INTRODUCTION

Aquatic plants perpetuate their life cycle in still or flowing water, or on inundated or non-inundated hydric soils (Philbrick and Les, 1996). These plants show many adaptations like presence of aerenchyma cells for buoyancy, extreme reduction of leaf and vascular tissues, absence of stomata and mechanical tissues. Although turbulent river rapids and violent waterfalls are not typically considered habitats for angiosperms, two families (Hydrostachyaceae, Podostemaceae) are restricted to them. Wetlands of Indian subcontinent are rich in aquatic macrophytes. Podostemaceae with many exceptional characters from hydrophytes are grouped under torrenticolous rheophytes by Van Steenis (1981). The family Podostemaceae represent one of the most interesting families of higher plants. They are a large family of aquatic dicots with ca. 48 genera and approximately 280 species (Cook and Rutishauser, 2007) of which 26 species are endemic to India (Sanavar et al., 2005). Podostemaceae are often called the ‘River Weed Family’ and consists of a unique group of thalloid rheophytic angiosperms restricted to the tropical riverine habitats all over the World. The Podostemaceae are different from typical angiosperms in morphological, anatomical, embryological and developmental features and consequently remained as an evolutionary enigma. This family deviates from other aquatic plants in the absence of aerenchyma, the predominance of sexual over asexual reproduction and the high rate of endemism (Philbrick, 1997). The family name comes from the type *Podostemum* (podos=foot, stamum=stamen, prominent foot like stamen supported by a stalk). Willis (1902a), the pioneer in the work of Podostemaceae, described them as a special group with highly varied morphological structure. This refers to the strange combination of simple undifferentiated thallus, perplexing polymorphism and number of growth forms surviving in the most erratic habitats. According to Pannier (1960), “the reason for lack of research on this interesting group of aquatic plants is undoubtedly due to the impossibility of maintaining them alive out of their natural habitat for any period of time”.

The family is divided into three subfamilies namely Podostemoideae, Weddellinoideae and Tristichoideae. The members of the Tristichoideae and Weddellinoideae are less specialized and wide spread whereas the members of the

Podostemoideae are highly distinctive and occupy a narrow range of distribution. They grow in torrential and violent rushing streams, rivers and waterfalls in tropical and subtropical regions of the World. A great variety of species of these plants grow where waters are most turbulent. The members carry out their life-cycle tenaciously attached to the rocks in torrential currents of river rapids and waterfalls. Their plant morphology deviates so markedly from the conventional root-shoot (CRS) model, typical of angiosperms, that morphological connotations such as stem root and leaf cannot be precisely applied. The members have a thalloid plant body, usually dorsiventral, resembling an alga, a lichen or a bryophyte. They grow tenaciously attached to submerged rocks by means of unicellular adhesive hairs and haptera that secrets a gummy substance for firm fixation. Podostemads possess with several remarkable embryological features not known in such combination in any other angiosperm. These characteristics not only make the podostemads markedly distinct from other angiosperms but also biologically interesting and evolutionarily enigmatic. The basic elements of plant structure in Podostemaceae seem bizarre and have defied interpretation (e.g. Jäger-Zürn, 1992; Rutishauser, 1997; Mohan Ram and Sehgal, 1992). The names of many species in the family reflect their ‘non-angiospermic’ appearance, e.g., *Apinagia fucoides* (Mart.and Zucc.) Tul. (resembling brown alga *Fucus*), *Zeylanidium lichenoides* (Kurz.) Engl. (resembling a lichen), *Willisia selaginoides* (Bedd.) Warm.ex. Willis (resembling the heterosporous fern-relative *Selaginella*).

Table No. 1: Relationship between Podostemoideae, Weddellinoideae and Tristichoideae. (Some modification after Nagendran, 1975).

