## REVIEW OF LITERATURE

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## Work done on charophytes in World

Oldest record of charophytes dates back in 1469, in the writings of Plinius. Actual description of charophytes was given by Bauhin (1623). In his work Linnaeus recognized some algal genera and identified them later. It was Allen (1882) who described the development of cortex in Chara for the first time. Charophytes were raised from the mud colleted in cape colony by Groves. These cultures showed presence of Lychnothamnus one of the seven genera of charophytes. The first classical work on charophyte was done by Groves and Webster (1920), who published two volumes on British charophytes. Along with the taxonomy physiological experiments were carried out by Karling (1924). In his experiments correlation between light and temperature, with growth on charophytes was found. This was the first experiment in the history of charophytes to use them in physiological experiment. Karling (1926) also observed the nuclear and cell division in Chara and Nitella. In the same decade of twentieth century collection of charophytes from Madagascar was made and notes were published. The basis of cytological observation in charophytes was laid down by Karling (1928), who found the suitability of the antheridial filaments to observe the stages in nuclear division in charophytes.

Reproductive structures of charophytes are the most debatable and studied organs due to their macroscopic size and development pattern. The morphology of these reproductive structures is not only unique but sometimes serves as the criteria for discrimination between forma and variety within species. The antheridium is made up of shield cells which constitute the outermost cover. Two categories of antheridia were found and recorded by Groves (1931). Along with the taxonomy, morphology, physiology the ecological studies of charophytes were initiated by Pal (1932) on Burmese charophyte. The other factors such as pH and nutrients were also studied in their observation of Burmese charophytes by Pal.

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Kundu (1934) observed algal specimens collected by Dr. Agharkar from Nepal. By the end of fourth decade Zaneveld (1940) published an extensive work on "Charophytes of Malaysia" and adjacent countries. In his account he described eleven species of *Chara*, twelve species of *Nitella* and one species of *Nitellopsis*. The inhibitory effect of charophytes on the other aquatic organisms especially mosquitoes was first reported by Ophel (1948) in his studies.

Extensive work on charophytes was undertaken by Wood, who for the first time published an index of characeae (1950). At the same time the ecological work on charophytes was also undertaken by the same author. In an initial attempt he studied stability and zonation of characeae. Field study and herbarium specimens collected from several lakes indicated that characeae may be transition plants or may occur for fifty or more years in a given habitat. Vertical zonation was used as a measure of ecological variation between species. In 1952 Wood published an extensive list of species belonging to characeae world over. According to him there were one hundred and sixteen species of *Chara*, one hundred and fifty three of *Nitella*, thirteen of *Tolypella*, four of *Lamprothamnium*, three of *Nitellopsis*, two of *Protochara* and one of *Lychnothamnous*. In addition to the list of Charophytes a list of useful taxonomic literature world over was also provided by the author. Imahori published a list of charophytes in Micronesia in 1952.

A detailed ecological analysis of charophytes was made by Wood in 1952. A survey of Twenty-six water systems in Woods Hole region, Massachusetts, was made to determine the occurrence of characeae with respect to major environmental conditions. The factors considered included, type of water basins, bottom, associated plants, pH, salinity, methyl orange and phenolphthalein alkalinity and temperature. Of the factors considered, marked correlation was found between species occurrence and salinity, M.O. alkalinity and pH values. A fair correlation was found with type of basin and little or no correlation was found between temperature, phenolphthalein alkalinity or type of bottom. Japanese charophytes were described and reported for the first time with their ecology, phytogeography and taxonomy by Imahori (1954). Proctor (1959) worked on the migration of charophyte species world over. He concluded that the migratory birds are responsible for the dispersal of oospores to a longer distance, sometimes from continent to continent.

In order to set the priority for new combinations, names and taxa in his forthcoming monograph on characeae Wood summarized the taxonomic revision of characeae in 1962. In his paper the author listed species not included in his earlier review.

