

THE FAMILY EQUISETACEAE IN INDIA

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A B S T R A C T

Equisetaceae a unigeneric family with only one extant genus. *Equisetum* L. having fifteen species and seventeen hybrids in the world, is represented by six species and one interspecific hybrid in India. The present treatment of the family provides historical notes, key from subgeneric to species level, general morphology of the taxa, their type citation, world and Indian distribution, discussion and notes on anatomy, cytology, gametophyte, micromorphology, ecology, chemistry and uses.

INTRODUCTION

The family Equisetaceae is ascribed to the subdivision Sphenophytina and class Equisetopsida. All the extant members of this subdivision belong to single family represented by a single genus *Equisetum* L., though some authors assign its members to two genera. Hauke (1974) summarized the present knowledge about this group and recognised two subgenera i.e. subg. *Equisetum* and subg. *Hippochaete* (Milde) Baker. His concept has been followed by most of pteridologists and is also followed here.

Roxburgh (1814) was first to mention the occurrence of '*Equisetum debilis*' (*nom. nud.*) in Bengal which was later on validated by Vaucher (1821) as *E. debile*. A coloured plate of *E. debile* is also made in Roxburgh's *Icones* vol. 35, t. 192 and plant is mentioned by Wallich (Wall. Cat. 397, 1828). It seems that Wallich also collected *Equisetum* species from Nepal and Kumaon which is included in catalogue, Num. List of plants as *Equisetum scoparium* Wall. (Wallich Cat. 398, p. 13, 1828). This specimen, however, is now designated as the paratype of the hybrid species, *E. × wallichianum* C.N. Page, occurring in Garhwal, North Western Himalaya (Page, 1974). Wallich collected another specimen probably along with his *E. scoparium* Wall. from Nepal in 1820 which is designated as the type of *E. diffusum* D. Don (Hauke, 1978). *E. pallens* Wall. (Cat. 1037, 1828) is synonymous to *E. debile* Roxb. ex Vaucher [= *E. ramosissimum* Desf. subsp. *debile* (Roxb. ex Vaucher) Hauke]. Also Wallich's *E. bicarinatum* and *E. leave* (in Herb. Hamilton Wall. Cat. 398. 1828) are synonymous to *E. diffusum* D. Don (Milde, 1867).

Griffith (1849) described a new species, *E. plantula*, based on his collection from "Boga Panee" in November 1835. The habit sketch of the plant along with stomatal structure are drawn in the plate.

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This plant appears to be *E. arvense*. Royle (1832) enumerated *Equisetum* along with other ferns and fern-allies of East India Company's Saharanpur Herbarium and in 1839 he recorded *E. debile* and *E. diffusum* from the Himalayas. Voigt (1845) described two species, *E. debile* with distribution in Dindygul (Tamil Nadu), Burma, Bengal, Silhet (Bangladesh), Northern Doab and Dehradun and *E. diffusum* with distribution in Nepal. He mentioned three other species, namely *E. bogotense* and *E. giganteum* native of Central and South America and *E. inglisii* which Royle (1839) made a mention of its occurrence in Kunawar. Boissier (1864) mentioned about two species of *Equisetum* occurring in India, viz. *E. arvense* and *E. ramosum* (= *E. ramosissimum* Desf. subsp. *ramosissimum*). Stewart (1869) found *E. debile* Roxb. abundant in wet places throughout Punjab plains and occurring upto 10,500 ft. elevation in the Himalayas. Clarke (1880) in his "Review of ferns of Northern India" recorded the occurrence and distribution of 4 Indian *Equisetum*, namely *E. arvense*, *E. diffusum*, *E. debile* and *E. elongatum* (= *E. ramosissimum* Desf. subsp. *ramosissimum*). Baker (1887) in his "Handbook of fern allies" mentioned about *E. diffusum* and *E. debile*. Strachey and Winterbottom collected 3 *Equisetum* species viz. *E. arvense*, *E. diffusum* and *E. debile* in 1846-1849 from Kumaon, Garhwal and Tibet (Strachey, 1906).

Prain (1903), Haines (1925) and Mooney (1950) reported two species, *E. diffusum* and *E. debile* from Bengal, Bihar and Orissa. Stewart (1916, 1945, 1951) reported the distribution of *E. arvense*, *E. diffusum* and *E. ramosissimum* from Ladakh and Kashmir. Schelpe (1954) made an ecological study of pteridophytes of Kangra valley and reported the occurrence of *E. arvense* and *E. debile* in conifer-deciduous forest association. *E. diffusum* has been reported from Pindari glaciers, Kumaon hills (Rao, 1960), *E. debile* and *E. diffusum* from Sikkim (Rao, 1963) and *E. arvense* from Lahul (Rau, 1960). *E. debile* and *E. diffusum* were collected from various places of Kashmir valley (Rao, 1961) and the latter species was reported from Bomdi-La, Arunachal Pradesh (Srinivasan, 1959). Mehra and Bir (1964) reported *E. debile*, *E. diffusum* and *E. ramosissimum* from Darjeeling and Mehra and Dhir (1968) reported the latter two species from Dalhousie hills. Tagawa (1971) and Iwatsuki (1975) reported *E. debile* and *E. diffusum* from Sikkim Himalaya. *E. debile* is distributed throughout the country. Stewart (1869) detected its occurrence throughout Punjab plains. Gammie (1895) found this species in the swampy areas near shallow lakes in Lakhimpur district, Assam. Duthie (1898) collected *E. debile* in Dras (Eastern Kashmir) at 4000 to 5000 ft. elevation and *E. arvense* in Ziarat (7,200 ft.), Mirga (6000-8000 ft.) and at places of lower elevations (4000 ft.). Pottinger and Prain (1898) during botanical exploration of Kachin hills, Upper Burma collected *E. debile* in Namlao and also *E. diffusum* in the neighbouring states, particularly in Manipur and Eastern Himalaya, *E. debile* from Jaspur, Chotanagpur and from Sirguja was reported by Wood (1902), *E. diffusum* from Upper Assam by Kanjilal (1914) and the former species from the banks of Sabarmati river, Gujarat by Saxton and Sedgwick (1918). Burkill (1924) collected it from the banks of Dihang river, Arunachal Pradesh and found *E. debile* at Kobo, Pasighat, Janakmukh, Rotung, Yambing and Monyang during Abor expedition. The species is also extensively reported from Madhya Pradesh (Varad Pande, 1931; Maheswari, 1963; Joseph 1963), from Kodaikanal, South India (Bir and Vasudeva, 1971), from Siang Division (Rao and Joseph, 1965) and Tirap of Arunachal Pradesh (Deb and Dutta, 1971), from Kangra valley, Himachal Pradesh (Kapoor and Sarin, 1978), from various places of Kashmir valley (Rao, 1961; Singh and Kachroo, 1976), from Orissa (Panigrahi & al., 1964) and from Tripura (Deb, 1981). *E. ramosissimum* Desf. subsp. *ramosissimum* reported from Kashmir (Singh and Kachroo, 1976; Stewart, 1916, 1945, 1951), Punjab (Mehra and Dhir, 1968), Delhi river bank of Yumna (Chatterjee and Mohan Ram, 1968), Rajasthan (Singh and Parmar, 1980) and Gujarat (Dixit, 1934).