Characters	Tristichoideae	Weddellinoideae	Podostemoideae
Flowers	Trimerous	Trimerous	Dimerous
Perianth	Present	Present	Absent
Spathella	Absent	Absent	Present
Stamens	1-25	Many	Many (1 or 2 in Indian taxa)
Staminodes	Absent	Present	Present
Pollen	Monads	Monads	Dyads
Ovary	Tricarpellary	Bicarpellary	Bicarpellary
Ovules	Many, Bitegmic	Many, Bitegmic	Few to many, Bitegmic
Pseudo-embryo sac	Organized after fertilization	Arises before fertilization	Arises before fertilization
Embryo	Plumule differentiated	Not known	Plumule not differentiated
Similarities			
Embryo sac	Apinagia type, Podostemum type	Apinagia type	Apinagia, Podostemum and Polypleurum type
Fertilization	Single (only syngamy)	Single (only syngamy)	Single (only syngamy)
Endosperm	Absent	Absent	Absent
Embryogeny	Solanad type	Solanad type	Soland type
Embryonal haustorium	Present	Present	Present

Life of the plant

All Podostemaceae, so far as is yet known, live in rapidly moving water or even broken water, such as is found in the rapids and waterfalls of mountain streams. They are only found attached to rocks as a rule, but occasionally may be seen growing upon logs of wood or other objects which have become firmly wedged in the rocks. All along the rocky part of the river the rocks are more or less overgrown with Podostemaceae, wherever they are covered by water during ordinary weather. These plants grow only on places where the water is in constant motion, and never in stagnant water. They even flourish on the rocks at the sides of the waterfalls, with the furious current rushing right over them. If the level of the water recedes at any time those plants which become exposed to the air soon die, and a kind of tidemark can be seen traced upon the rocks by their covering of Podostemaceae. This mark indicates the average level to which the water falls during their growing season, above which it may temporarily rises during heavy rain, or below which it may sink during exceptional dryness of the weather.

Influence of Rainfall and their distribution

Perhaps the most important factor in the life-history and ecology of Podostemaceae is the rainfall and its distribution throughout the year, as this factor controls the level of the water, and hence the local distribution and the period of flowering of the plants.

When the south-west monsoon begins from April-May in Kerala (India), with gentle winds and a good deal of rain, the seeds start germinating with the wetting. The first onset of the monsoon is not violent, and is locally known as the " little monsoon'' but there is usually enough rain to wet the seeds and raise the water-level so high that most of the seed germinate. About the end of May, the big monsoon sets in with violent wind and rain from the south-west, causing the river to rise very high. During June and July it usually remains high, but in August and September there is usually less rain, and the level of the water starts sinking. The initiation of the flower buds and development of the flowers take place during the high water of the two months of the year and by the middle of December the flowers are generally completely formed, ready to open as soon as exposed to the air.

Distribution of Podostemaceae

The Podostemaceae are usually restricted to swift-flowing rivers and streams, rapids and waterfalls, with distinct seasonality in the tropics and subtropics (Graham and Wood, 1975). No other angiosperms, except the Hydrostachyaceae, live in such extreme habitats, clinging to the rocks in water rapids, cataracts and waterfalls. They are widespread in the New World from Mexico to South America and in the Old World in tropical Africa and Madagascar, India, Sri Lanka, Eastern Asia, and Australia (Cook, 1990). Few taxa, however, extend to temperate regions. The family is represented in the temperate regions by species of *Cladopus moller* and *Hydrobryum* Endl. in Japan and India (Ohwi, 1965; Cusset, 1992; Kadono and Usui, 1995, Nagendran, 1975) and *Podostemum ceratophyllum* in north-eastern America, both Canada and United States (Philbrick and Crow, 1983). The occurrence of fossil species like *Podostemonites corollatus* Zafer and *Podostemonopsis tertiara* Weyland was evidence that Podostemaceae thrived in Europe during the tertiary era (Szafer, 1952; Weyland, 1937). About 60% of the species occur in the New World. Few species reach temperate regions. *Podostemum ceratophyllum* Michx. is the only temperate New World species (Philbrick and Crow, 1983) ranging from Nova Scotia and Quebec south in the US to Georgia and west to Eastern Oklahoma.

