing necessary facilities.

I sincerely thank Professor N. P. Todaria for his encouragement and help in site selection.

I am grateful to faculty members, Department of Forestry, NERIST especially Dr. (Mrs) U. Melkania, Dr. Binay Singh, Dr. S. C. Tiwari, Dr. A Arunachalam and Dr. (Mrs.) K. Arunachalam for their valuable support and help and also to Dr. N. D. Singh for his kind co-operation.

I remain grateful to Mrs. P. Saikia, Mr. J. P. Thapa, Mr. M. Chutia and Mr. Pradip Basumatary for their help and kind assistance. It is my pleasure to acknowledge help received from Mr. C. K. Chungkrang, Mr. J. Saikia, Mr. D. Deori and Mr. B. Basumatary in field works.

Thanks are due to Mr. Padmaraj Gajurel, Mr. Suresh Kr. Singh, Mr. Kalidas Upadhaya, Mr. Lalbihari Singh, Mr. Bulbul Gogoi, Mr. N. Chutia, Mr. Awadesh Kumar, Ms. Ashalata Devi, Mr. Simanta Kalita and Ms. T. Das for their kind cooperation and constructive criticism.

I also extend my thanks to all the Research Scholars of Ecology Laboratory, Department of Botany, NEHU for their helping hand. Special thanks to Dr. Babu John, Mr. Krishna Upadhaya, Mr. Om Praksh Tripathi and Ms. Swapna Prabhu for their constant help throughout the study.

Financial assistance received from DST, New Delhi and CSIR (for Senior Research Fellowship award) is gratefully acknowledged.

I express my sincere thanks to Dr. S. Trivedi, Divisional Manager, Arunachal Pradesh Forest Corporation, for necessary help during the field study and data collection.

I take the privilege to acknowledge the help received from Dr. K Haridasan, Mr. L. R. Bhuyan, SFRI, Itanagar and their research scholars in identification of the plant specimens.

Moral support received from Ms. Reshma is acknowledged.

Last but not the least, I thank all my family members for their constant inspiration and unstinted support during the course of this study.



(PUTUL BHUYAN)

## **CONTENTS**

<b>GENERAL INTRODUCTION</b>			...1
<b>CHAPTER</b>	<b>I.</b>	<b>Review of Literature</b>	...8
<b>CHAPTER</b>	<b>II.</b>	<b>Study Sites: Climate, Soil and Vegetation</b>	...39
<b>CHAPTER</b>	<b>III</b>	<b>Tree Diversity and Population Structure in Undisturbed and Human Impacted Forest Stands</b>	...44
<b>CHAPTER</b>	<b>IV</b>	<b>Regeneration Status and Population Structure of Rudraksh</b>	...64
<b>CHAPTER</b>	<b>V</b>	<b>Fruit Set, Dispersal and Nut Bank Dynamics in Rudraksh in Relation to Cultural Disturbances</b>	...72
<b>CHAPTER</b>	<b>VI</b>	<b>Regeneration of Rudraksh: Germination Strategies</b>	...95
<b>CHAPTER</b>	<b>VII</b>	<b>Survival and Growth of Seedlings in Nursery and Forest Stands</b>	...110
<b>CHAPTER</b>	<b>VIII.</b>	<b>Vegetative Propagation of Rudraksh Through Branch Cuttings</b>	...121
<b>GENERAL DISCUSSION</b>			...126
<b>SUMMARY</b>			...137
<b>REFERENCES</b>			...145
<b>APPENDICES</b>			... i & ii

