The thesis presents scientific information of some important and less understood aspects of life history characteristics and regeneration of *Gymnocladus assamicus* which is a critically endangered tree species endemic to northeast India. The studies focused on the following aspects:

1. Documentation and mapping of the available *G. assamicus* population in Arunachal Pradesh.
2. Life history characteristics of *G. assamicus* and its associated vegetation.
3. Population structure and regeneration status of *G. assamicus* in selected study sites (Changfu Moon, Dambla village and Moishing village).
4. Reproductive ecology of *G. assamicus*.
5. Seed biology, its structure, viability and germination strategies and different modes of regeneration.
6. Seedling growth and survival in *ex-situ* and *in-situ* conditions as well as performance of reintroduced seedlings in its natural habitat.

**Biology, distribution, phenology and associated vegetation of *G. assamicus***

*Gymnocladus assamicus* (Leguminosae; subfamily Caesalpinioideae) is a critically endangered tree species endemic to northeast India. Individual trees in the same population bear male and hermaphrodite flowers, a condition known as androdioecy. Average number of flowers per male and hermaphrodite inflorescence was 72.50 (±4.01, n=20) and 23.40 (±4.01 n=20) respectively. Both male and bisexual flowers are small, tubular, violet-coloured and odorless. The fruits of *G. assamicus* are typical pod, 10-16 x 2.5-4 cm in dimension and are compressed and turgid over the seeds. Pericarp is polished and fleshy mesocarp
is highly saponaceous. Each pod contains 4-8 seeds. Seeds are 14-15 x 15-17 mm in dimension, ovoid or subglobose having black horny testa and are extremely hard.

The pods are used by local people for cleansing purposes in domestic as well as rituals. Fully mature Gymnocladus pods are harvested during January-February and stored for future use. Destructive way of harvesting by cutting down the pod bearing branches is also noticed.

Gymnocladus assamicus is a rarely documented species and very little information is available on its distribution. On the basis of field survey and environmental niche modelling, twenty G. assamicus locations have been reported. Number of trees in each location ranged from 1 – 7. A few sites were having only male trees while few others were having hermaphrodite trees only. The sites are mostly distributed on the hill slopes and along the banks of streams.

Sixty plant species (16 tree species, 16 shrubs and 28 herbs) belonging to 37 families and 60 genera were found associated with G. assamicus in the three study sites. Quercus griffithii and Rhus wallichii were the most common trees growing with G. assamicus. Dominant tree species in Changfu Moon site were Pinus roxburghii, Quercus griffithii, Juglans regia and Rhododendron arboreum while Erythrina stricta, Schima khasiana and Juglans regia were dominant in Dambla site. Moishing site was dominated by Quercus griffithii and the bamboo species Phyllostachys mannii. On the other hand, the density of G. assamicus was very low in all the sites and ranged between 0.5 (Moishing) to 1 (Changfu Moon and Dambla) individuals per hectare.

**Population structure and regeneration status of G. assamicus**

Studies on population structure of G. assamicus revealed that it has very less population. Frankel et al. (1995) designated a species as 'critically
endangered' when the total number of reproducing individual is less than fifty. Therefore, *G. assamicus* may be categorized as 'critically endangered' as the reproducing individual were found nine only. The age structure indicates that it has very poor regeneration in Changfu Moon and Dambla site except Moishing site. Very less number of seedlings, saplings and mature trees of *G. assamicus* in each site indicate that it has very poor natural regeneration and survival potential. Seedling population was found significantly (P<0.05) higher at 4 - 8 m radius under the parent tree canopy whereas sapling population was significantly higher (P<0.05) at 8 – 12 m radial distance. This follows Janzen and Connell's 'escape hypothesis' which says that tree seedling survive best at distance from the parent plant (Janzen 1970, Connell 1971). Survival of tree seedlings was found better in less human impacted forest. On the other hand, very poor regeneration in Dambla site may be due to anthropogenic activities (over harvesting of mature pods, forest clearance and grazing) because of its location nearby human settlements.