Panigrahi and Chowdhury (1962) enumerated *Equisetum* species occurring in Eastern India. Raizada and Chowdhury (1954, 1961) recorded *E. diffusum*, *E. maximum*, *E. arvense*, *E. ramosissimum*, *E. debile* and *E. debile* var. *pashan* Mahabale from Upper Gangetic Plain. Chowdhury (1973) in his book, Pteridophytes of Upper Gangetic Plain dealt with the same five species and three varieties namely *E. arvense*, *E. maximum*, *E. diffusum*, *E. ramosissimum*, *E. debile* and *E. diffusum* var. *pseudoarvense*, *E. diffusum* var. *ramosum* and *E. debile* var. *nudum*. However, according to recent monographs on *Equisetum* (Hauke, 1963, 1978), *E. maximum* Lam. is not nomenclaturally valid and *E. debile* has been reduced to subspecies of *E. ramosissimum* though Pichi Sermolli (1979) prefers to keep the earlier name *Equisetum debile*. Holub (1972), Sen and Sen (1973) and Schelpe (1970) retain *Hippochaete ramosissima* (Desf.) Börner, treating *Hippochaete* as a separate genus. Page (1974) explored Sino-Himalayan region for *Equisetum* species and recorded the occurrence of *E. arvense*, *E. diffusum*, *E. palustre* and a hybrid species, *E. × wallichianum* (*E. arvense* × *E. diffusum*) from the Himalayan region ranging from Kashmir to Sikkim. Chowdhury (1971) has given a brief but excellent account of works done by the Indian scientists on *Equisetum*.

Recently *E. hyemale* L. has been reported from Nainital (Saxena, 1976) and *E. giganteum* L. from Tawang, Arunachal Pradesh (Chandra, 1980) but no specimen of these species could be available from the collectors for examination, nor any voucher specimen of the two new records could be found deposited by them in any herbarium. The present author conducted an exploration tour to Kashmir Himalaya in 1983 and collected *E. diffusum*, *E. arvense*, *E. ramosissimum* subsp. *ramosissimum*, *E. ramosissimum* subsp. *debile*, *E. palustre* and *E. hyemale* from different parts of Kashmir valley.

Gametophytic study : Kashyap (1914, 1917, 1930, 1932) studied sporophytic and gametophytic structures of *Equisetum debile* including the variations of endodermal layer and abnormal formation of fertile cones. Sinha (1956) described abnormality of *E. debile* cones. Sethi (1926, 1928) studied the ontogeny of male and female gametophytes, their fertilization, embryo development and general life-cycle of *E. debile*. Phatak (1931, 1932, 1935) examined gametophytic structure, meristem and sex differentiation in *Equisetum* species. Mahabale (1945) described the prothallus, distribution of sex organs (antheridia and archegonia) in the gametophytes of the species. He opined that vestigial organs such as foot, hydathodes, centripetal xylem, annulus etc. are reminiscent of their high development in primitive ancestral members in geological past.

Anatomy : Chatterjee (1964) and Pant and Kidwai (1968) studied the structure of stomata and 'water-stomata' (Hydathodes) of *E. ramosissimum* subsp. *ramosissimum*. Sen and Sen (1973) opined that in considering the morphology of the rhizome, stomata, subsidiary cells and cone, physiology of the vegetative shoots, cytology and embryology, the family Equisetaceae should have two genera namely *Equisetum* (*sensu stricto*) and *Hippochaete* following Börner (1912), Farwell (1916) and Rothmaler (1944). Hauke (1987) observed that the inner epidermis of rhizome sheath teeth are expanded to protect the growing apices of rhizome forming a root-cap like protection cap being continuously replaced by the new ones as the rhizome grows and as the sheath are sharply pointed, they help the growing rhizome penetrate the soil. In earlier work Hauke (1985) studied the distinctive anatomical features of C-cells (commissure cells) in the commissure region *i.e.* the region between two segments of leaf-sheath of the staminal nodes of *Equisetum*. He studied the peculiar development of C-cells previously termed as anchor cells or chain cells in the four species of *Equisetum*: *E. arvense*, *E. diffusum*, *E. telmateia* etc., which divide only transversely whereas the neighbouring cells obliquely resulting in a bending of sheath structure causing deep furrowing in the commissure.

Bir (1978) studied the anatomy of the tubers of *E. diffusum* D. Don and remarked that in respect of endodermal character and casperian thickening on the radial walls of the tuber *E. diffusum* resembles *E. arvense*. The carinal canal unlike in the rhizome is absent in the tuber. He recorded that root stele of *E. diffusum* may be either di-or-triarch. Bohra & al. (1980) studied the vessel elements of *E. ramosissimum* and confirm the earlier observations of Bierhorst about the ontogeny of vessel elements in *Equisetum*. It is found that nodal and internodal vessel elements are different morphologically and the vessel elements in roots are similar to those of the internode.

Cytology : Cytological studies of *Equisetum* species in India have been made by a number of eminent workers. Ninan (1955) first studied the chromosome number of *E. debile*. Mehra and Bir (1959) studied the chromosome number of 4 Indian species: *E. arvense*, *E. diffusum*, *E. debile* and *E. ramosissimum*. Later Bir (1960) studied the chromosome number of several species of Netherlands. The chromosome counts of all the Indian *Equisetum* species contributed by the Indian authors were later compiled by Bir (1973).

Palaeobotany : Ottokar Fiestmantel opened the chapter of Palaeobotanical study in India from the seventies of Nineteenth Century. He and later Birbal Sahni, the most renowned Indian palaeobotanist and subsequently Surange, Maithy, Srivastava, Saksena, Kar, Sah and Ganju and many others discovered and described many fossils equisetaceous stalks, stems, cones etc. belonging to several fossil equisetacean genera (Lakhanpal & al., 1976, Surange, 1966).

Ethnobotany, medicobotany and uses: Watt (1890), Kirtikar and Basu (1935) and Chopra & al. (1956) have cited Stewart's record (Stewart, 1869) of ethnobotanical use of *Equisetum debile* as a cooling medicine and near Jhelum in Punjab the plant is given for gonorrhoea. Kirtikar and Basu (l. c.) have mentioned that the genus *Equisetum* is diuretic and astringent and almost all the species are medicinally used in Europe, Africa and Asia. Chopra & al. (1956) have reported that *E. arvense* has haemostatic and haemopoetic properties and is considered useful in dropsy, gravel and kidney affections, acidity of stomach and dyspepsia. Banerjee and Sen (1980) have tested the antibiotic properties of *E. diffusum* and have stated that both the common and penicillin-resistant strains of *Staphylococcus aureus* have remarkable inhibition in the ether, alcohol, methanol, acetone and water extracts of the vegetative parts of the species.

While Watt (1890) recorded the use of *E. debile* as good fodder for cattle, Chopra & al. (1956) state that *E. arvense* is a menace to livestock. Chowdhury (1973), Singh and Parmar (1980) have recorded that *E. ramosissimum* is poisonous to livestock producing intoxication, giddiness and stupidity in the affected animal lasting for over a fortnight and often proving fatal. Watt (l.c.) mentioned that the joints of *Equisetum* stem having much silica is used by tribals for nails polish. For the polishing of domestic utensils, furniture and as abrasive for fine polishing, *Equisetum* stems of almost all the species particularly of *E. hyemale* as mentioned by Watt, is used.