Out of the ca.48 genera that are currently recognized, 30 are in the Old World and 19 occur in New World (*Tristicha* occurs in both). Although more genera occur in the Old World than in the New World, the species diversity is higher in New World. Opinion has differed among botanists with regard to the number and kinds of genera in the Podostemaceae (Rutishauser, 1997). Among the Asian group, Cusset (1973) and later Cook (1996a) included the genus *Griffithella* (Tul.) Warm. in *Cladopus*, removing *Griffithella* as an Asian genus. However, Cook (1996b) reinstated the genus *Griffithella* in his work on aquatic and semi-aquatic plants of India. Similarly, Vidyashankari and Mohan Ram (1987) and Mathew and Satheesh (1997) also listed *Griffithella* as an Asian genus.

Most of the genera in the family, Podostemaceae are small. Twenty-three (46%) are monotypic; only five (10%) genera have more than 10 species, twenty-two (44%) genera have between two and nine species. Many species in the family show a high degree of endemism (Philbrick and Novelo, 1995). Several species and some genera are known only from small geographical areas or a single river or country (Cook, 1996a). For instance, *Angolaea fluitans* Wedd. occurs in the Quanza river in Angola (Baker and Wright, 1909; Cook, 1996a); *Marathrum rubrum* is confined to the Horcones river in Mexico (Philbrick and Novelo, 1995), *Willisia selaginoides* occurs only in Periyar river in Kerala (Uniyal, 1999) and *Indotristicha tirunelveliana* found only in Thulukumparai falls in Tamil Nadu (Uniyal, 2001). *Tristicha trifaria*, which has the widest distribution in the family, is found in the central, and South America, Africa and Madagascar (Graham and Wood, 1975; Cook, 1996a). Indian Podostemaceae has been reported from the Uttarakhand, Goa, Maharashtra, Kerala, Karnataka, Tamil Nadu, Andhra Pradesh, Madhya Pradesh, Orissa and also in the hills of Assam, Arunachal Pradesh, Manipur and Meghalaya. It is noteworthy that out of 28 species in India, 26 are endemic.

Table No. 2: Occurrence and Status of Podostemaceae in India (Sanavar et al., 2005)

S.No.	Taxa	Distribution	Status
1	*Cladopus hookeriana*	Kerala, Karnatak	Endemic
2	*Farmeria metzgeriodes*	Kerala	Endemic, Rare, Threatened
3	*Hydrobryopsis sessilis*	Western Ghats of Karnataka Maharashtra and Andhra Pradesh	Endemic, Rare, Threatened
4	*Hydrobyrum griffithii*	North-Eastern Himalaya in Arunachal Pradesh, Meghalaya, Assam, Manipur, Sikkim and Garhwal	Endemic, Rare, Threatened
5	*Maferria indica*	Tamil Nadu	Endemic, Rare, Threatened
6	*Podostemum barberi*	Karnataka, Madhya Pradesh	Endemic, Rare, Threatened
7	*Podostemum subulatus*	Kerala, Tamil Nadu and Maharashtra	Endemic
8	*Polypleurum agharkarii*	Assam and Meghalaya	Endemic and Rare
9	*Polypleurum dichotomum*	Maharashtra and Tamil Nadu	Endemic
10	*Polypleurum disciforme*	Kerala	Endemic and Rare
11	*Polypleurum elongatum*	Kerala and Tamil Nadu	Endemic and Rare
12	*Polypleurum filifolium*	Kerala and Orissa	Endemic and Rare
13	*Polypleurum minor*	Karnataka, Kerala, Tamil Nadu, Maharashtra, Rarely in Assam Meghalaya	Endemic and Rare
14	*Polypleurum munnarense*	Kerala	Rare
15	*Polypleurum prostratum*	Kerala	Endemic and Rare
16.	*Polypleurum stylosum*	Maharashtra, Kerala, Karnataka, Tamil Nadu, Rarely occur in Assam, Meghalaya	Endemic and Rare
17.	*Polypleurum stylosum* var. *laciniata*	Kerala	Endemic and Rare
18.	*Polypleurum wallichi*	Meghalaya	Endemic and Rare