As dispersal by scatter-hoarding rodents and birds have important impacts on natural regeneration of many tree species (Price & Jenkins 1986, Vander Wall 2001, Hulme 2002, Jansen & Forget 2001), lack of dispersal in *G. assamicus* may act as a potential regeneration constraint.

**Reproductive ecology of *G. assamicus***

*G. assamicus* has clear sexual dimorphism in which male and hermaphrodite flowers are borne on separate trees. Observation on reproductive phenology revealed overlapping of flowering between the two sexes and thus chances of pollen transfer from male to hermaphrodite trees may be expected. Floral morphology showed that male flowers are slightly smaller in size than hermaphrodites. However, developmental stages, nectar secretion pattern and
floral life span were similar in both the morphs. Pollen germination percentage of male and hermaphrodite flowers showed a gradual increase with the increase in opening time and a maximum of 60% viability has been recorded at fully opened stage. This observation revealed that, both the sexes of *G. assamicus* have viable pollen grains.

Cross breeding experiments showed that hermaphrodite individuals of *G. assamicus* are self-compatible and autogamous and they can set fruit successfully. Xenogamous crosses with male pollen source also showed 56.85% fruit set which is an evidence of the fertility of male pollen. Present observations on breeding systems of *G. assamicus* revealed that hermaphrodite trees are self compatible for production of fruits and viable seeds. On the basis of such observations and according to the definition of functional androdioecy Pannell (2002a), *G. assamicus* is confirmed to bear clear sexual dimorphism with males lacking female function while hermaphrodites exhibit both sexual functions. Hence *G. assamicus* is a functional androdioecious species.

**Seed biology and modes of regeneration**

Seeds of *G. assamicus* have been classified as orthodox type with extremely hard testa. Seed surface morphology showed that hard and impermeable testa is the main barrier for imbibition and consequently retards germination. Extreme hard seed coat in the mature dry state may be due to the presence of heavily thickened galactomannan or mannan polymers on the walls of the endosperm cells. Scanning electron microscopic observation showed very compact nature of testa having a continuous layer of tightly packed palisade cells which may prevent uniform intake of water throughout the seed surface.

Different treatments for breaking hard seed-coat imposed dormancy improved germination and boiling water treatment was found as the most
significant. Germination experiments at different soil depths indicated that *G. assamicus* seeds germinate well at 1 cm depth rather than surface or 2 cm depth.

Seed predation by animals has been sighted and major seed hoarding animals noticed were hill cattle, goats and arboreal rodent. Pod and seed damage by fungi, especially by *Aspergillus* sp., *Mucor* sp. and *Humicola* sp. were common.

Vegetative mode of propagation has been tried by treating branches in different concentrations of rooting hormones. Though there was leaf initiation from the cuttings, no rooting has been noticed and the branches died after a few days.

**Seedling dynamics of *G. assamicus***

Seedling growth performances were always better during April-September *i.e.* during rainy season than dry and cool season *i.e.* October-March. Growth of *G. assamicus* was found better in shaded environment with low or medium light condition. Seedling mortality was found more during dry season than wet season. This may be due to chill and dry weather during December-March and are vulnerable to death. Seedling survival also varied site-wise and was highest in Dirang nursery followed by Moishing and transplanted seedlings in Dirang. Heterogeneous survival responses in case of *G. assamicus* may be due to differences in micro-environmental conditions in those areas.

Very poor seedling growth and survival of transplanted seedlings in NERIST botanical garden may be mainly due to spatial heterogeneity and vast change in microclimatic conditions to that of the native *G. assamicus* population in Dirang. Seedling growth in terms of height and collar diameter was almost uniform among the seedlings of Moishing site and the transplanted seedlings of Dirang site. This may be due to favourable growing conditions at Dirang as well
as specific attributes of the seedlings to influence the physiological ability to utilize the environmental resources efficiently.