EQUISETACEAE

Rich. ex DC. in Lam. & DC., Fl. Franç ed. 3. 2: 580. 1805.

Type: *Equisetum* L.

Perennial or annual herbs with subterranean rhizomes, stems either all alike and green (homophyadic) or dimorphic *i.e.* sterile stems green, chlorophyllous and fertile stems whitish or brownish, non-chlorophyllous and stouter (heterophyadic). Stems distinctly ribbed or grooved and articulated or jointed at each node; internodes longitudinally furrowed and ridged, ridges and furrows being variable in number. Stems simple unbranched or verticillately branched, when branched, the branches are in whorls and arise from the nodes. Nodes generally solid but internodes generally centrally hollowed, but occasionally solid, when hollowed, the large hollow in the pith region forms central canal surrounded by 2 rings of alternating smaller cavities known as carinal and vallecular canals. Stomata on the stems and branches either flush with the surface of the epidermis or sunken below the surface of the epidermis, linearly arranged either in single line or in bands of 1-4 lines. The whole plant body including stomatal apparatus covered with silica deposition which with its various ornamentation covering plant surface and stomatal apparatus with variegated arrangement of pilulae and mamillae. Scale-like leaves small, arranged in whorls to form a sheath above each node, the sheath ending in free teeth, free teeth persistent or soon falling. Leaf gap lacking. The stele of the aerial shoot is endarch, siphonostele consisting of a number of separate collateral vascular bundles in the internodes which join at the nodes to form a continuous ring. Reproductive organs in terminal cones or spikes borne on the main stems or lateral branches. Cones consisting of whorled, pedicellate, peltate, scale-like sporangiophores. Sporangia numerous, globular, sac-like, pendulous; sessile, spores of one kind (homosporous), each provided with 4 hygroscopic elaters attached to one point and remain coiled before shedding but after, inflated. Prothallia cushionlike at base, above with flat green lobe, chlorophyllous, generally dioecious, sometimes with archegonia and antheridia succeeding each other on the same prothallium. Antherozoids multiciliate.

Notes : The family received several names in the past (Pichi Sermolli, 1970). It was called *Gonopterides* by Willdenow (in Rebutisch, Prodr. Fl. Neomarch, 9: 1804, *Iulospermae* by Wiggers (Prim. Fl. Holsat. 74. 1780), *Peltasporae* by Schultz (Nat. Syst. Pflanzenr. 277. 1832), *Peltata* by Hoffmann (Deutsch Fl. Bot. Taschenb. 2. 1-2. 1796), *Peltiflorae* by Batsch (Dispos. Gen. Pl. Icnen. 64. 1786) and *Peltigerae* by Batsch (Tab. Affin. 260. 1802). However, none of these names are validly published. The name Equisetaceae with the describing author is conserved (Pichi Sermolli, 1970, 1981) against Brissaeu-Mirbel's (1802) "Equiseta" and Michaux's (1803) Equisetaceae being *nomen nudum*. Recently Pichi Sermolli (1993) defends his view, though however, Equisetaceae Michaux ex De Candolle (Hauke, 1993) or Equisetaceae Richard ex Lam. et DC. (Martinez, 1995) is used.

Distrib. : With single extent genus *Equisetum* L., widely distributed in both the Hemispheres from the tropics to cold temperate region.

EQUISETUM L.

Sp. Pl. 2: 1061. 1753; Gen. Pl. ed. 5. 484. 1754. *Allostelites* C. Börner, Fl. Deutsch. Volk. 59, 283. 1912. *Hippochaete* Milde, Bot. Zeit. 23: 297. 1865.

Type : Britton and Brown (1913) first designated *E. fluviatile* L. as the lectotype for the genus. Pichi Sermolli (1971) states *Equisetum fluviatile* was selected as the type of the genus merely because Linnaeus in his Genera Plantarum (1754) ascribed as the first species of the genus *Equisetum* and he concludes that *E. arvense* is the best qualified species to be designated as the lectotype of the

genus. Accordingly Pichi Sermolli (1977) cites *E. arvense* as the lectotype of the genus *Equisetum*. Hauke (1978) does not accept *E. arvense* as the lectotype as the species is dimorphic and Linnaeus confused it with *E. palustre*. He accepts *E. fluviatile* as the lectotype of the genus as it has Linnaean holotype though he is aware of the present confusion between *E. fluviatile* and *E. telmateia*. I adopt his view.

Description as for family.

Etymology : The latin name is derived from *equus* (horse) and *saeta* or *seta* (bristle or hair) and hence *Equisetum* is horsetail (Pichi Sermolli, 1971).

Taxonomy : Milde (1865) was the first to split the genus *Equisetum* into two genera establishing the new genus *Hippochaete*. However, later Milde (1867, 72) reunited the two genera treating Equisetaceae as unigeneric family and divided *Equisetum* into two sections, sect. *Equisetum* and sect. *Hippochaete* Milde, which however are not followed by the modern authors. Holub (1972), Sen and Sen (1973) recognize these two as separate genera but the majority of pteridologists (Hauke, 1963, 1978; Page 1972, 1974) adopt a single genus *Equisetum*. It is subdivided into two subgenera *Equisetum* and *Hippochaete*. In subg. *Equisetum* the stomata lie at the level of epidermic cells, the strobiles are blunt at tip, the chromosomes are smaller than those in the subg. *Hippochaete*, the antheridia have four or more cover cells, the superficial siliceous ornamentation are more developed when observed under the Scanning Electron Microscope (SEM) and the tendency towards the hybridization between the species of the group is high. Other differences such as the arrangement of the stomata, the morphology of the subsidiary cells, the presence or absence of a central lacuna in the branches, the length of the internode in comparison with the leaf-sheath and the surface of the rhizome, have been pointed out by some authors, but these characteristics are not constant enough and no taxonomical value can be attributed to them (Paola and Paola, 1978).

The genus consists of 15 species, 8 belonging to the subg. *Equisetum* and 7 to the subg. *Hippochaete*. There are several interspecific hybrids.

The genus is represented in India by six species, three of the subg. *Equisetum* namely, *E. arvense* L., *E. diffusum* D. Don and *E. palustre* L. and three of the subgenus *Hippochaete* namely, *E. giganteum* L., *E. hyemale* L. and *E. ramosissimum* Desf. (subsp. *ramosissimum* and subsp. *debile* (Roxb.) Hauke and a hybrid *E. × wallichianum* Page.