## LIST OF TABLES

Tables	Page no.	
II.1	Light intensity and soil characteristics of the study sites.	42
III.1	Consolidated details of families, genera, species, diversity index, concentration of dominance, stand density and basal area in four forest stands experiencing different degrees of disturbance.	48
III.2	Tree families, genera, species richness and density in four forest stands experiencing different degrees of disturbance.	49
III.3	Importance value index of tree species in four forest stands experiencing different degrees of disturbance.	51
III.4	Regeneration status of tree species in four forest stands experiencing different degrees of disturbance.	54
III.5	Density of shrubs in four forest stands experiencing different degrees of disturbance.	56
III.6	Density of herbs and vines in four forest stands experiencing different degrees of disturbance.	57
IV.1	Basal area of Rudraksh in four forest stands experiencing different degrees of disturbance.	67
IV.2	Seedling survival and growth rate of seedlings in four forest stands.	67
IV.3	Characteristics of four planted stands of Rudraksh near the natural stands.	68
V.1	Yearwise variation in flower and fruit production and percentage of aborted flowers in trees of different CBH classes of Rudraksh in different forest stands experiencing different degrees of disturbance.	81
V.2	Mean fruit weight of Rudraksh in different forest stands.	82
V.3	Relationship between seed density per sq. m (Y) and dispersal distance in metre (x) in Rudraksh.	83
V.4	Fraction of dispersed/disappeared, insect damaged and undamaged fruits in the total fruit population of Rudraksh during the fruit fall period; and of disappeared, dormant/rotten and germinated nuts in the undamaged nut population during the post fruitfall period in four forest stands.	84
V.5	Dispersed, disappeared, dormant/rotten and germinated seeds expressed as fraction of the total number produced by Rudraksh in four forest stands experiencing different degrees of disturbance.	85
V.6	Nut bank in the soil (per 100 sq. m) and fraction (%) of predated and undamaged nuts in the total nut population of Rudraksh before the next fruit-fall crop in the four forest stands.	87
VI.1	Nut germination (%), period required for final germination, period required for germination to commence and period required for 50% germination in Rudraksh.	102
VI.2	Growth of one year old seedlings as affected by number of seedlings emerging from the single nut.	104
VI.3	Seedling survival (%) as affected by number of seedlings emerged from the single nut after one year of germination.	105
VII.1	Environmental parameters of the three stands where seedlings were transplanted.	114
VII.2	Survival of Rudraksh seedlings and their infestation by various agents in different forest stands.	116
VIII.1	Response of cuttings to various growth hormones in different seasons.	123

## LIST OF FIGURES

- Figure I.1. Summary of environmental influences on the establishment of naturally regenerated forests.
- Figure I.2. Major causes and consequences of patterns of natural regeneration of forest trees.
- Figure II.1. Rainfall, relative humidity and temperature data for the study area during January to December (mean values for the years 1997, 1998, 1999 & 2000).
- Figure III.1. Density of tree species in various girth classes in four forest stands.
- Figure III.2. Species richness of tree species among various girth classes in four forest stands experiencing different degrees of disturbance.
- Figure III.3. Population structure of some important trees growing with *Elaeocarpus ganitrus*.
- Figure IV.1. Density of tree, sapling and seedling populations of Rudraksh in four forest stands experiencing different degrees of disturbance.
- Figure IV.2. Population structure of Rudraksh in four forest stands.
- Figure IV.3. Number of cut stumps and percentage of sprouting stumps in different natural and planted forest stands.
- Figure V.1. Dispersal curves of Rudraksh in different forest stands.
- Figure V.2. Percentage of disappeared and dormant/rotten nuts at different distance from parent tree of Rudraksh in different forest stands.
- Figure V.3. Disappearance of fruits of Rudraksh as influenced by their ripeness and pulp in the undisturbed (UND), mildly disturbed (MID), moderately disturbed (MOD) and highly disturbed (HID) forest stands.
- Figure V.4. Schematic diagram of general trend of different events in Rudraksh.
- Figure VI.1. Frequency distribution of 10,000 Rudraksh nuts having different number of locules or 'faces'.
- Figure VI.2. Frequency distribution of seeds per nut (n= 405).
- Figure VII.1. Seedling growth in terms of shoot elongation, collar diameter, leaf number and leaf area under nursery conditions.
- Figure VII.2. Growth rate of seedlings in three forest stands; open canopy (stand I), sparse canopy (stand II) and dense canopy (stand III).
- Figure VII.3. Growth rate of seedlings in terms of shoot length, collar diameter, leaf number and leaf area in stand I, stand II and stand III after one year period of transplantation.

