Chapter 1

General Introduction

*Gymnocladus* is a small archaic genus belonging to the family Leguminosae having very few species and shows interesting pattern of distribution. The etymological meaning of *Gymnocladus* is 'naked twigs' (Greek). The genus was first described by Lamark with two species *Gymnocladus canadensis* and *Gymnocladus arabicus* from eastern Canada and Egypt respectively. *Guilandina dioca* L. is an earlier name for the Canadian species *Gymnocladus canadensis* which is again synonymised to *Gymnocladus dioica* (L.) K. Koch (Lee 1976). Lamark's another species *G. arabicus* is now considered as synonymous with *Moringa optera* of the family Moringaceae (Sanjappa 2002).

According to the International Legume Database and Information Service (Roskov *et al.* 2005) five species of *Gymnocladus* are taxonomically accepted. However, according to Missouri Botanical Garden (TROPICOS Nomenclatural Data Base) eight species of *Gymnocladus* are distributed worldwide. Three species of *Gymnocladus* namely *G. dioica* (L.) K. Koch, *G. arabicus* Lam. and *G. angustifolius* (Gagnep.) J.E. Vidal are reported to be restricted to North America, Egypt and Vietnam respectively while the remaining three species viz. *G. chinensis* Baill., *G. assamicus* Kanj. ex P.C. Kanjilal and *G. burmanicus* C.E. Parkinson are confined to the trijunction of India, China and Myanmar. In India, *Gymnocladus* is represented by the occurrence of *G. assamicus* and *G. chinensis* and are known only from the northeastern states (Sanjappa 2002).

Another sister genus of *Gymnocladus* is *Gleditsia* which was described by Linnaeus with a single species *Gleditsia tricanthose* from Virginia (North America). Currently, there are about 14 species in the world out of which ten
species are found in temperate Asia, 2 or 3 in North America, *G. amorphoides* (Griseb.) Taub. in South America and *G. caspica* Desf. in Caspian sea. In India, the genus *Gleditsia* is represented by *G. assamica* Bor. and *G. delavayi* Franch and is also restricted to northeastern region of India (Sanjappa 2002).

A phylogenetic study of two species of *Gymnocladus* and eleven species of *Gleditsia* by Schnabel et al. (2003) revealed their centre of origin to be eastern Asia and originated during the Eocene. Eastern North American species of both the genera are most likely to be evolved from ancestors that migrated across the Bering land bridge, but the Eastern Asian/Eastern North American disjunction appeared to be more primitive in *Gymnocladus* than in *Gleditsia* (Schnabel et al. 2003). Floral characteristics of the genus *Gymnocladus* is also bedeviling. Some taxonomic accounts have described the genus *Gymnocladus* as polygamous or dioecious (Shu 1783) while others have described the genus with unisexual flowers (Watson & Dallwitz 1993). On the other hand, *Gymnocladus chinensis* has been described as polygamous by Jia (1875).

*Gymnocladus* belonging to the sub-family Caesalpinioideae are medium sized trees (15-20m height) with multifarious characteristics in life form and utilization pattern having potential commercial and therapeutic qualities. Dried fruits of *G. chinensis* have long been known in oriental medicine as saponin drugs and used as diuretics and expectorants (Konoshima et al. 1995). In a recent study, MeOH extracts of the fruits of *Gymnocladus* is found to exhibit anti-HIV activity (Konoshima et al. 1995). In another similar study by Lee and Morris-Natschke (1999) it is found that *Gymnocladus* saponin isolated from fruits inhibited HIV replication with EC_{50} value of 27 \mu M.