Key to species and subspecies

- 1a. Stomata sunken below the surface, arranged in single line or in bands; subsidiary cells having 16-24 bars which are parallel at the point of their origin; branches hollow with a central canal; first internode of branches always shorter than the stem sheath; true endodermis lacking; cones apiculate; rhizomes rough with silica tubercles ... 2. (Subg. *Hippochaete*)
- 1b. Stomata superficial; flush with the surface and in bands several to many lines; 7-10 rarely 14 bars on the subsidiary cells; bars radiating outwardly from their point of origin; branches solid or hollow; first branch internode shorter or longer than stem sheath; true endodermis present; cones non-apiculate; rhizome smooth ... 5. (Subg. *Equisetum*)

- 2a. Stems with regular verticels of branches; stomata in bands of two or more lines; individual endodermises in stem (Section *Incunabula*) ... 1. *E. giganteum*
- 2b. Stems with regular verticels of branches, irregularly branched or unbranched; stomata either in single lines or in bands of two or more lines, individual, outer common or double common endodermises in stem ... 3
- 3a. Stems often irregularly branched or unbranched; stomata in one to several lines, sometimes in bands of two or more lines; individual outer or double common endodermises in stem; evergreen or deciduous; ridges convex (Section *Ambigua*) ... 4
- 3b. Stems unbranched, evergreen; stomata always in one line; ridges rarely convex, mostly bituberculate; rhizome with individual endodermises; sheaths with black girdles, white above; teeth articulated, teeth breaking off; ridges bituberculate (Section *Hippochaete*, subsect. *Perennantia*) ... 3. *E. hyemale* var. *hyemale*
- 4a. Stems branched or unbranched, evergreen or deciduous with double common endodermises; stomata in one to several lines; teeth persistent ... 2a. *E. ramosissimum* subsp. *ramosissimum*
- 4b. Stems branched and evergreen or deciduous with individual endodermises; stomata in single lines; teeth regularly broken off ... 2b. *E. ramosissimum* subsp. *debile*
- 5a. Stems monomorphic or homophyadic, branched or unbranched vallecular collenchyma lacking; first branch internode shorter than to nearly equalling the subtending stem sheaths; branches with simple valley having stomatas scattered throughout with transverse alignment of silica mamillae (Section *Equisetum*) ... 6
- 5b. Stems dimorphic or heterophyadic; vallecular collenchyma present; first branch internode longer than the subtending stem sheath; branches with channelled valleys having stomata in single or double lines on each side; silica mamillae either obscure or longitudinally aligned (Section *Heterophyadica*) ... 6. *E. arvense*
- 6a. First branch internode shorter than to barely equalling subtending sheath; branch ridges grooved and branches solid; central canal absent to obscure with only partial break down of the pith tissue; branch internodes with or without distinctly biangulate ridges but with rounded furrows ... 4. *E. diffusum*
- 6b. First branch internode shorter than the subtending stem sheath; branch ridges not grooved and branches hollow; central canal small *ca* 1/6 – 1/3! dia. of stem and vallecular canal barely as large; branch internodes with only low, rounded angles and shallow and shallow rounded furrows ... 5. *E. palustre*

Equisetum subg. *Hippochaete* (Milde) Baker, Handb. Fern Allies 2. 1887.

Basionym : *Hippochaete* Milde, Bot. Zeit. 23: 297. 1865.

Lectotype : *Equisetum hyemale* L.

Milde was the first to attribute a taxonomic rank to *Hippochaete* when considered within *Equisetum* as a single genus. Börner (1912), Farwell (1916), Rothmaler (1944) and Holub (1972)

accepted *Hippochaete* and *Equisetum* as two distinct genera while Hauke (1962, 1963) rejected the generic separation of the two groups of Equiseta and retained *Equisetum* as a single genus of the family Equisetaceae.

Baker (1887) treated *Hippochaete* with the taxonomic rank of subgenus within the genus *Equisetum* and accordingly he is considered as the author of the subgenus (Hauke, 1962, 1963; Paola and Paola, 1978).

Etymology : The name has the same meaning as *Equisetum* for it comes from ippos, horse and xaitn, flowing hair and hence a tail (Pichi Sermolli, 1971).

Taxonomy : Hauke (1963) divided the subgenus *Hippochaete* into three sections: sect. *Incunabula* Hauke, sect. *Ambigua* (Farwell) Hauke and sect. *Hippochaete*. Under the section *Incunabula* only the primitive species *E. giganteum* L., under sect. *Ambigua* *E. ramosissimum* Desf. with its two subspecies and *E. myriochaetum* and under sect. *Hippochaete*, *E. hyemale*, *E. variegatum* and *E. scirpoides* with their varieties and a large number of hybrids have been described.

Distrib. : In India, the subg. *Hippochaete* is represented by three species: (i) *E. giganteum* L. (sect. *Incunabula*) (ii) *E. ramosissimum* Desf. with its two subsp. *E. ramosissimum* and subsp. *debile* (Roxb.) Hauke (sect. *Ambigua*) and (iii) *E. hyemale* (sect. *Hippochaete*).

Equisetum* subg. *Hippochaete* sect. *Incunabula Hauke, Amer. Fern J. 52: 29. 1962.

Basionym : Since Hauke (l.c.) has created new section (*Incunabula*), it is not based upon any name used by previous authors, hence no basionym.

Holub (1972) has treated *Hippochaete* Milde as a genus and has elevated Hauke's sect. *Incunabula* to a subgeneric level; subg. *Incunabula* (Hauke) Holub.

Type : *Equisetum giganteum* L. Hauke designated the species as the type of his section *Incunabula* and it being the monotypic section containing the single species *E. giganteum*, the type of the species is the type of the section.

Synonyms : Hauke (1963) furnished a complete list of synonyms of this section. Milde's *Equiseta pleiosticha* divided into *Equiseta monocylindrica* and *Equiseta tricylindrica* and Schaffner's *Equiseta primitiva* have been regarded as synonyms of the section.

Etymology : The name 'Incunabula' meaning 'origin or beginning' in latin was chosen for this section on account of the most primitive character of its only species, *E. giganteum*.

Taxonomy : According to Hauke (1962, 1963, 1974) and Holub (1972) sect. *Incunabula* consists the only species *E. giganteum* L.

1. *Equisetum giganteum* L., Sp. Pl. ed. 2. 1517. 1763.

Synonyms : Hauke (1962, 1963) provided a complete list of synonym of *E. giganteum*.

Taxonomy : Hauke (1963) has provided a detailed taxonomic treatment of the species. The plant he has described are all from the Central and South American States. But it is seen that even within the geographical boundary of these areas, the species assumes distinct variations of morphological features for which the same species was previously supposed to be different in different geographical regions and accordingly were differently named (Milde, 1867a). For instance, A Braun's *E. poeppigianum*, De Candolle's *E. caracasenum* and Milde's *E. brasiliense* which have all been merged into *E. giganteum* were shown by Milde in his monograph under 'variationes' (Abänderungen).

Hauke (1963) enlisted fifty synonyms of *E. giganteum* of which six were the varieties of *E. giganteum* and eleven were forma and varieties of other synonymous species, such as of *E. martii* Milde, *E. brasiliense* Milde, *E. ramosissimum* H.B.K. and *E. elongatum* Willd.

While the first three species along with their varieties and forma have been merged into *E. giganteum*, only three varieties viz. var. *scaberrimum* Milde, var. *affine* Milde and var. *dolosum* Milde of *E. elongatum* are considered under that species. *E. elongatum* with other varieties described mostly by Milde and a few by Kunze and Doell are considered synonymous to *E. ramosissimum* Desf. subsp. *ramosissimum* (Hauke, 1963; Milde, 1867a).