19.	*Willisia arekaliana*	Silent Valley (Kunthipuzha), Kerala	Endemic and Rare
20.	*Willisia selaginoides*	Kerala (Pooyamkutty) and Tamil Nadu (Parambikulam)	Endemic, Rare, Threatened
21.	*Zeylanidium johnsonii*	Karnataka, Kerala, Andhra Pradesh	Endemic and Rare
22.	*Zeylanidium lichenoides*	North Eastern India, Western Ghats including Maharashtra, Kerala, Karnataka, Tamil Nadu, Madhya Pradesh, Orissa, Andhra Pradesh	Widely distributed
23.	*Zeylanidium maheshwarii*	Kerala	Endemic and Rare
24.	*Zeylanidium olivaceum*	Western Ghats of Tamil Nadu and Kerala, North eastern India in Arunachal Pradesh	Endemic and Rare
	Sub-family Tristichoideae		
25.	*Dalzellia gracilis*	Kerala	Endemic
26.	*Dalzellia zeylanica*	Western Ghats of Karnataka, Kerala and Tamil Nadu	Endemic
27.	*Indotristicha ramosissima*	Western Ghats of Karnataka, Kerala and Tamil Nadu	Endemic
28.	*Indotristicha tirunelveliana*	Tamil Nadu (Thulukumparai)	Endemic, Rare, Threatened

Origin and Evolution

Willis (1915a, 1926a) proposed that the ancestors of Podostemaceae must have been land plants on the bank of rivers that sent out creeping roots along the stones of waterfalls. These plants might have shifted to water at one time and undergone whole of the evolution in water. Probably their habitats had been continuously flooded and they adopted such unique morphology, reproductive biology and seed germination. Willis (1926a) explained the origin of Podostemaceae as a result of single massive mutation without natural selection. From a study of Podostemaceae, Willis (1902b, 1914, 1915a) arrived at certain views that these plants have been derived from some terrestrial habit. Willis (1902c) suggested that a possible origin for the family is from plants that are already growing on the banks of mountainous streams with creeping adventitious roots (thallus) upon which secondary shoots (leaves and flowers) were regularly developed. These secondary shoots might provide the opportunity for an entrance into aquatic life. Most of the peculiarities of the group can be traced to the remarkable plasticity of the skeleton-less root and to the parallel dorsiventrality of the vegetative organs and flowers. The dorsiventrality is associated with their plagiotropic method of growth, forced upon by the fact that they live only upon an unyielding substratum.

Arber (1920) while agreeing with Willis (1915a) on the concept of natural selection does not explain the origin of specific and distinctive entities, urged caution in accepting Willis's assertion that natural selection is unimportant in contributing to adaptation. The Podostemaceae as it seems, afford an example of evolution unhindered by the limiting effects of competition and natural selection. Arber (1920) surmised that the absence of adaptation may in part be attributed to the absence of competition and therefore of natural selection.

The Podostemaceae thus exhibits a great variety and marked specific differentiation, but the features in which the genera and the species differ from one another cannot be explained as adaptation. The natural selection can scarcely be a factor of any great importance in Podostemaceae and yet there is a quiet extraordinary variety of specific forms, many of which are confined to extremely limited areas.

Adaptations

With the exception of some of the parasitic orders, such as the Balanophoraceae, there are probably no families in flowering plants which are so completely transformed from the average or mesophytic type of the phanerogams into types which are so completely unique and peculiar, as the Podostemaceae. There is a remarkable variety in morphological structure in this family in the manner:

i) that the families contain the most astonishing variety of morphological structure. They are thalloid and completely appressed to the rocks or stones.
ii) that as there are no changed conditions to which to be adapted, there can be no adaptation to conditions other than to the general conditions which are common to all, and have been common to them since family began and
iii) that therefore, can be in all possibility, be no selection of infinitesimal variations, but progress must have been by something of the nature of mutations or fixed changes without natural selection. There are some factors

which appear to have had an influence in the evolution of these remarkable families. The structure of the plant body as well as the condition under which they live is being unique and highly adapted to such habitats. The flat thallus-like expansions of stem or root being looked upon as admirably suited to the rushing water in which they live.