## LIST OF PLATES

- Plate I.1. Nuts of Rudraksh collected from the forest being sold in market in different forms and the beads are worn as sacred jewelery.
- Map I.1. Showing the distribution of Rudraksh in India and north-eastern region.
- Map I.2. Showing the distribution of natural and planted populations of Rudraksh in Arunachal Pradesh.
- Map II.1. Showing the location of study sites.
- Plate II.1. View of the forest stands exposed to various degrees of disturbance (A) - An overview of a part of the undisturbed stand, (B) - Close up of a small patch of the same forest, (C) - Mildly disturbed stand, (D) - Moderately disturbed stand, (E)- Highly disturbed stand.
- Plate IV.1. Debarking in adult Rudraksh tree by wild animals (A), humans for medicinal purposes (B), bark destroyed by termites (C).
- Plate IV.2. An overview of Rudraksh plantations.
- Plate IV.3. Natural regeneration of Rudraksh through seeds.
- Plate IV.4. Cut stumps (A&B) and regeneration through stump sprouting in Rudraksh (C).
- Plate V.1. (A)-Close view of the inflorescence of Rudraksh, (B)- abortion of flowers, (C)- fruit setting.
- Plate V.2. Nuts found in elephant droppings (A), hoarded by rodents & stored in rotten logs (B), stored nuts germinated in rotten logs and dead seedlings due to overcrowding and physical absence of mineral soil(C).
- Plate VI.1. Rudraksh fruits/nuts showing the locules (A) and seeds (B).
- Plate VI.2. Elaborating the correct placing of nut for making the cracks by vise.
- Plate VI.3. Emergence (A), and clustering of seedling (B), and seedling population of Rudraksh in nursery(C).
- Plate VII.1. Herbivory in Rudraksh seedlings in nursery conditions (A) and in forest stands (B), insect cocoon(C) and grasshoppers (D) noticed on the Rudraksh seedlings.

APPENDICES

Appendix (i) Publications arising from the thesis

Appendix (ii) Biodata

Faint, illegible text in the first section of the page, likely bleed-through from the reverse side.

Faint, illegible text in the second section of the page, likely bleed-through from the reverse side.

## **GENERAL INTRODUCTION**

Rudraksh is a conjugate word related to Lord Shiva. The ancient Indian scriptures describe the importance of Rudraksh. "Rudra" means "Shiva" and "Aksh" means "Eyes" where the two words combine to form Rudraksh and literally it means "the eyes of Rudra". According to mythological story in Puranas, Rudra (Lord Shiva) had fought for a long time by keeping his eyes wide open in order to kill dangerous "Asur" named "Tripur" of Himalayas. In prolonged struggle the eyes of Lord Shiva got tired and tears rolled down on the earth and took the shape of a plant. Lord Brahma, the creator of Universe directed that this plant should be called Rudraksh as it was formed from Lord Shiva's flowing tears.

Many rare plants and their parts are used in Tantric (Hindu occult Science) system. Nature has created many things, which destroy negative planetary forces, get rid of evil auras in our homes, protect us from enemies or opposition around and create powerful friendly auras for health, wealth, success and happiness. The holy Rudraksh does this - a unique link between the material world and occult world. Its powerful presence keeps away all evil and negative forces. Rudraksh is the fruit stone of the Rudraksh tree (*Elaeocarpus ganitrus*). When fruit pulp is removed, the Rudraksh bead is found inside. The bead is rough in texture, with the surface divided into segments by ridges running from top to bottom. These form the faces of Rudraksh. The number of faces ('mukhi') ranges from 1 to 14, however, a major percentage of beads have 5 or 6 faces.

There are twin beads (beads joined together) called *Gaurishanker*, which are considered to be very auspicious. Natural beads have configurations on them. Such beads are extremely rare. Moreover one 'mukhi' Rudraksh is very rare while two to three and from nine to fourteen 'mukhi' Rudraksh are also difficult to find. One 'mukhi' Rudraksh has more importance, it is more effective and regarded as highly powerful. Quality of all other Rudraksh beads is cumulatively available in one 'mukhi' beads. It is believed that the person, who is lucky enough to get it, becomes wealthy in all respect. One 'mukhi' Rudraksh is related to the sun; by wearing it, a person can alleviate his bad effect to a large extent. According to Kalidas Vajpeyi, the author of *The Science of Mantara*, the five 'mukhi' Rudraksh is the best among all the other Rudraksh (cited in Hazarika 2001).