General morphology : Stem tall, thick, smooth to rough, ca 3-4 m high, evergreen, with regular whorl of branches; ca 15-20 mm in diam., the stem having 15 to 40 ridges, silica forming cross bands on ridges. Stomata in bands of 3-4 lines on either side of the groove, 30-50 μ wide, 60-100 μ long. Cross section of the stem showing a separate endodermis around each vascular bundle, carinal collenchyma extended to the vascular bundle or nearly so but the vallecular collenchyma variable. Sheath light brown, as wide as long, 7-15 $\times$ 6-16 mm, teeth white, persistent. Cones occasionally at the apex of the branches, 24-14 $\times$ 8-6 mm, with a short but distinct apiculum. Spores well formed. Rhizome dark brown to tan, dull and almost smooth, 3-10 mm diam. with central canal larger than vallecular canal.

Type : Tab. CXXV f. 2 in Plumier's Cat. Pl. 1755 (K). As in this plate illustration is made of an identified wild plant of the species, the plate itself is regarded a holotype following Linnaeus (Milde, 1867a). I have seen the xerox/photocopy of the plate, obtained from Kew Herbarium.

Icones : Vaucher, Monogr. Prêles t. 7. Fig. 1-3. 1821; W.J. Hooker, A sec. Cen. Ferns t. 74. 1861; J. Milde, Monogr. Equiset. in Nov. Actorum. Acad. Caes. Leop-Carol. German Nat. Cur. t. 21, fig. 1-14. 1867a; J. Milde in C.F.P. de Martius Fl. Brasil 1(2): 629-644 t. Lxxvi fig. 1-6. 1872; Sadebeck in Engl. & Prantl, Nat. Pflanzenf. 1(4): 547. t. 343 A. 1902; Hauke, Beih. Nova Hedw. 8: t. 1 (a), 2(a), 3(a), 5(c, k), 6(d, e-j), 7(b, e, a, m, n) 8(d).

Distrib. : The distribution of the taxon is mainly concentrated in the New World, in the West Indies, Central and South American countries, between 20° N to 40° S lat. and 80° W to 40° W long.

India : Jammu & Kashmir, Arunachal Pradesh.

Specimens examined : INDIA: Jammu & Kashmir: Nattur valley, North of Gilgit, 9-10,000 ft., J.F. Duthie 12434 dt. 5.8.1892 (DD); Kashmir, T. A. Rao 526 dt. 7.11.1956 (CAL); Rho Basti, Tawang, Kameng district, Arunachal Pradesh, P. Chandra 80452 dt. Aug.-Sept. 1976 (LWG).

Note : In India, till now there are three reports of the collection of the species. The earliest collection had been made by Duthie from Nattur valley, Gilgit in 1892. The other two collections have been made recently- one from Kashmir by T.A. Rao in 1956 and the other from Kameng district, Arunachal Pradesh by P. Chandra in 1980. A herbarium specimen having field number, T.A. Rao 526 is in the BSD herbarium. Its place of collection as given in Pahalgam, 2500 m and the date of collection is 15.4.1958. It is determined by C.N. Page with *E. ramosissimum*. But in Herb. CAL, sheets of 2 specimens of identical field numbers T.A. Rao 526, place of collection as mentioned is only Kashmir and the date of collection as given is July, 1956. These specimens have been studied by me in detail. In all respect including stomatal arrangement as denoted by Vaucher, Milde and Hauke, the specimens appear to be *E. giganteum*.

Fr. : All the specimens collected in India are in the month of August-September but no report whether the plant bear cones during the time is not available from the collection. It appears that the plants of the species bear cones in later times possibly in winter or early spring.

Anatomy : Milde (1867a) studied the anatomy of the species and illustrated his findings but later Gwynne-Vaughan (1901) and Browne (1922) studied the characteristic anatomical features of the species in more detail particularly their centripetal/centrifugal development of the metaxylem in vascular bundle in the nodes and internodes, the continuity of protoxylem in the internodes through nodes, their endarch vascular bundles etc. which call for both advanced and primitive character.

Gametophyte : Hauke (1969) studied gametophytes of *E. giganteum* in culture. The gametophytes are bisexual, yielding 50 per cent male and 50 per cent female in the prothallus after germination of spores. The gametophyte structure represents predominant bisexuality in the species, hence it is considered the most primitive of all the *Equisetum* species.

Uses : Milde (1872) quoted the use of *E. giganteum* as a folk medicine by the Brazilian natives for diarrhoea, mictus cruentus, abortus and macies.

Discussion : The large plant, profusely branching at every nodes with an archaic look resembles primitive sphenopsids. Schaffner (1921) put the species under a section, named 'primitiva'. Browne (1922) after studying the anatomy of *E. giganteum* found in it, no doubt the element of primitiveness but at the same time doubted its primitivity. In her opinion, its reduced stelar structure and largest amount of xylem in the bundles is obviously primitive but the lateral metaxylem which are claimed to be centripetally developed indicating primitiveness cast doubt of its actual primitiveness because of the position of the tissue outside the endarch protoxylem which makes it difficult to regard it as a vestige of the central centripetal xylem of a protostele. Hauke (1969) by studying the gametophyte of the species concludes that the gametophytic stage of the species shows bisexuality in a degree unlike that of other species- a primitive character.

Equisetum subg. *Hippochaete* sect. *Ambigua* (Farw.) Hauke, Amer. Fern J. 52: 30. 1962.

Basionym : Genus *Hippochaete* sect. *Ambigua* Farwell, Mem. New York Bot. Gard. 6: 464. 1916.

The name *Ambigua* was adopted for the first time by Milde in his monograph (1867a) but he used the name with a description value only and never designated it a "Section" but as group (B) under sect. *Hippochaete*.

Farwell was the first to adopt sect. *Ambigua* as a taxonomic group.

Type : *Equisetum laevigatum* A. Br. in Amer. J. Sci. & Arts 46: 87. 1844.

Etymology : The name *Ambigua* was chosen by Milde for this section on account of the variable arrangement of the stomata on the stem surface. In description of the group he stated, 'Stomatum series uni-quadri linneatae, cryptopora' (1867b).

Taxonomy : According to Hauke (1963, 1974) the section consists of three species: *Equisetum ramosissimum*, *E. myriochaetum* and *E. laevigatum*. Milde included only *E. ramosissimum* Desf. and his own species *E. sieboldi* under the section. *E. myriochaetum* and *E. laevigatum* were placed under two different subgroups, *Equiseta mexicana* and *E. robusta* respectively of the group *Equiseta monosticha* Milde (1867b) by him but *Equiseta robusta* was replaced by *Equiseta hiemalia* which contained *E. robustum* A. Br. and *E. hiemale* L. in addition to *E. laevigatum*. Holub (1972), however, who treats *Hippochaete* as a genus put only *Hippochaete ramosissima* under section *Ambigua* Farwell.

Distrib. : *Equisetum ramosissimum* is wide spread in Europe, Asia and Africa and is recently reported from the New World (Hauke, 1979). On the other hand, *E. myriochaetum* and *E. laevigatum* are known to occur only in America but not in the Old World.

2. *Equisetum ramosissimum* Desf. Fl. Atlant 2: 398. 1799 (1800).