Several ecological, silvicultural and phytochemical works have been carried out in the North American species *G. dioica* (Kentekuchi Coffee-tree) by different authors. The common name 'Coffee-tree' stems from the resemblance of
the seeds to coffee beans. The early immigrants to Kentucky are said to have roasted and ground the Coffee-tree beans and used as an inferior substitute for coffee. There are some reports that indigenous North American people used the seeds for food but they have a bitter unpleasant taste and contain the alkaloid 'cystosine' that causes gastrointestinal disorders and may lead to irregular pulse and coma (Bowles 2004). Cattle fatalities have also been reported after ingesting Gymnocladus seeds. The dark, round shiny seeds also have some aesthetic appeal and used as beads in rustic jewelry. They are known as 'hully-gullies' and are sometimes carried by children as a good luck charm. The wood of the tree is coarse-grained, heavy and strong. In the United States, it is sometimes used for railway ties, fence-posts and construction but is of little commercial importance because the tree is never abundant. The species is also grown extensively as an ornamental tree (Bowles 2004).

Gilman and Watson (1993) gave a general introductory description, use and management of Gymnocladus dioica. Ball and Kisor (1985) studied the acid scarification requirements of G. dioica seeds. Harr (1927) and Weisehuege (1935) studied the structure and behavior of Kentucky Coffeetree during germination while comparative adventitious shoot induction is being studied by Geneve (2005). The tree prefers deep rich soils in bottomlands, deep ravines and moist lower slopes (Elias 1980). Ripe seeds of G. dioica contain hydrocyanic acid which can be destroyed by thoroughly heating the seed for at least 3 hours at 150°C to make them edible (Facciola 1990). Wong and Ng (2003) purified an antifungal peptide using affinity chromatography from seeds of G. chinensis (Yunnan bean) and found active against the fungal species Fusarium oxysporum and Mycosphaerella arachidicola.

Though legume taxonomy in India is more or less well studied, the northeastern states especially Arunachal Pradesh remained less explored. The
edapho-climatic conditions of northeastern India favour luxuriant growth of vegetation attaining the stage of climax formation which is represented by scattered oak forests of the region. For its high endemism and threats of species extinction, the region is prioritized for conservation and included in the list of global biodiversity hotspot as Himalayan hotspot (Mittermeier et al. 2005). Arunachal Pradesh is located in the extreme northeastern part of India with a geographical area of 8.37 million ha and is the largest state of the region. It consists of 16 districts and is covered with amazingly high biodiversity. The state has a wide range of elevations ranging from 100 m in adjacent areas of Assam plains to 7000 m in the Shiwalik hill ranges of the greater Himalayas. The species richness of the state is very high with 4000-5000 species of vascular plants per 10,000 sq. km and thus considered as the second richest biodiversity region in the global context (Valdiya 2002). It is endowed with 6 major forest types within 4 major climatic categories (Kaul & Haridasan 1987) and is the house of 4117 species of flowering plants belonging to 1295 genera and 192 families (Chowdhery & Pal 1997). Major groups include 600 species of orchids, 89 species of bamboos, 18 species of canes and 400 species of ferns, 24 species of gymnosperms and innumerable species of algae, fungi, lichens, bryophytes and microorganism (Hegde 2002). Faunal diversity of the state is also very rich with more than 214 species of mammals, 770 species of birds, 83 species of reptiles, 130 species of fishes and 7 species of non-human primates with numerous species of insects (Hegde 2002). Cultural diversity of the state is incredible and is home to 26 major tribes of Indo-Mongoloid origin, consisting of 125 sub-tribes and clans with diverse social structures and idiosyncratic acculturations (Bhagawati 2002). Arunachal Pradesh has a forest area of 5.15 million ha and constitutes 61.50% of the total geographic area, out of which a mere portion of
12.03% area of the state is covered under protected area networking (Kutty & Kothari 2001).

At the same time, habitat destruction is continuing at increasing rates all over the world and if it is to believe the habitat-species curves, thousands of species will disappear during the coming decade (Theilade 2003). Due to continuous threat to the biological diversity, conservation of threatened species has become a prime necessity to sustainability in resource management. Conservation biology has become a mission-oriented science aimed at preserving biological diversity (Gibbons 1992). Regeneration study has thus received greater attention when a particular species is facing the verge of extinction and a clear cut strategy is needed for successful conservation and restoration of such species. This will also ensure substantiated yield and utilization of natural resources. Restoration ecology, an important and growing discipline within the field of conservation biology, aims to re-establish or re-habilitate damaged or lost plant and animal population or species assemblages native to the area of interest (Jordan et al. 1987). Restoration ecology, like much of conservation biology, often relies on fundamental autecological knowledge of the target species (Soberon 1992). It can also be viewed as a truly powerful research technique for restoration of a viable population or species assemblages as nothing else can (Bowles & Whelan 1996).