Rudraksh beads can be of the size of small peas or as large as marble. These beads can be worn around the neck, kept in the pocket or purse, in cash box or places of worship or at various points in home. Rudraksh brings good luck, health and many material comforts. When kept under pillow, it induces sound sleep, pleasant dreams, mental stability, better memory and happy feelings, stabilizes the blood pressure etc. (Hazarika 2001). Rudraksh should be worn after being fortified by specific mantras, which make it more effective. The Shiva Purana says that the Rudraksh protects a person from premature death, fulfill desire and bestows worldly pleasure and salvation forever. The Rudraksh improves health, protects from misfortune and planetary afflictions, brings purity and tranquility of mind; it also helps to relieve pain and is especially effective in high blood pressure, heart problems, epilepsy, cough, mental and

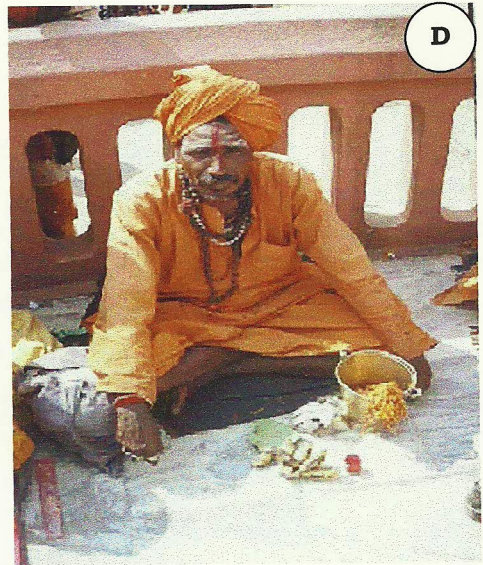
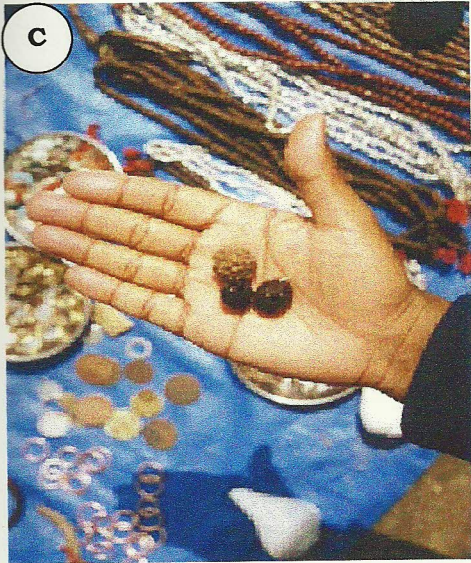
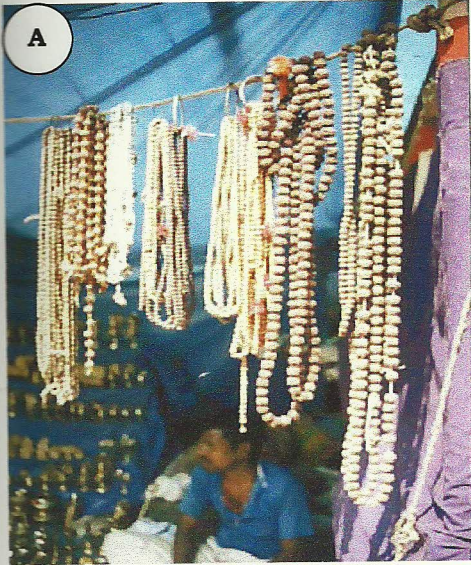
gynaecological problems. Ghosts and evil spirits cannot withstand the power of the Rudraksh.

Vedic As per modern psychology, mind in many ways is governed by the brain, its neurons, neurotransmitters, endocrine glands etc. For example, low level of serotonin causes depression, worry, lack of energy, low self esteem and higher level of it causes happiness, energy, higher level of confidence and self esteem etc. Dopamine causes over-activity of neurons resulting in mental agitation, restlessness, tension, fear, lack of control etc. Conversely, decreased level of dopamine results in peace, tranquility, stability etc. Psycho-pharmacological drugs like tranquilizers and antidepressants etc. control the activities of neurotransmitters to effectively soothe mental disturbances. According to Suhas Roy (unpublished), Rudraksh beads have certain electromagnetic and inductive properties and when worn over the heart, they send out corresponding signals differing for different 'mukhis' to the brain, acting or controlling certain brain chemicals and neurotransmitters, thereby influencing the status of mind. For example, the mental agitation and dopamine level of those who wore 5 mukhi Rudraksh was found to be less and the serotonin level of those who wore 1 mukhi and 12 mukhi Rudraksh beads was found to be high. The activity of neurons in the right part of the brain was found to be high among the wearers of 14 mukhi Rudraksh beads (right part of the brain controls abstract and lateral thinking as against logical and structural thinking controlled by left part of brain). This perhaps, is the reason behind the change in personality and attitude of the wearers of different types of Rudraksh beads. When the person gets a positive confident frame of mind, the impact goes deep into his subconscious mind sending out powerful vibrations thereby changing the way of nature and others

