GENERAL DISCUSSION

The Rudraksh tree occurs sporadically in all districts of Assam and Meghalaya, but is more frequent in Arunachal Pradesh. In Arunachal Pradesh it is common along the foothill of all districts except Tawang and Upper Subansiri and some other high altitude areas. The Rudraksh is found in tropical evergreen forest, which is characterized by three-tier forest structure. Rudraksh is usually present in the second story. 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 for changing the forest microenvironment and reduction of forest cover. 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 bears very low regeneration power and mainly reproduces through seeds. However, the germination of Rudraksh is very poor and erratic, and so it is a difficult task to raise the species in nursery.

The overall structural pattern of the community reveals that the studied four forest stands harbouring Rudraksh and experiencing different degree of disturbances are dominated by *Dipterocarpus macrocarpus, Shorea assamica, Castanopsis indica, Terminalia* spp., *Vatica lancefolia, Duabanga* sp. etc. The forest stands have highly heterogeneous distribution of trees like other forests of Eastern Himalayas (Singh & Singh, 1987). *Dipterocarpus,*

Shorea, Duabanga, and *Terminalia* form the top canopy layer, restricting the availability of light to the ground vegetation especially in the undisturbed stand. However, in the other stands which were exposed to human disturbance, the microsites created were such that they facilitated the occurrence and growth of light demanding and opportunistic tree species like Rudraksh (Ohsawa *et al.* 1986). Thus human induced disturbances (mining, timber extraction etc.), livestock grazing, etc. cause changes in species number, tree diversity, basal area (Rao *et al.* 1990, Vetas 1993, Murali *et al.* 1996). Removal of over-story trees might have favoured germination and seedling establishment through increased solar radiation on the forest floor and consequent increase in surface temperature, and through reduced competition from the trees of upper canopy (Koller 1972, Oliver 1981, Noble & Slatyer 1988). Variation in regeneration behaviour of tree species and vegetation structure of the forest stands signifies the role of prevailing disturbance (Whitmore 1975, Saxena & Singh 1984, Primack 1985, White *et al.* 1993). Positive role of mild disturbance on the regeneration of trees has been reported by Harris & Farr (1974), Boring *et al.* (1981) and Khan *et al.* (1987).

Species composition of the forest depends on the magnitude of disturbances caused due to collection of timber, fodder and firewood by the people of the adjacent human settlements. The highly disturbed stand was devoid of the dominating over-story species. Moreover, due to human intervention in many areas, the forests are being converted to *Taungya*

plantations and cash crop plantation such as tea and coffee plantations. Forest composition is also being changed in certain cases due to pest and disease attack especially in the dense forest stand where light penetration is poor (Augspurger 1984b, Sundriyal *et al.* 1994). Many species face the threat of extinction due to biotic pressure, and absence of regeneration in the natural forest.

Rudraksh population was very erratic, discontinuous and sporadic compared to the canopy species. The canopy species were regenerating with abundance of seedlings and saplings, but the Rudraksh population was very small with a few seedlings and saplings that too in the undisturbed stand (Chapter IV). This disparity in abundance may be attributed to the canopy condition and human disturbance in the disturbed stands. The age structure of Rudraksh population indicates that this species has poor regeneration potential. Though the seedlings were found, the saplings were absent in most localities and the adults were scattered and had very few girth classes (Figure; IV. 3, Chapter IV). Discontinuous population structure has been reported for a number of other tropical light demanding pioneer species such as *Endospermum medullosum* in Solomon Island (Whitmore 1984), *Trema micrantha* (Brokaw 1987) in Panama, *Scalesia penduculata* (a pioneer tree) in Galapages Island (Itow & Muller-Dombios 1988) and *Grewia pandaica* in Western Ghats (Parthasarathy & Karthikeyan 1997b).

Folivory by leaf eating caterpillars, other beetles, and spider webs were more frequent in the undisturbed stand due to gregarious tree habitation

(Chapter IV & VII). Moreover, seedling mortality was of common occurrence due to lack of light interception and pathogenesis as also reported in the case of other species (Stewart 1975, Horsely 1977, Augspurger 1984b).

Human settlement nearby forest area is a common phenomenon and people depend on forest for fulfilling their various requirements. The collection of firewood and non-timber forest produce as well as timber operations are quite common. Timber operations leave the stumps of cut trees both in planted and natural forests. Resprouting of cut stumps was observed both in natural forests and plantations, but resprouting ability varies with stump diameter and forest stands. Stumps in natural stands resprout more frequently compared to planted stands.