A few authors have done floristic studies of Arunachal Pradesh up to certain extent. Some of the notable works are by Haridasan et al. (1987), Haridasan & Deori (1991), Chauhan et al. (1996) and Chowdhery (1998). Very few studies have been undertaken on regeneration ecology of important tree species in Arunachal Pradesh. Khan et al. (1999) studied the effect of fruit size and seed number on germination and seedling fitness in *Mesua ferrea*. Bhuyan et al. (2002) conducted a detailed study on ecological aspects of seed production, dispersal,
germination and seedling fitness of Rudraksh (*Elaeocarpus ganitrus*) at Deomali Forest Division of Arunachal Pradesh. Khan (2004) found that seed mass effects on seedling success in *Artocarpus heterophyllus*, a tropical tree species of north-east India. Similar result was also obtained in case of *Artocarpus chama* by Khan and Uma Shankar (2004). However, studies to evaluate the constraints on natural regeneration of many of the important and endangered species of this region has remained far been arbitrary.

Sharma *et al.* (2002) accounted a total of 223 species of legumes belonging to 73 genera in Arunachal Pradesh. The state has also a few rare and endemic legume taxa *viz.* *Albizia arunachalensis*, *Albizia gamblei*, *Crotalaria bhutanica* and *Dalbergia clarkei*. Other than these, one of the most important tree legumes *Gymnocladus assamicus* Kanj ex P.C. Kanjilal which was earlier reported only from its type locality Khasi hills of Meghalaya is reported from West Kameng district of Arunachal Pradesh. For its extremely small population, this economically important tree species is categorized as critically endangered (CAMP report 2003). Because of its high endangerism, the species has also been included in priority list for recovery programme in India (Ganeshaiah 2005). *G. assamicus* is intricately associated with the daily life and rituals of Monpa tribes of Arunachal Pradesh for its rich cleansing properties (Choudhury *et al.* 2007a). However, no detail information is available on distribution range, regeneration status and niche requirements of the species.

As mentioned earlier, the floral characteristics of the genus *Gymnocladus* is much perplexing and no extensive work has been done on it. During the present observation, it was found that individual trees bearing male and hermaphrodite flowers coexist. Such co-occurrence of males and hermaphrodites in a sexually reproducing population is called as ‘androdioecy’. This phenomenon is regarded as exceedingly rare and considered to have evolved from dioecy as a result of
selection for self-fertile hermaphroditism (Pannell 2002a). However, no information is available on floral biology and reproductive ecology of G. assamicus which is a prerequisite for successful restoration and conservation of rare/endangered plant species.

With these objectives, the present investigation was undertaken to study the regeneration and reproductive ecology of Gymnocladus assamicus in West Kameng District of Arunachal Pradesh, India. The study covers a wide range of ecological aspects such as population structure, regeneration status, phenology, reproductive ecology, seed biology, seedling survival and growth as well as various factors affecting these parameters such as seed dispersal, predation, microenvironmental variables and microsite heterogeneity. These will be helpful to develop a strategy for successful restoration and conservation of the species from danger of extinction.

The focused objectives of the study are:

1) Documentation of population stock of Gymnocladus assamicus through field survey in Arunachal Pradesh.
2) Phenological studies of G. assamicus.
3) To investigate natural regeneration status and different modes of regeneration.
4) To Study the reproductive ecology of G. assamicus.
5) Regeneration behaviour of the species in natural and controlled environment.
6) Study of environmental factors and soil physico-chemical characteristics influencing the regeneration and growth of Gymnocladus assamicus.