Herbivory was found one of the major causes in seedling mortality among all the study sites. Major damage to seedlings took place during dry and cold season i.e. during December-March when domestic animals graze in the forest areas. Pathogen attack and insect infestation were also reported to cause mortality in G. assamicus seedlings.

It has been found that G. assamicus seedlings express full growth and development in rich soil moisture areas under lower irradiance level. Survival of transplanted seedlings was also found better in the above areas. On the basis of such observations, it may be suggested that plantation of G. assamicus should be raised along river or stream banks where soil moisture is sufficient. Seedlings may be planted under medium irradiance level along established forest/plantations with small or medium gaps.

**Constraints to natural regeneration**

Though fruit set seems to be sufficient (Prof. Amots Dafni, personal communication), other extrinsic and intrinsic constraints to natural regeneration were identified in G. assamicus. Major threats to natural habitats are expansion of agricultural activities in forest land and construction of roads and houses in and around forest areas. Such activities may be adversely affecting population of seedlings and saplings in Changfu Moon and Dambla village. A few specific threats to G. assamicus are over-harvesting of mature pods for domestic use, grazing, predation of seeds by scatter-hoarding animals and fungal damage to seeds (Plate 10). Other intrinsic constraints are lack of dispersal and a hard-waxy seed coat. Seed dispersal necessary for the survival of the offspring, farther from
Plate 10- Different threats to G. assamicus
the mother tree was not observed in *G. assamicus*. Limited number of fruiting (hermaphrodite) trees may also be a natural constraint.

**Conservation status**

Present investigation revealed that the population of *G. assamicus* is extremely small. Hence, active protection measures and continuous monitoring of the existing populations should be given top priority. As the numbers of mature trees are very limited, all the populations should be preserved with equal importance. Rare and endangered taxa often exist as relatively small and relic populations (Holsinger & Gottlieb 1989, Subash Chandran *et al.* 2008) and are subject to population bottlenecks (Fenster & Dudash 1994). Thus, a short-term conservation goal should be adopted to ensure that the vigor of a population is maintained or restored in the face of inbreeding through appropriate manipulation of the remaining genetic variations. According to the demographic characteristics of this species, it is found that the seedling and sapling populations do not contribute to the maintenance of natural regeneration stock. Thus, artificial introduction of the species in suitable ecological habitats may be one of the options to restore the populations of *G. assamicus*.

**Conservation initiative**

Population restoration by supplementary regeneration could be an adaptive strategy to combat the declining population of *G. assamicus*. This may be achieved by introducing nursery grown seedlings to compensate the lack of natural regeneration. Since major threats to *G. assamicus* are habitat degradation and overharvesting of mature pods, awareness among local people, preservation of existing reproducing individuals and sustainable harvest of mature pods may be effective in successful conservation of the species. As an initial step, local
Communities have been involved in conservation of the existing population and several awareness meetings have been conducted to conserve the species from danger of extinction. As a part of conservation initiative, nursery grown seedlings have been distributed to the local people for increasing the population of *G. assamicus* in its natural habitat. Government agencies such as State Forest Department, NGOs and other conservation agencies may take initiatives in developing and distributing as well as planting nursery grown seedlings in suitable habitats. Homegardens play significant role as storehouse of rare/endangered tree species (Das & Das 2005). For this, plantation of seedlings in homegardens, along traditional agricultural land or in wayside is also recommended. Such locations are generally protected and for this growth and survival of seedlings may be ensured.

For conservation of the germplasm in national gene bank, seeds have been deposited to the ARIS cell of the National Bureau of Plant Genetic Resources, New Delhi, India (IC no. IC-551620).

Various fundamental and scientific information on distribution, population structure and regeneration status, reproductive ecology, seed biology and seedling ecophysiology gathered during the present study may be utilized for conservation and restoration of *Gymnocladus assamicus* in Arunachal Pradesh and elsewhere. Being a critically endangered tree species, *G. assamicus* should be given priority conservation initiative and recover the species from danger of extinction.