In nature germination of Rudraksh is very low and erratic, since nuts are unable to absorb water because of their hard stony nature. Hard seed coat impermeability which is a characteristic feature of many leguminous and non leguminous species, may be considered as a delaying mechanism that prevents germination under conditions unsuitable for establishment (Ballard 1973, Cavangh 1980, Baskin & Baskin 1989, Tybirk 1991). Further, hard seed coat confers several advantages on seeds. It allows endozoic dispersal, recolonization after fire and helps the seeds to withstand unfavourable conditions such as heat, drought and mechanical damage remaining viable for a long period in the soil waiting for the conditions favourable for germination (Coe & Coe 1987, Sabitii & Wein 1987, Tybirk 1991, Tybirk *et al.* 1994).

Mechanical treatment of hard coated nuts improves germination in many tree species (Khan & Tripathi 1987b, Todaria & Negi 1992, Negi & Todaria 1995, Demel Takety 1997). It was found that in the case of Rudraksh, the cracking of nuts enhances the speed of germination significantly by allowing immediate entrance of water in the nut. However, most of the evidences indicate that continuous layer of tightly packed palisade cells in the nuts/seed coat acts as major barrier to the entry of water into the nut (Tran & Cavanagh 1984, Cavanagh 1987, Egley 1989). It has been shown that the decomposition process in nature or mechanical injury by several specific treatments make the seed/nut coat permeable to water in most of the cases. It is true for Rudraksh too.

Seed number in a nut of Rudraksh varies from 1-5, which may be due to selective abortion of fertilized ovules of maturing seeds (Ganashaiah & Uma Shaanker 1991). Generally, the number of seedlings arising from a single nut varies from 1-4. However, clustering of seedlings adversely affects their growth and development (Campbell 1964, Lohrey 1970) and if the seedlings arising from a nut is less in number, they develop faster and grow better than when they are more crowded (Chapter VI).

Flower and fruit production in *Elaeocarpus ganitrus* varied greatly in time and space. Barik *et al.* (1996) and Khan *et al.* (1999) also reported similar results on shade-tolerant species and Milton *et al.* (1982) and DeViana (1999) in light demanding pioneer species. Fruit production may differ among populations of the same species and individual trees within a population may

also vary in fruit set (Howe 1982, Grubb 1977, Schupp 1990, Barik *et al.* 1996, Khan *et al.* 1999). Resource availability may be one of the causes of yearly variation in fruit production (Fenner 1991). Many extrinsic factors such as rainfall, hailstorm, and wind speed, particularly during flowering season may affect fruit production (Khan *et al.* 1999, Felfelli *et al.* 1999). Unusual rainfall in a particular year may significantly decrease flower and fruit production (Chapter V). With the increase in disturbance intensity the flower and fruit production increases. Higher fruit production in the disturbed stands may be attributed to stimulation of flowering in sunlight. The high light intensity may elevate bud temperature, stimulating growth regulating chemicals especially gibberellins (Phrais & Kuo 1977, Ross *et al.* 1983), which induce flowering and fruiting. Tall individuals offer more foraging opportunities thereby increasing pollination chances and protection from predators (Ducan & Chapman 1999).

Fruit dispersal is the process that links generations of plants both in time and space. The fruit/nut of Rudraksh is very hard, heavy and has low ability to be dispersed without transportation by animals. Therefore, fruit dispersing animals are very important for this species for reducing sibling competition, decreasing genetic relatedness of patches and enabling it to colonize new areas. A large number of fruits was found deposited in rotten logs hoarded by rodents. The ripe fruits were preferred by dispersers over the unripe fruits and fruits without pulp. Fruit colour, nutritional content, pulpiness

and aroma attract dispersal agents (Herrera 1981, Snow 1981, Janzen 1983, Howe 1985, Howe *et al.* 1985).

Hornbill, bat and flying squirrel are the dispersal agents that take away the fruits from the crown, while monkey drops the fruits beneath the tree crown. Some animals like deer and wild pig were seen to eat ripe fruits fallen on the forest floor. The nuts are not swallowed and normally regurgitated under the crown, suggesting cost paid to animals but the species did not get the reward in terms of dispersal (Hedge *et al.* 1991). Rodents viz, *Vandeleuria oleracea* and *Rhizomus prunosus* are the main consumers, dispersers and hoarders of the fruits. In general about 40-70% fruits disappeared during fruit fall period and large proportion of the remaining fruits dispersed during post fruit fall period. Fruit dispersal decreased with increase in distance from the tree.

The study on the nut bank dynamics reveals important stages at which nut losses could occur. The major loss of fruits occurs immediately after the fruit fall. The fruits that are still left on the forest floor disappear gradually due to the activities of secondary dispersers. About 89% of the nuts present on the forest floor were found predated and the remaining 11% were intact but not readily germinable (Figure V. 5, Chapter V). The dormant fraction may give rise to seedlings in near future. Hubbell (1980) suggested that recruitment is higher close to the parent tree due to greater seed abundance. A large fraction of nuts hoarded by rodents is damaged by ants which eat up

cotyledons of the seeds. Moreover, due to ethnic importance nuts are collected in huge quantities from the forest floor causing reduction in nut bank.