Taxonomy : Hauke (1962, 1963, 1974) subdivided *E. ramosissimum* into two subspecies: subsp. *ramosissimum* and subsp. *debile* (Roxb.) Hauke. On the contrary, other authors traditionally considered the two taxa as two separate species (Pichi Sermolli, 1977; Page, 1972) following Vaucher (1821). Many other authors in the past, however, established even some varietal forms of the two taxa (Braun 1839; Doell, 1857; Milde 1861, 1864; Mahabale, 1935).

The main differences of the two subspecies are the following; subsp. *ramosissimum* stem with double common endodermis, i.e. with an inner endodermis and an outer endodermis surrounding all bundles, stomata is one to several line, teeth persistent, in subsp. *debile*: stem with individual single endodermis, i.e. with an inner endodermis surrounding each vascular bundle. Stomata is single lines, teeth irregularly breaking off (Hauke, 1963). Details of the differentiating characters between the two subspecies are given in the key. However, these and other minor characters show many intermediate forms in the areas where the two subspecies overlap geographically, particularly in Indian and far Eastern Asia. Both the two subspecies occur in India.

Distrib. : *Equisetum ramosissimum* with its subsp. *ramosissimum* and *debile* has an extremely wide distribution, from 55°N to 35°S and 180° E to 30° W. The ranges of the two subspecies overlap in South and Eastern Asia. Hauke recently reported its occurrence in North America.

2a. *Equisetum ramosissimum* Desf. subsp. *ramosissimum* Hauke, Amer. Fern J. 52: 32. 1962; Beih. Nova Hedwig. 8: 54-56. 1963. *E. ramosissimum* Desf. Fl. Atlant. 2: 398. 1799 (1800).

Hauke (1963) provides a complete list of synonyms of the subspecies.

Taxonomy : Milde (1867a) examined the Indian specimens of the subspecies and designated var. *jacquemontii* based on *Jacquemont* 928 collected from Kashmir, alt. 2600 m and var. *malabaricum* based on Herb. Ind. Or. *Hook. fil. et Thomson s.n.* collected probably from Malabar.

Hauke (1963) cited enormous varieties recorded under the subspecies and ignored the trivial differences of morphological features that have a poor taxonomic value and are in fact geographical variations. In this connection, mention may be made of an extract of Hauke's view (1974). "*Equisetum* display a great morphological plasticity in response to varying environmental stress. Thus named varieties or forms which obviously have no genetic reality".

General morphology : Stems 30-250 cm in height, somewhat rough to smooth, with usually 2-3 branches per node, generally persisting through the year, upto 5 mm diam., internodal ribs prominent, 10-25 in number, grey-green in colour, the ribs or ridges with crossbands of silica, the grooves plain or with silica rosettes, these sometimes fused into bands, sheaths subcylindric, campanulate to funnel shaped, always longer than wide. The lower sheaths light brown with a dark brown girdle, the upper green, rim of sheath often becoming whitish. Segments rounded to slightly flattened with two lateral ridges. Teeth 2-8 mm long, narrow with brown center and white margins or becoming all white, thin and drying leaving a crown of thick brown or white bases adorning the sheath. Cones normally terminal on the main stems, narrowly ellipsoid, obtuse to apiculate, yellow to black, 5-20 mm long, 7-10 mm wide with the apiculum reaching a length of 1 mm, enveloped basally by the uppermost nodal sheath. Spores well formed. Rhizomes very long, penetrating to depths of upto 1.5 m below soil level, dark or blackish brown, rough, glabrous, nodal sheath hairy.

Type : Mt. Zowan, Tunis, Tunisia, *R. Desfontaines, s.n.* Holotype at P, Photo!

In the herbarium of Museum Nationale d'Histoire Naturelle, Paris (P)- holotype, isotype (FI).

In Paris Herbarium there are two sheets marked with the following words. "Herbier de la Flore Atlantique donné au Muséum, par. M Desfontaines No." Of the two sheets, on one only "*Equisetum*" and on the other, full name of the species, *E. ramosissimum* Desf. is written. The sheet bearing full name of the species contains a large number of the specimens bundled in a circle and on the other bearing only name of the genus, a few plants with cone and a few staminal apical parts with cones are arranged scatteredly.

In the protologue, Desfontaines gave the information about the collection place of the type specimen "Habitat ad radices montis Zowan apud Tunetanos" which means that the type had been collected from Mt. Zowan, Tunis, Tunisia by Desfontaines.

According to Stafleu and Cowan (1975) the Flora Atlantica herbarium is kept in Paris (P), while Desfontaines general herbarium is in Florence (FI). I have seen the photos of holotype kept at Paris and have also seen the photo of isotype kept at Herbarium Webbianum in Florence (Herb. Universitat. Florenti., Museo Botanico, Firenze Photo No. 226: Prot. No. 2414).

The isotype of Florence is labelled "*E. ramosissimum* Desf., Zowan which perfectly agrees with the original description. Hauke (1963) refers this specimen as the type of *E. ramosissimum* subsp. *ramosissimum*."

Icones : Milde, Monogr. Equiset., Nova Actorum Acad. Caes. Leop.-Carol. German. Nat. Cur. t. 24. 1867; Milde in Martius, Fl. Brasil. t. 77. f. 2. 1872; Vaucher, Monogr. Prêles t. 6. 1821; Sim, Ferns S. Afr. ed. 2. t. 174. 1915; Hauke, Beih. Nova Hedw. 8: t. 1(6). 1963; Täckholm, Fl. Egypt ed. 2. t. 1. 1974; Ballard, Fl. Iraq 2: t. 1(1-6) p. 57. 1966; S.J. Roles, Brit. Fl. Illus. 1: t. 12. 1957; T. Makino, Illus. Fl. Japan t. 2927. f. 976. 1887-91; Schukuhr, Crpyt. Gewachse t. 172 b. 1809.