Evolution is usually supposed to have produced the extraordinary forms now existing by adapting members of very different families to very different conditions of life. In this family the evolution can be studied with many complications of factors that are removed or simplified. The conditions of their life are almost absolutely uniform all over the world. In such turbulent sites there is no competition as the family has its habitat to itself. They can grow naked on water worn rock in similar climate that grow in running water in the subtropical or tropical zone, and are represented by seed in colder period. Perhaps these plants took to water at different stages of evolution into a family upon land, they must obviously have gone through the whole of their evolution in water forms at an extremely early stage, during which the ancestors probably retained a certain power of surviving upon land. Presently, the family consists of about 48 genera and 280 species of the most varied morphological structure possible under perfectly uniform conditions which cannot have varied except for all alike, since the evolution of families began. The evolution consequently cannot have been any sort of response to a necessity of adaptation to different conditions, for there are and have been no different conditions to which to be adapted since the first members of this family began to live in running water.

Habitat Characteristics and Ecology

Podostemaceae, with many exceptional characters of hydrophytes are grouped under torrenticolous rheophytes by Van Steenis (1981). Cook (1990) classified them as haptophytes, which are the plants attached to rocks but do not penetrate the substratum. Grubert (1975) viewed that Podostemads are able to withstand enormous tensile strength that higher and larger plants cannot. Earlier, these plants were believed to be attached to the rocks by a cementing substance (a kind of gum) excreted by their haptera (Vidyashankari and Mohan Ram, 1987). It is also evidenced through *in-vitro* grown plants that a gum comes out from the adhensive hairs which help in firm fixation (Uniyal, 2001). However, Jäger-Zürn and Grubert (2000) suggested that the strong attachment of podostemaceae to the substratum was effected through EPS (extra polymeric substance) of the bacterial bio-film.

Podostemaceae are usually the most significant macrophytes in tropical rivers and play very important roles in tropical river ecology. They are involved in primary production contributing to autochthonous carbon (Quiroz et al., 1997), and are important food source for aquatic herbivores (Gessner and Hammer, 1962). They are also involved in nutrients uptake and release. Their eventual use by detritus feeders is also important. They also act as substrata for diverse assemblage of epiphytic microscopic flora as well as habitat for aquatic fauna (Uniyal, 2001).

Forty four rivers in Kerala, arising from the Western Ghats and a combination of north east and south west monsoon make it an ideal place for growth of hydrophytes especially rheophytes. Nayar and Sastry (1987) suggested that many Podostemaceae are endemic to Western Ghats, though a few are reported from Arunachal Pradesh, Sikkim, Meghalaya, Assam, Maharashtra and Goa (Vartak and Bhadbade, 1973).

Each organism or population is regarded as influencing ecosystem according to its own ecological life history (Mishra, 1960). The floral and palynological adaptations together with seed and seedling establishment are all directives to the features of the whole ecosystem itself.