These publications included:

- 1. New sub-genera, sections and sub-sections.
- 2. New names for numerous previously described sub-genera, sections and subsection to bring them in accordance with International Code of Botanical Nomenclature.
- 3. Recognition of all taxa on the basis of overall similarity in gross and microscopic morphology. A treatment in contrast to the practice of subdividing taxa on the presence and/or absence of single key characters.
- 4. Re-organization of the taxa into a system which requires the reduction of large number of then accepted species, sub-species and varieties.
- 5. Re-evaluation of certain popular key characters

e.g. a) monoecious vs. dioecious, b) brachydactylae vs. macrodactylae, c) relative number of corticated branchlet segments. The revision was based upon extensive study of specimens.

To the revision of World Charophyceae, Forsberg (1963), made some notable remarks. The noteworthy remark was that the revision of charophyceae was mainly aimed at setting priority for new combinations, names and taxa than at giving an improved expression of the interrelationships within the charophyte.

Within the seven genera of charophytes the least known is the Lychnothamnus. The first report on the chromosome number and its comparison with

other genera was made by Hotchkiss (1963). The studies on population of Chara zeylanica were carried out by Griffith and Proctor (1964) in Texas, Oklahoma. They observed 140 collections of Chara zeylanica from southern America. In addition to morphology, chromosome numbers from these populations were also compared and detailed survey was made. The confirmation of chromosome number of charophytes was made by Tyndall and Sawa (1964). In the same year Forsberg carried out observations regarding growth and distribution of charophytes in various water bodies. They also commented on the critical factors controlling the growth of charophytes. Griffin and Rhodes (1965) studied the oospore wall ornamentation in Chara zeylanica. Imahori and Iwasa (1965) cultured the charophytes and studied the effect of combination of various amino acids as well as vitamin B<sub>12</sub> on the culture of charophytes. Hotchkiss (1966) confirmed the basic chromosome number n = 5 in Tolypella. Instead of taxonomy, cytology and physiological studies Proctor et al. (1967), studied the breeding experiments in different species of Chara. Fenson et al. (1967) determined the relative pore size in living membrane of Nitella by electro osmosis technique. The taxonomic status of Chara braunii was studied by Proctor in 1970. The question of sub- generic complexes within Chara was discussed by Proctor, Griffith and Hotchkiss (1971). Wallen (1973) investigated physiology of uptake of amino acids in Nitella flexilis. The question of incrustation in charophytes was discussed by Lucas and Smith (1973). New reports on the charophytes from Norway were published by Langangen who recorded twenty species of charophytes from Norway islands. Hypothetical classification of algae was proposed by Stewart and Mettox (1975). In this work the stress was given on cytology of various orders including charales. The phenomenon of geotropism of charophytes was studied by Juniper (1976).

The chemical analysis of charophytes was done by Allery Bernard et al. (1980) who isolated glycoproteins from cell-wall of *Chara*. On the basis of experiments done by Proctor, Croy (1982) studied the breeding pattern in dioecious species of *Chara*. The development of rhizoids and bulbils was studied by Andrews et al. (1984) in the culture of charophytes. A new species of *Nitella* viz. *Nitella woodii* was described by Hotchkiss and Imahori (1987).

Testermark (1988) measured the potassium ( $K^+$ ) currents in plasma lemma of cell wall of *Chara corallina*. In the exploration of charophytes the Arabian scientists have also contributed their share. Khoja and Hussain (1990) collected and identified charophytes from Saudi Arabia. In his volume on "Handbook of Protoctista" Grant (1990) gave these macroscopic algae a status of phylum. Jelena and Dobrina (1991) collected charophytes from Iraq. In 1991 a book entitled "Origin of Land Plants- A Theory Based upon Facts of Alternation" was written by Graham Linda. In her discussion special consideration was given to charophytes to trace the origin of land plants. A new species of *Chara* viz. *Chara hyalina* was found in Argentina by Garcia (1993). The succession of charophytes in Spain was studied by Feist and Anandon (1994). Distribution of *Chara* along with cytological and physiological features of banding pattern was reported by Chaw and Bissan (1994). In the last decade of twentieth century number of publications regarding physiology and biophysical observation