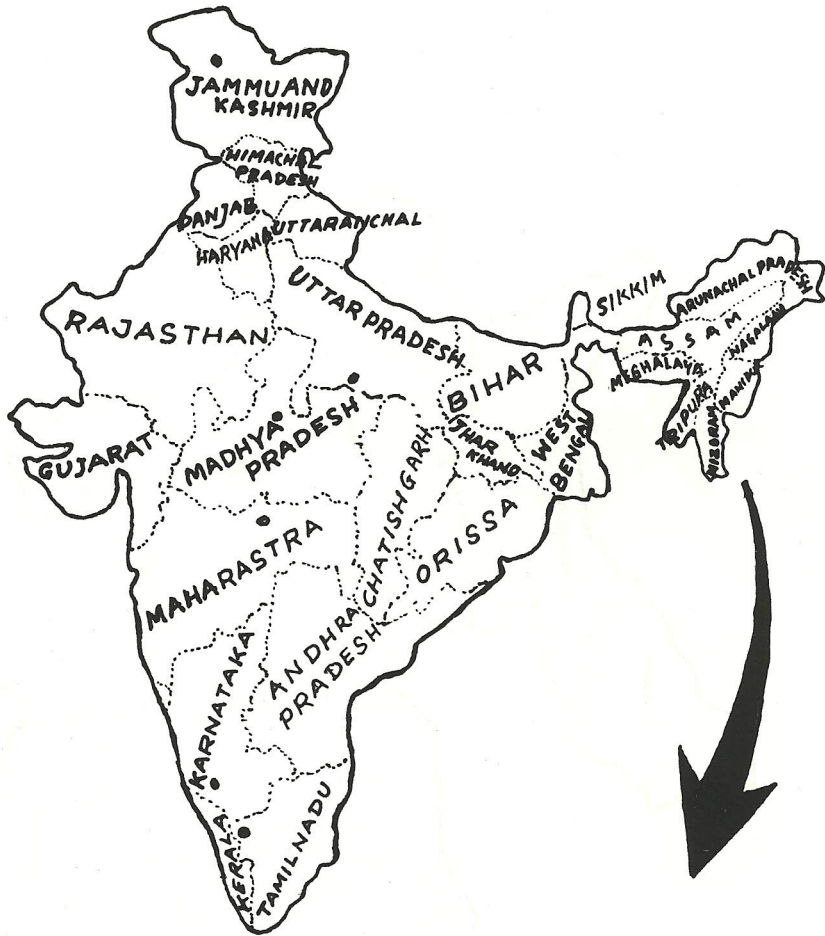
reaction to him. He also takes quick decisions and frequently finds himself in right place at the right time. This is perhaps called 'luck'. What have been said in Vedic scriptures is increasingly being proved almost with 100% precision scientifically (from unpublished literature).

*Elaeocarpus*, a genus with about 360 species of Elaeocarpaceae family, contains hard and highly ornamental stony endocarp commonly known as 'Rudraksh'. Stony endocarp (nut) is used as religious jewellery in the form of beads throughout India and Southeast Asia (plate1.1). The sculpturing of the stony endocarp surface appears as faces, commonly known as 'mukhi', associated with the locules of the ovary, normally five in number. Nuts with fewer or more locules are due to abnormalities. Each locule houses a seed. Out of about 120 species of *Elaeocarpus* reported from different parts of Asia including Nepal, Bhutan, Sikkim, Tibbet, Java, Indonesia, foot hill of Himalayas and various parts of India, 25 species are found in different parts of India, such as Uttar Pradesh, Maharastra, Bihar, Madhya Pradesh, Assam, Arunachal Pradesh, Meghalaya etc (Map1<sup>1</sup>). The Rudraksh tree occurs sporadically in all districts of Assam but is more frequent in Arunachal Pradesh. In Assam, Rudraksh is found in places like Charaideu, Digboi, Margherita, Dibrugarh, Jorhat, Golaghat etc. In Arunachal Pradesh it is common along the foothill of all districts except Tawang and Upper Subansiri and some other high altitude areas (Map1<sup>2</sup>).