Rivers of tropical rapids are the most productive regions of rivers harbouring diverse assemblage of aquatic invertebrates, fishes, amphibians, algae and mosses (Sculthorpe, 1967). Macrophytes colonies of plants such as Podostemaceae possibly alter the surface flow patterns of riverine habitat (Grimm, 1994). In the new world Podostemaceae forty eight percent shows high local species endemism, being located in a single river or a single spot. In such a situation, negative impacts of global climate changes, occurring in these rivers will directly affect these riverweeds (Grimm,1994; Allan, 1995). Sioli (1986) suggested that tropical rivers are the heavily polluted among aquatic habitats, since they are utilized to the maximum. Demographic and developmental pressures show a thorough ascending pattern in the tropics. Hence, sewage and agricultural as well as industrial pollution also increase correspondingly. Influence on water level manipulation due to hydroelectric dams lead to extreme siltation and unpredicted floods. Quiroz et al., (1997) worked on the relation between water quality and podostemads population in Mexican rivers for the first time. Complete loss of habitat is a major threat to endemic flora. These may happen due to natural or anthropogenic causes. Willis (1902a) has reported similar loss of population of *Hydrobryum griffithii* in Sikkim owing to floods. Uniyal (2001) reported the loss of a population of *Hydrobryopsis sessilis* due to the construction of bridge on Killoor river (Karnataka). Large number of dams for hydroelectric purposes in a single river, erratic climate and unsustainable tourism might be some factors causing irreversible changes in the riverine ecosystem of Kerala.

Associations with plants and animals

Competition with other plants is a factor of very slight importance indeed with all the more modified Podostemaceae; they live in water so rapid that no other flowering plant and only occasionally any Cryptogam other than some minute alga are found there. In the dry season, when the water level decreases enough to bring the podostemaceae to the surface, they become covered with filamentous algae, but by this time it can matter but little to their success or life. These plants escape from competition to a degree that is very rare in the plant kingdom. This absence of competition is probably a very important factor in the morphological features of these plants; they have been enabled to adapt themselves structurally, mainly in relation to the physical factors of their environment, rather than to the biological.

Animal life also seems to have but little effect on the Podostemaceae. The movement of the water is too swift to allow them to be attacked by fish, some aquatic small animals and the larvae of various water insects; these feed greedily on the thalli and seeds, which are usually very rich in starch. Indirectly, wading birds are probably of much importance, because they walk about on the rocks with wet feet in the dry weather, and the small sticky seeds must cling to their feet, and thus probably be at times carried to suitable places for growth in other localities.

Vegetative morphology and anatomy

The vegetative body consists of a dorsiventral thallus which roughly corresponds to stems and leaves in superficial appearance. The thallus adheres firmly to the substratum either by masses of hair like structures (rhizoids) which originate as extension of the lower epidermal cells or by more complex organs which superficially resemble the haptera. The internal structure of podostemads is similar to that of many other submerged plants in having reduced xylem, absence of stomatas and presence of chlorophyll in the epidermis. However, the aerenchyma is totally absent.

The flowering plant family, Podostemaceae, is of extraordinary interest anatomically. Its parenchymatous “thallus” which is rootless, grows closely appressed to rocks in rapidly moving streams, rivers and cataracts. The occurrence of silica bodies, especially, in the superficial tissues of the thallus is an important feature. It seems on the whole most probable that this silica is merely useless by-product of the plants metabolism. In some species, these are sufficiently numerous to form a kind of armour or carapace which prevents the plant from collapsing during the lowering of water level. The most anatomical peculiarity of the podostemads is the extreme reduction of the intercellular spaces (Warming, 1881) in the respect that the members of these families contrast most remarkably with other water plants. This feature is probably associated with the thorough aeration of the torrential water which they frequent. The vegetative parts of podostemads die very quickly when the water level recedes and plants become exposed. The flowering and seed-setting take utmost rapidly.

The adaptive modifications of structure such as the gradual reduction through a series of forms, of the shoots by vegetative budding, the reduction in the number of flowers per shoot, the increase dorsiventrality of characters were shown to be rather correlated with the rise and fall of the water than with the velocity of the river. The extremely local distribution of many forms, their anomalous morphology and progressive dorsiventrality and great variety of types of structure which they present, offer every incentive to speculation.