Specimens examined : INDIA: Jammu & Kashmir : T.A. Rao 536 dt. 15.4.1958 (BSD, CAL); Pahalgam, Kashmir, 2500 m, T.A. Rao 526 no date (BSD, CAL); Kandala Pass, S.E. of Leh, Ladakh, Herb. Schlagintweit Cat. No. 1733 August-Sept. 1856. Karu, Indus river valley, Ladakh, 3400 m, U.C. Bhattacharyya 41154 dt. 13.9.1970; Pooh, near army barracks, K.P. Janardhanan 47839 dt. 7.6.1972 (BSD); Dras, Ladakh, 3100 m, B.M. Wadhwa 58550 dt. 16.7.1976(BSD). Uttar Pradesh : Dehradun, G. King s.n. 1869 (CAL); Ambara, Kheri Oudh, Inayat 22940 dt. 10.4.1898 (DD); Chuka, Pilibhit, C.L. Malhotra 50510 dt. 28.8.1972 (BSD); Dehradun, Canal Side, near hospital, Ram Dayal 1445 dt. 28.10.1966 (DD); Ghajipur, U.C. Bhattacharyya 13769 dt. 13.2.1961 (BSD); Banda, Mrs. A.S. Bell 1013 dt. 4. 1902 (CAL); Shetale, Garhwal, M.A. Rao 10372 dt. 20.6.1959 (BSD); Bajahi, Dudhwar range, Kheri, Oudh, Inayat 22941 dt. 1.5.1898 (DD); Mohan Pass, Siwalik range, J.F. Duthie s.n. dt. 4. 1874 (DD); near Mussoorie, Falconer s. n. no date (DD); Gomti river bank, Lucknow, S.L. Kapoor 18879 dt. 26.2.1955 (LWG) and S.L. Kapoor 24097 dt. 17.10.1955 (LWG); Motipur forest, Baharaich district, Hiralal 13418 dt. 1954 (LWG); Baharaich, M.A. Rau 8189 dt. 9.2.1959 (BSD). Himachal Pradesh : Pangi village, Kinnaur district, 2900 m, N.C. Nair 30444 dt. 3.9.1963 (BSD); Madhya Pradesh : Kutumsar, Bastar, G. Panigrahi 1184 dt. 19.2.1963 (BSA); Chitea, Kot, Janki Kund forest Satna, J.K. Maheswari 80449 dt. 13.6.1968 (LWG). Punjab: Hansi, N.C. Nair 16146 dt. 30.7.1961 (BSD); Hoshiarpur, Punjab plain, U.C. Bhattacharyya 39485 dt. 18.10.1962 (BSD). Tamil Nadu : Water Falls, Kalhatti, Nilgiri district, B.D. Sharma 35630 dt. 20.8.1970 (MH). Arunachal Pradesh : Northern Bank, Becham river, near Suspension foot bridge, Kameng district, A.S. Rao 50634 dt. 23.11.1970 (ASSAM). Central India : G. King s.n. no date (CAL); Goona, G. King s.n. no date (CAL).

Distrib. : The subspecies *ramosissimum* has very wide distribution from 55° N to 35° S and 145° E to 30° W geographical region. It occurs in North, East, Central and South Africa, Malagasy, Mauritius, Canary Islands, Azores. In Europe, in North to South Germany, Czechoslovakia, Lithuania, Netherlands and England. In Asia, Asia Minor, Trans-Caucasia, Northern to Northern India, Tibet, central China and Taiwan. Hauke (1979) reports its occurrence in North America.

In India it occurs in Northern Indian plains and Himalayan belt from Jammu & Kashmir to Arunachal Pradesh. The subspecies has been reported from Jammu & Kashmir, Himachal Pradesh, Uttar Pradesh, Rajasthan, Gujarat, Madhya Pradesh, Bihar, West Bengal and other Northern Indian states and recent report of it from Peninsular India.

Fr. : August to October in the rainy season, occasionally upto December during winter in India.

Anatomy : Milde (1867a) studied the anatomy of the subspecies in detail. Vaucher (1821) entered a short note on anatomical features in his monograph but Duval Jouve (1864) delineated in detail the anatomical features of various organs and interpreted their evolutionary significance. In the past century, Barratt (1920), Bierhorst (1958a, b, 1959, 1971), Browne (1912, 1915, 1920a, b, 1921, 1922, 1923, 1941), Bold (1971), Foster and Gifford (1959) and many other authors studied or referred

to the anatomical works on vascular bundle, stem structure, fertile spike and cones of *E. ramosissimum*.

Gametophyte : Detailed works on the prothallus and gametophyte of subspecies *ramosissimum* have been worked out by Chatterjee and Mohan Ram (1968) and Mohan Ram and Chatterjee (1970) and also by Duckett (1979) in which Duckett compared the gametophytic features of the two subspecies and also of other members of the subgenus *Hippochaete*.

Micromorphology : The subsp. *ramosissimum* is characterized by having numerous pilules of silica over the surface including the silica over-arching the stomata (Hauke, 1979) but according to a different author (Page, 1972) pilules are present on the surface of the stomata of *E. ramosissimum* to a lesser extent than they are on the surface of *E. debile* and on the whole they are less numerous, less prominent and less well defined than they typically are in subg. *Equisetum*.

Mention may be made in this regard that Hauke's material for SEM studies was collected from North Carolina and Florida (U.S.A.) while Page collected his material for the same study from Canary Islands.

The impact of geographical variation, thus, on stomatal ultrastructure in *E. ramosissimum* is obviously evident here.

Cytology : Extensive work has been done on the chromosomal studies of *Equisetum* species. It is found that all the species of both the subg. *Equisetum* and subg. *Hippochaete* have haploid chromosome no. $n = 108$ and in diploid $2n = 216$ (Manton, 1950; Löve and Löve, 1961; Chiarugi, 1960; Bir, 1960; Mehra and Bir, 1959; Sorsa, 1963). Regarding *E. ramosissimum* Desf. (*E. ramosissimum* subsp. *ramosissimum*) Bir (1960) cited Manton's (1950) and Mehra and Bir's (1959) chromosomal count. Manton's report of chromosome number of *E. ramosissimum* Desf. collected from Italy is $n = ca\ 108$ while Mehra and Bir (1959) reported chromosome no. $n = 108$ of *E. ramosissimum* Desf. var. *altissimum* A. Br. (the same subsp. *ramosissimum*) occurring both in E. Himalaya (Darjeeling) and Western Himalaya (Mussoorie).

Mehra and Bir (1959) report that the size of bivalents at diakinesis is small in *E. diffusum* and *E. ramosissimum* var. *altissimum* than *E. debile* and they are somewhat more contracted.

Chemistry : Saleh and Abdall (1980) have studied the flavonoids of the subspecies *ramosissimum*. Earlier Hegnauer (1963) quoted Harada and Saiki (1955) as reporting some flavonoids such as apigenin and luteolin occurring in the taxon.

Ecology : The subsp. *ramosissimum* generally occurs in pastures, cultivated fields and in the dry river beds and near the water and swampy places. It often grows in a dense vegetation forming tufts or clumps. The soil pH at which *E. ramosissimum* subsp. *ramosissimum* thrives well varies from 6.8 to 7.8. Many of the places of North Western India including Delhi area [Mohan Ram and Chatterjee (1970) report the soil pH of Yamuna river bed at Delhi is 7.9 where the gametophyte of the subspecies grow well in wild condition] have very weak acid to nearly alkaline soil where the subspecies *ramosissimum* occurs.

Hybridity : Duckett (1979) has compiled up-to-date of interspecific hybrids of *Equisetum*. The report denotes that *Equisetum ramosissimum* subsp. *ramosissimum* forms hybrids with two other species of subg. *Hippochaete*. With *E. hyemale* var. *hyemale* it forms *E. × moorei* Newm. reported long ago by Newman (1856) from Europe and with *E. variegatum* it forms *E. × naegelianum* Koch ex Rothm. reported recently from Europe by Rothmaler (1944) and later referred to by Hauke (1963).

Since the occurrence of *E. variegatum* in India is not known and that of *E. hyemale* var. *hyemale* is very recently known and that also in a very narrow restricted zone, the possibility of *E. ramosissimum* subsp. *ramosissimum* forming interspecific hybrids *E. × naegelianum* is out of question and that of *E. × moorei* is considered remote and is not reported till date.