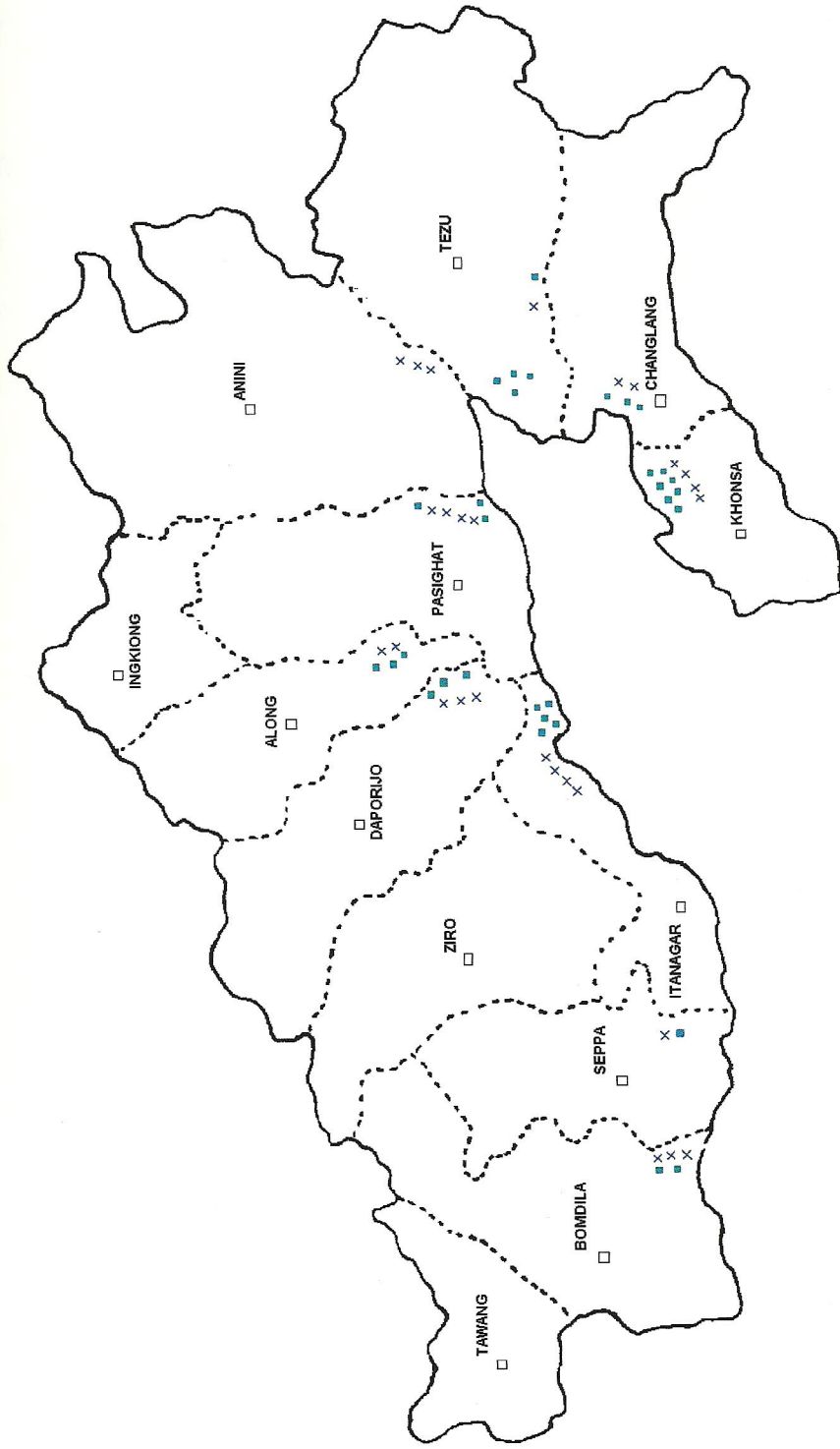
Kaul & Haridasan (1987) have classified the forest vegetation of Arunachal Pradesh into five broad types. Rudraksh is found in tropical evergreen forest which is characterized by three-tier forest structure. The emergent top canopy trees are straight boled with an average girth of 2-5 m and height of 40-50 m. They do not form continuous close canopy. Second story is composed of



**Plate[1. Nuts of Rudraksh collected from the forests being sold in market (A, B & C) in different forms, and the beads are worn as sacred jewellery (D).**



Map 1. Showing (●) the distribution of Rudraksh (*Elaeocarpus ganitrus*) in India and North Eastern Region.