Developmental Biology: *In-vitro* seed germination and seedling development

The vast majority of flowering plants rely on seeds for perpetuation of populations as well as the dispersal and establishment of new populations. Interpretations of basic form of plants are hindered by lack of knowledge of how seedlings develop into mature plants under extreme conditions. Early observations of seed germinations were based on field collected seedlings. However, botanists have been dissuaded from detailed field based study of seedling biology and development because seedlings are inconspicuous and remain deep in water, difficult to identify to taxon and occur in often inaccessible habitats.

The seeds of most species are tiny, ovate in shape, smooth when dry, and composed of a mucilaginous outer integument. In Podostemaceae, the outer integument of the seed plays a central role in the attachment of seeds on solid substrate (e.g. rocks) (Gessner and Hammer, 1962; Grubert, 1970, 1975, 1976; Philbrick, 1984). When seeds are initially shed from capsules, cells of the outer integument are dry and collapsed. Upon wetting, however, these cells take up water rapidly, expand and become mucilaginous (sticky). When a wetted sticky seed comes in contact with a rock, the outer integument adheres the seed to the substratum. This is especially pronounced when wet seeds come in contact with a solid dry surface.

In Podostemaceae, the mature embryo does not show histological zonation. The polar ends, i.e. hypophysis and epiphysis, can be recognized only on topographic grounds (Mukkuda and Chopra, 1973; Nagendran et al., 1981). The life cycle of Podostemads start in the beginning of monsoon. It is difficult to study the seed germination and establishment of plants in the water. The events of seed germination in Indian Podostemaceae were studied using *in-vitro* techniques (Vidyashankari and Mohan Ram, 1987; Sehgal et al., 1993; Uniyal and Mohan Ram, 1996, 2001; Mohan Ram and Sehgal, 1997; Uniyal, 1999, 2001)

The embryo consists of two cotyledons only without distinct plumule and radicle. The radicular pole produces rhizoids for fixation to substratum after a week of germination. During this period the mucilaginous seed coat remain firmly attached to the rock and hold the seedling. The plumular pole produces 3-4 leaves and then a lateral outgrowth arises at the hypocotyl region of the seedling. This lateral outgrowth creeps over the substratum, take a form of dorsiventral thallus and throw the branches in all directions. Leaves and flowers appear on the dorsal side of the thallus. In the members of Tristichoideae the plumule produces leaves and buds consisting of green scale leaves (ramulus) and this activity continue unlike that of Podostemaceae. At the base of the hypocotyl, 3-4 root primordia originate and creep horizontally on the substratum and adhere to it by means of hairs and discoid hapteras. These creeping roots grow apically and produces shoot buds on their dorsal surface and root primordia on the ventral surface.

Reproductive Biology

The reproductive cycle in Podostemaceae is determined by the water level of the river, because during rainy season these macrophytes remain submerged and vegetative growth occurs (Philbrick and Novelo, 1995). After the rainy season, water level recedes and plants emerge and are exposed to potential pollinators (Willis, 1902a; Van Royen, 1951). The pollination mechanism in the family has not been studied extensively but has been reported to be entomophilous, anemophilous or hydrophilous (Sculthorpe, 1967; Hall, 1971). Willis (1902a) suggested selfing whereas Sculthorpe (1967) proposed insect pollination. In Podostemaceae, diverse pollination mechanisms ranging from anemophily to entomophily have been reported. Consequently, the breeding system in Podostemaceae varies from allogamy to autogamy (Willis, 1902a; Philbrick, 1984; Philbrick and Novelo, 1997; Rutishauser and Grubert, 2000; Khosla et. al., 2000, 2001; Ameka et. al., 2002; Okada and Kato, 2002). Anthesis usually occurs above water. Fruits are dehisced at maturity and seeds are shed on the rocks or other solid substratum where they eventually germinate at the onset of the rains. Many of the members of the river-weed family are annuals; some are perennials while others can be both annuals and perennials. Such species grow as annuals if they grow in the seasonal monsoon streams and dries up annually, but assume a perennial habit in persistent rivers and streams.