Seedling growth and survival are determined by interactive influence of biotic and abiotic factors of the forest environment (Augsperger 1984a), such as light intensity (Whitmore 1975, Vance & Running 1985, Clark *et al.* 1996), soil moisture (Muller-Dombois *et al.* 1980) and pathogen (Augspurger 1984b). Tree canopy in the upper layer determines the light penetration to the ground vegetation and subsequent growth process of the plants growing beneath the tree canopy. In low light condition the biomass allocation to leaves tends to be greater (Poorter *et al.* 1995, Poorter 1999) and so, there was an increase in leaf area (Chapter VII). On the contrary, in high light condition plant reduces transpiration losses by producing small size, thick leaves with low leaf area (Poorter 2001).

Relative growth rate of Rudraksh was more under the intermediate light condition than the full sun light. At full sunlight net assimilation rate compensates for a decline in leaf area. Plants grown in full sunlight suffer from limitation of soil moisture and high temperature. At high irradiance level photosynthetic system may be damaged causing bleaching of leaves (Oberbauer 1985). Higher irradiance load requires a larger biomass allocation to roots for water uptake to compensate for transpiration loss. Therefore, less biomass can be invested in leaf material, which reduces photosynthetic rate and potential growth rate (Kormer 1994). It was found that shade-tolerant species showed optimum relative growth rate at 16 to 27% radiation level,

above which RGR declined (Veenendaal *et al.* 1996). Pioneer species show optimum growth between 26 and 100% light intensity in the field.

In the dense forest stand where light penetration was very less, the incidence of pest disease attack was more (Chapter VII). Likewise in the dense canopy condition predators and pathogen attack were more frequent. Insects like caterpillar, beetle, fly, and other coleopteran insects damage the leaf blade along with the midrib resulting in falling of leaves sometimes giving scaletonized appearance. It was recorded that herbivores preferred the older leaves compared to the younger ones. However, Coley (1983) reported that insect preferred young leaves due to lack of toughness, and higher levels of water and nitrogen. Barboni *et al.* (1994) reported that alkaloid content is higher in young plants, and reproductive organs as a defensive strategy of the species and more so in pioneer species.

Vegetative propagation is an easy and quick method of plant propagation. However, the study on vegetative propagation in Rudraksh using branch cuttings did not show satisfactory results. Branch cuttings in February and May resulted in sprouting but no rooting. A number of workers have shown that rooting of cutting is facilitated when carbohydrate reserve food is in abundance (Kraus & Kraybill 1918, Knight 1926, Carlson 1929, Duguma 1988).

Seasonal stimulus plays an important role in callus formation in cuttings of trees. Much of the growth activities remain suspended during winter and as soon as the temperature starts rising from February onwards

the reserve food material is mobilized, which helps in growth flushes. Thus the cuttings made in the beginning of February are full of reserve food materials and the rising temperature gives stimulus to sprouting and rooting. During vegetative propagation, growth of the sprouts depends on food reserve available in the cuttings (Wright 1975). But where root formation lags behind the shoot formation, survival rate becomes very low and the cutting is likely to die (Duguma 1988). According to Adraince and Brison (1955) low carbohydrate/nitrogen ratio encourages better shoot growth but poor root formation. Thai (1977) suggested that early shoot formation might have unfavorable effect on root formation because this creates a competition between root and shoot formation for nutrient reserve in the cuttings.

It is concluded that the seed production, dispersal and regeneration of the tree species depend on the influence of biotic and abiotic factors of the environment. Though the prevailing disturbances directly influence the availability of dispersers and ultimately affect the regeneration of the Rudraksh, still a thorough study is required. Mild disturbances have a positive role in the regeneration of Rudraksh. Seedling population requires favourable microsites for better survival and growth. Thus populations are regulated by overhead canopy, ground vegetation, pest attack and other biotic interactions.

The present investigation throws light on certain important aspects of dispersal and regeneration of Rudraksh. However, in order to gain deeper

insight into the regeneration of the species, following studies need to be undertaken in detail:

1. Detailed studies on the impact of prevailing disturbances on regeneration of Rudraksh and to identify the intensity of disturbance that may favour the regeneration of species.

2. Study on secondary dispersal and identification of the dispersers involved in such dispersal.

3. Studies on the identification of predators, pests and pathogens in different habitats that influence the regeneration.

4. A study to develop quick method of vegetative propagation.

Results of the present study could be quite useful in understanding the regeneration behaviour and population dynamics of Rudraksh, and based on these findings, appropriate strategies could be evolved to conserve this threatened species.