Map 2. Showing the distribution of natural (■) and planted (x) populations of Rudraksh (*Elaeocarpus ganitrus*) in Arunachal Pradesh.

other tree species, which occur gregariously to form a closed canopy ranging in height between 20-30 m. Rudraksh is usually present in this story. A few thin boled tree species occupy the lower level of the canopy as well.

regone However, tropical forests of Arunachal Pradesh are being modified and degraded due to increased anthropogenic pressure. The age-old practice of shifting agriculture is one of the potent factors changing the forest microenvironment and reducing the forest cover (Mishra & Ramakrishnan 1981, Ramakrishnan *et al.* 1981, Kushwaha & Ramakrishnan 1987). The 'jhum' cycle has been shortened as a result of population pressure, diversification and consequent shrinkage in available land area for agriculture due to logging activities (Ramakrishnan 1985). Accelerated search for new timber resource for industrial purposes is another cause of forest exploitation. Improved technology, pattern of forest resource use and infrastructure development have widely increased the effective wood harvesting and land clearing activities. It is believed that if the present trends continue and effective conservation measures are not implemented, most of the still existing forests will be destroyed or replaced by degraded communities (Thapliyal 1991, Beniwal & Haridasan 1992a, b, Menon *et al.* 2001). Rudraksh population in the natural as well as planted forest stands has been decreasing day by day due to household and other industrial uses. Moreover, nut collection for beads has caused the shrinkage of the seed bank in the soil, which has adversely affected the regeneration of the species. Thus the species is being pushed to the threatened category (Rao & Haridasan 1983). The species flowers during May to June and fruits ripe during November to December. The ripe fruits are blue in color. The fruits are consumed and dispersed by large birds. The fruits are consumed as a whole and the endocarp

is passed through the digestive tract. Sometimes small birds partly strip the fleshy exocarp. The exocarp is rich in carbohydrates and proteins and provides nutritious reward to consumers (Lee 1998). The species bears very low regeneration power and mainly reproduces through seeds.

Rudraksh is a fast growing species and has been included under the social forestry programme of Arunachal Pradesh and has been planted along roadside, in institutional premises, as small forest pockets etc. Many pockets of Rudraksh plantation can be noticed in various parts of the state. Many forest nurseries are engaged in raising the seedlings of this species to meet the requirement of various types. However, the germination of Rudraksh is very poor and erratic, and so it is a difficult task to raise the seedlings in nursery.

Although certain aspects of Rudraksh such as its biology (Lee 1998), chemical properties of nuts (Dutta & Mathur 1992), taxonomy of the species (Mitra *et al.* 1992), medicinal and aesthetic values (Sayani 1999, Hazarika 2001), and biochemical properties (Das *et al.* 2000) have been studied to some extent, there is a conspicuous lack of studies on fruit/nut production, dispersal and regeneration of the species. Thus a study on regeneration of Rudraksh (*Elaeocarpus ganitrus* Roxb.) was undertaken.

The present study focusing on the regeneration of Rudraksh (*Elaeocarpus ganitrus*) covers the following aspects:

1. Quantification of the population stock of Rudraksh in different forests of Arunachal Pradesh.
2. Study of the phenological events of Rudraksh in fragmented and undisturbed forests.

3. Investigations relating to the natural dispersal mechanism of Rudraksh (*Elaeocarpus ganitrus*) in fragmented and undisturbed forests and to find out as to how this dispersal mechanism has been changed/modified in response to human induced disturbances such as deforestation and harvest of nuts.
4. The determination of the nut bank in fragmented and undisturbed forests.
5. Evaluating the fitness components of the species (e.g. seed germination, seedling growth, seedling establishment and vegetative propagation etc.).

The '**General Introduction**' which sets out the objectives of the thesis is followed by the '**Review of Literature**' (**Chapter I**), which is followed by **Chapter II** on the climate, soil and vegetation of the study sites. The experimental data on various aspects mentioned above have been presented in **Chapters III – VIII**. Each chapter has been provided with a separate discussion. In addition to this, the results contained in various chapters have been discussed in an integrated manner under '**General Discussion**'.