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## Work done on charophytes in India

The oldest record of algal collection from Bombay Presidency was that of Nitella by Stroke (1847). In the beginning of 20<sup>th</sup> century Hate (1909) reported occurrence of two species of Chara from Bombay Island, these were Chara verriculata and Chara flaccida. Groves (1924) published the occurrence of Nitellopsis from northern India. A series of papers (1931, 35, 40a, 40b, 42) were published by Dixit on charophytes from Bombay Presidency and also Dixit made survey of algal investigations from Bombay Presidency. Mukerjee (1932) made a survey of Dal Lake, Kashmir and reported charophytes viz. Chara fragilis, Nitella acuminata, Nitella dispersa, Nitella hyaline, Nitella obtusa etc. Publication of two specimens by Kundu (1939) from Shillong revealed the occurrence of dioecious Nitella in those areas. Allen (1936) collected charophytes from Bareilly and recorded four species of Nitella, six species of Chara and one species of Tolypella. The initiation on cytological studies of Indian charophytes was made by Sunderlingam (1946). In 1954 Biswas published historical sketch of studies on Indian charophyte. Sunderlingam (1954) studied the development of various parts of Chara zeylanica. These studies were later confirmed by many phycologists. The phylogeny of charophytes was discussed by Desikachary (1958) in an article "Taxonomy of Algae". Sunderlingam and Francis (1958) investigated two species of Chara viz. Chara zeylanica and Chara corallina from Madras Presidency.

A new species of *Nitella*, viz. *Nitella terrestris* sp. *nova* was reported by Iyengar (1958), the father of Indian phycology, from South India. This was the first record of terrestrial charophyte so far known. This alga showed various terrestrial adaptations. It was closely associated to *Nitella tenuissima* and *Nitella batrachosperma*. However, it differed from them in having gametangia on special axillary branches and quadriscutate antheridia.

A systematic account of South Indian charophyta was given by Sunderlingam. He also provided keys for identification of the species of both *Nitella* and *Chara*. A short series of notes on charophytes from Benaras United provinces in Northern India was published by Allen (1961). A new species *Nitella saharanpurensis* sp. nova along with sixteen other species of *Nitella* and thirteen species of *Chara* were reported in this paper.

Affinities and inter-relationships of Characeae were discussed by Desikachary and Sunderlingam (1962) proposing a phyllogenetic scheme. These authors considered Nitelloideae and Charoideae as two distinct lines. *Nitella* being more advanced than *Chara* and within *Chara* ecorticate forms were considered to be derived from corticate forms. In their discussion they also made comments regarding the chaetophorelian origin of charophytes. Globel's view regarding the antheridium and its shield cells was supported by these authors. In conclusion they also discussed the taxonomic status of this group arguing to give a special status to these macrophytes.

Sunderlingam (1962-63) studied the developmental morphology of some species of *Nitella* and *Chara*. For the developmental studies of *Chara*. two ecorticate species viz. *Chara corallina* and *Chara wallichi* were selected. An illustrative monograph on Indian Charophyta was published by Pal, Kundu, Sunderlingam and Venkatraman in 1962. Eighty six species belonging to seven genera were dealt in detail in the monograph along with their taxonomic description, distribution and ecology of Indian charophyta were also incorporated. This monograph has always remained a first hand reference for the study of Indian charophytes.

A special attention to the charophytes from Western India was paid by Vaidya and Gonzalves (1963). They reported thirty one species of charophytes belonging to genera *Chara* and *Nitella*. The classification of charophytes and their taxonomic status is a matter of discussion. Sarma (1964) discussed their status as an independent group supporting the proposal by Round (1981).