The Podostemaceae have several remarkable embryological features such as four nucleate, four celled mature embryo sac, absence of antipodal cells, occurrence of single fertilization and consequently absence of endosperm, presence of pseudo-embryo sac, presence of suspensor haustoria and lack of plumule and radicle in the mature embryo sac. Embryologists have been intrigued by the unusual patterns of female gametophyte development (Jäger-Zürn, 1997b). Moreover, double fertilization and endosperm production, two defining features of angiosperms, do not occur in Podostemaceae. Consideration of Podostemaceae relative to other aquatic angiosperm groups reveals further anomalies. Vegetative growth predominates over sexual reproduction in most aquatic plant groups, i.e there is an apparent trade off between sexual and asexual reproduction (Philbrick and Les, 1996).

Podostemaceae grows strongly attached to solid substratum and lack the various modified vegetative structure that promotes asexual reproduction and dispersal in other aquatics. The high degree of flowering and seed production in many Podostemaceae contrasts with the general pattern of low sexuality in aquatic angiosperms (Philbrick and Novelo, 1995). Reproduction via seed seems of primary importance in the biology of Podostemaceae (Philbrick and Novelo, 1995). Indeed, considering the general trends associated with aquatics overall, Podostemaceae seems to be on the line of adaptation to land habit.

Ecological Niche Modeling (ENM)

The distribution, richness and uniqueness of taxa must be assessed if priorities for conservation action are to be established. Only then the areas representing concentrations of rare, endangered or endemic species be accorded high priority in conservation decisions (Wilson, 1988). Obtaining detailed and accurate distributional information for such species therefore becomes a critical step in the biodiversity conservation challenge. Recent years have seen impressive growth in use of modelling approaches based on relationships between known occurrences of species and features of the ecological and environmental landscape (Guisan and Zimmermann, 2000; Pearson and Dawson, 2003; Peterson, 2003; Soberón and Peterson, 2004). These models are often termed ‘distribution models,’ ‘climatic envelope models,’ or (most generally) ‘ecological niche models’. Ecological niche modelling (ENM) is a recent tool which uses computer algorithms to generate predictive maps of species distribution in a geographic space by correlating the point distributional data with a set of environmental raster data. They help in gaining ecological and evolutionary insights in species geographic distributions, and are now being widely used in modelling species distributions in terrestrial, freshwater and marine environments (Elith and Leathwick, 2009). Through ENM approach, it is possible to identify areas that are suitable for the conservation of a species (Papes, 2006, Irfan-Ullah et al., 2006) and reintroduction of species threatened category (Martinez-Meyer et al., 2006).

Ecological niche modelling has seen numerous applications some of which are as follows:

1. Predict the potential distributional area of species and plan targeted biodiversity survey in new area (Giriraj et al., 2008; Irfan-Ullah et al., 2006; Adhikari et al., 2012).
2. Identify potential areas for species reintroduction (Martinez-Meyer et al., 2006, Wilson et al. 2011, Adhikari, et al., 2012).
3. Identify areas having potential for species invasions (Peterson and Vieglais, 2001; Barik and Adhikari, 2011).
4. Mapping risk areas for emerging infectious diseases (Peterson et al. 2005, Levine et al., 2007, Adhikari, et al., 2009).

THE BROAD OBJECTIVES OF THE PRESENT WORK ARE

1. Habitat characteristics in relation to water characteristics, temperature, associates etc.
2. To study the morphological and anatomical features of the 3 selected species.
   a. *Polypleurum stylosum* var. *laciniata* (Wright) J. B. Hall
   b. *Zeylanidium lichenoides* (S. Kurz) Engler; and
   c. *Willisia selaginoides* (Bedd.) Warming ex. Willis
3. Developmental Biology - *In-vitro* seed culture of the selected species to study the patterns of seed germination, percentage of germination, thallus formation events.
4. Aspects of reproductive biology of the selected species like floral characters, events of the formation of embryo sac, pollen - ovule ratio, ovule - seed ratio, type of pollination, etc.
5. To produce a prediction map of distribution of each of the three species using Ecological Niche Modelling.