Some ecological factors controlling the growth of charophytes were studied from thirty five localities from Western India by Vaidya (1967). This was the first attempt to correlate the chemical factors of water such as pH, hardness, alkalinity, carbonates, chlorides etc. with the distribution of charophytes from a wide region. An attempt was made to compare charophytes from India and South Eastern United States by Sinha and Chaudhari (1968). Among ninety-two taxa of charophytes comprising sixty-seven species thirteen varieties and twelve forma of *Chara* and *Nitella* were found common in the two regions. Rao (1969) reported the occurrence of charophytes for the first time from Chittor district of Andhra Pradesh. They reported four species of *Chara* and three species of *Nitella*. In continuation with the studies on comparative account of charophytes from India and United States, Chaudhari (1969) described in detail forms of *Chara zeylanica* from the two countries viz. India and America. Sarma et al. (1970) discussed the phylogeny, interrelationship and evolution on the cytological standpoint in charophyta. In this account these authors hypothesized that species *Chara* are more evolved than the species *Nitella*. Studies on fossil charophyta were carried out by Khan (1973). He discussed systematics and stratigraphy of charophyta in detail. Khan concluded that algal fossils were important rock builders and could be useful as indicators of environment.

Chennaveraiah and Bharati (1974) studied the morphology in four varieties of *Chara gymnopitys*. The occurrence of *Lychnothamnus barbatus* was noted for the first time from Madras (Chennai) by Sunderlingam and Bharathan (1978).

Chatterjee (1979) reported the occurrence of new species of *Chara* viz. *Chara fibrosa* var. *fibrosa* f. *longicorolata* (Kasaki) R. D.W for the first time in India, which was supposed to be endemic to Japan. The inclusion of different taxa under *Chara zeylanica* as proposed by Robinson (1906) and Wood-Imahori (1965) was questioned by these authors. According to them out of six taxa of *Chara zeylanica* four should be raised to varietal level and two should be separated as independent species.

Detailed survey of geographical distribution of Indian charophyta was made by Khan and Sarma (1981). According to them about ninety- six taxa belonging to six genera of charophyta were known from India. Indian charophytes have relatively equal proportion of species of *Nitella* and *Chara*. They also concluded that the higher frequency of distribution in Indian charophyta was probably the indication of suitability of Indian habitats for charophytes. They also made a remark on origin of world charophycean flora that Bihar and Uttar Pradesh might be primary centers of origin in view of several taxa. Developmental morphology of *Nitellopsis obtusa* (Desv) Groves was studied by Bharathan (1982). Subramaniam (1983) reported two new charophytes from the region viz. *Nitella kanagambigae* sp. *nov* and *Nitella kolanchiappensis* sp. *nova*. Morphology of *Chara haitensis* Turnip, collected from Gujarat was described by Patel and Jawale (1985). Bharathan and Sunderlingam (1984) discussed the taxonomic validity of *Chara vandulerensis*. Morphological evidences and results of experimental work on infertility tests revealed that *Chara vandulerensis* is a taxonomically distinct species.

New form of Lychnothamnus barbatus f. gigantia f. nova from Gujarat was reported by Patel and Jawale (1985). Jawale and Patel in the same year recorded a new forma of Nitella, viz. Nitella polycarpa f. gujaratensis f. nova. The presence of oogonia at the base of branchlet confirmed the species but differences in other characters led authors to establish new forma. Subramanian (1985) reported new varieties of Nitella, viz. Nitella pseudoflabellata var. corymbosa var. nova., var. athanurensis var. nov. and var. puduchitterensis var. nova which are new to science, described from Tamil Nadu. He also reported two new aquatic species of Nitella with quadriscutate antheridia and further discussed evolution of quadriscutate antheridium in Nitella. Contribution to the knowledge of ecology of charophytes was made by Rama Kant and Pandey (1985). Study of various ecological factors affecting the growth of charophytes from two lakes was conducted and different parameters like pH, temperature, alkalinity, calcium, magnesium, phosphates etc. were analysed. They also collected a rare genus Nitellopsis from the lakes of Kashmir and Srinagar in the same year giving its detailed morphology. A new terrestrial variety of Nitella, viz. Nitella terrestris sp. nova. was reported from South India by Iyengar (1985). Ruma Pal (1986) observed morphological changes in corticated species of Chara, viz. Chara zeylanica and Chara vulgaris by gamma irradiation. Morphological changes like increased calcification formation of giant cells, variations in cortex and stipulodes, branching patterns were noted in irradiated materials.

Phyllogenetic and evolutionary status of the genus *Tolypella* with respect to morphology, geology, ecology, cytology and development was described by Bhatnagar (1987). *Chara vandalurensis* was merged in *Chara zeylanica* complex by Wood and Imahori (1965) on the basis of morphological features. Bhatnagar (1988) emphasized the primitive and advanced characters of charophytes considering haplostephanus ecorticated and haplostichous species primitive over diplostephanous, corticated and diplostichous species of *Chara*. Bhatnagar (1988) found that various

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ecological factors like temperature, pH, and depth of water body influence the general morphology in Indian charophytes. Gamma ray induced morphological changes in two species of *Chara* viz. *Chara zeylanica* and *Chara vulgaris* were observed by Pal Ruma (1988) confirming her earlier reports. Independent species or varietal status to various merged forms of *Chara globularis* complex was suggested by Bhatnagar. Bandyopadhyay and Chatterjee (1989) recorded a new taxon *Chara fibrosa* var. *fibrosa* f. *keukensis*. It was first record for India. They also found that occurrence of aneuploidy in charophyta from India is quite unusual as compared to forms from Europe and America.

Poorak and Noor (1991) studied the effect of chloramphinicol on growth of *Chara corallina*. Mukharjee and Ray (1993) made scanning electron microscope study of compound oospore wall. Pundhir et al. (1993) made morphological observations on *Nitella hyalina* f. *indica*. They also noted the occurrence of *Nitella hyalina* var. *hyalina* f. *brachyactis* for the first time in India. Guha (1995) explored ecological control of *Chara* in rice fields. Various ecological parameters like low light condition, turbidity, low pH, and low concentration of phosphates in water found to be determental to *Chara*. A detailed account on comparative morphology of *Chara longifolia* was carried out by Pundhir and Chavan (1997). The aquatic vegetation of Uttarkashi Garhwal Himalayan region was screened by Lal (1997) who reported the presence of *Chara* and *Nitella* species. Use of cytoplasmic streaming in *Nitella* for monitoring aquatic pollution was suggested by Pandey et al. (1997).Verma (1998) studied the morphotaxonomy and cytotaxonomy of charophytes from Indian Subcontinent.

Kazmierczak A. and M. Rosiak (2000) worked on content of gibberellic acid in apical parts of male and female thalli of *Chara tomentosa* in relation to the content of sugars and dry mass. Vassya Bankova, Keremedchieva G, and Kujumgiev A (2001) observed secondary metabolites and lipids in *Chara globularis*. Toole G. A, Smith A. C., Waldron K. W (2002) studied the effect of physical and chemical treatment on the mechanical properties of the cell wall of *Chara corallina*. Chirananda De (2003) showed first record of charophytes from the Permian Barakar, formation of the Talchir Gondwana basin, Orissa. Bulychev A.A along with A.B. Rubin and S.C. Muller (2004) worked on the aspects of effect of a single excitation stimulus on photosynthetic activity and light-dependent pH banding in *Chara* cells. Vouilloud A and P. I. Leonardi (2005) studied the changes in the absolute configuration of the basal/flagellar apparatus and evidence of centrin during male gametogenesis in *Chara contraria* var. *nitelloides*. In 2006 Deepika Abrol and S. K. Bhatnagar studied the biodiversity of few Indian charophyte taxa based on molecular characterization and construction of phylogenetic tree. Boegle, M. G and Arnulf Melzer (2007) studied the differentiation of *Chara intermedia* and *C. baltica* and compared it with *C. hispida* based on morphology and amplified fragment length polymorphism. In the same year Casanoval M. T et al. (2007) studied and observed *Nitella hookeri* and studied its implications for endemism, speciation and biogeography. Limbach C and Markus Braun (2008) studied electron tomographic characterization of a vacuolar reticulum and of six vesicle types that occupy different cytoplasmic domains in the apex of tip- growing *Chara* rhizoids.