Ethnobotany and uses : Singh and Parmer (1980) have reported that the subspecies is toxic as fodder to cattle in Rajasthan. Its uses as folk medicine for cure of venereal diseases by village folks and tribal people in India through ages has been reported by many Indian authors.

Discussion : Hauke (1979) in his report on the new record of *E. ramosissimum* Desf. for North America states that the species can easily be mistaken for *E. giganteum*, *E. × schaffneri* or *E. myriochaetum* when stomatal arrangements between the ridges along the stem are considered. The subspecies also resembles, he adds *E. hyemale*, *E. laevigatum*, *E. × ferrissii* or *E. × moorei* on one or the other characteristics features which are common among them. The combination of several features characteristic of the subspecies, however, isolate them from others species. Earlier, Hauke (1963), however, criticized the "erroneous" thought about the occurrence of *E. ramosissimum* in America. He mentioned of Humboldt and Bonpland's collection of *E. giganteum* from S. America which was published by them as *E. ramosissimum* Humb. et Bonpl. (in Willd., Sp. Pl. 5: 9. 1810), but later, however, was treated as synonym of *E. giganteum* by Milde (1867a, 1872). On the other hand *E. ramosissimum* Desf. described by Milde from S. America (1872) entailed synonymy of 4 species that were erroneously taken for *E. ramosissimum* by none other but De Candolle, Willdenow, Vaucher and Gray. Due to the diverse morphological characters of the subspecies Milde described six varieties of *E. ramosissimum* varieties distributed from Mexico to Chile. Earlier in the monographic studies, he listed under *E. ramosissimum* 34 varieties (1867a), Hauke (1963) listed 107 synonyms including species, subspecies, varieties and forma described by a large number of authors.

While the world-picture of *E. ramosissimum* is such, it is not so in India. Because species and hybrids co-occurring *E. ramosissimum* in America and Europe and resembling it do not occur here; instead the subspecies *ramosissimum* co-occur with subsp. *debile* in this region, which though somewhat similar to each other but differs by some other morphological features characteristic to each of them.

In India, the distribution of the subspecies *ramosissimum* overlaps with that of the subsp. *debile* in the Himalayas and in the northern part of the country. In China and Japan where this subspecies co-occurs with the subsp. *debile*, some intergradation of characteristic morphological features of the species are seen among them. But in India, this intergradation is less. In Kashmir and Punjab concentration of the subsp. *ramosissimum* is far greater.

In the rest of India, subsp. *debile* dominates over subsp. *ramosissimum*. In places where the two subsp. occur together and from where collection made is mixed with two subspecies, no difficulty is envisaged to identify them.

Hauke (1963) states that he examined 2 mixed collections of subsp. *ramosissimum* and subsp. *debile*, one from the Himalayas (Herb. Royal Gdn. Kew 1250) and the other from Nilgiri (R.F. Hohenacker Pl. India Or. 1240).

2b. *Equisetum ramosissimum* Desf. subsp. *debile* (Roxb.) Hauke in Amer. Fern Journ. 52: 33. 1962; Beih. Nova Hedwig. 8: 61. 1963.

Synonyms : Hauke (1963) furnished a complete list of synonyms. What Hauke could not include are: *Hippochaete debilis* (Vauch.) Holub. Preslia 44: 128. 1972; *H. ramosissima* (Desf.) Börner subsp. *debile* (Roxb.) Sen and Sen, Israel Journ. Bot. 22: 166-174. 1973.

Taxonomy : The subspecies of varieties *debile* is very variable in its taxonomic features and has been divided into a number of varieties. Milde (1861, 1863, 1864) recognized 11 varieties most of which were distributed in South- Central and Eastern asia. In Monograph (1867), Milde, however, described 7 varieties of the species. One variety, *E. debile* var. *pashan* has been described from Western India by Mahabale (1938). All these varieties have been merged into subspecies by Hauke in his monograph (1963). Its earlier species rank as *E. debile* Roxb. ex Vauch. (should actually be, *E. debile* Roxb. ex DC.) attributed to it by Vaucher (1822) has long been recognised by various pteridologists of the past and present including Pichi Sermolli (1979). However, I follow Hauke in considering the taxon as the subspecies *debile* of *E. ramosissimum* because though subsp. *ramosissimum* and subsp. *debile* have been traditionally considered as separate species as in certain respect they are two well defined taxa, but, "they intergrade completely along their zone of contact and intermediate forms are wholly fertile". In their usual forms, however, the two are different in several characters and the number of intermediate is relatively low (Hauke, 1961).

Lectotype : Roxb. 1648.1 kept in J.E. Smith Herbarium, Linnaean Society of London (LINN, Xerox!). The lectotype has been designated by C.V. Morton (1974). From the copy it is seen that the specimen was collected by Roxburgh from Calcutta in the year 1809.

I have seen the xerox of the lectotype Roxburgh 1648. I received from C.E. Jarvis of British Museum (Natural History), London.

Note : In 1970, Morton designated a Roxburgh specimen kept in De Candolle Herbarium, Geneva (G) consisting of only two internodes of a stem which was annotated by Vaucher as *Equisetum debile* Roxb. ex DC. (Prêle penchée) in 1823 and further annotated by Chiov as *E. timorianum* Vauch. et Chiov as the holotype. But Morton never published this typification (David B. Lellinger; U.S. National Herbarium, Official Commun.). Whenever this was communicated to Dr. R.L. Hauke, he commented "I doubt that it should be designated as holotype, since the designation must be made by the describing author, and Vaucher never designated any individual specimen as holotype. Therefore I believe, that it would serve as lectotype".

Morton (1974), however, hinted in his work on the lectotypification of *E. debile* Roxb. ex DC. that if a specimen is located in Geneva Herbarium- eventually it will become the holotype and the lectotype will be abandoned. He reminded, "according to the original description, Vaucher did see a specimen but only part of a branch, the description was taken from a manuscript by De Candolle".

Regarding this specimen, Morton wrote, Alston searched Geneva Herbarium unsuccessfully, but he himself was hopeful about its finding and though holotypified a fragmented specimen kept in De Candolle herbarium but later thinking it of not being worthy to be holotypified, made no subsequent publication on it.

I have seen the xerox of the specimen sheet received from Dr. Patricia Geissler, Keeper of Cryptogams, Geneva Herbarium (G).

While describing the lectotype of *Equisetum debile* Roxb. ex DC., Morton (1974) made reference of a similar plant but lacking strobili, kept in British Museum (BM).

I have seen the xerox of the original specimen sent by Miss. J. M. Camus of the Herbarium (BM) which had been annotated as the isotype of the species, but he made no publication.

General morphology : Stems tall, smooth, irregularly branched, evergreen, 0.5 to 4.0 m tall, 2.5 to 10 mm diam., with 10 to 30 ridges, having usually small cross-bands of silica. Stomata arranged in one line on each side of the groove, 71 to 102 μ , 56 to 78 μ wide. Carinal collenchyma usually extending to vascular bundle, vallecular collenchyma well developed, often reaching to vallecular canal, the ratio of vallecular to carinal collenchyma being 1.3 to 2.3; each vascular bundle being surrounded by an endodermis. Sheaths green, cylindrical, 4.5 to 12 mm long, 2 to 10 mm wide, sheath segments smooth, midrib prominent basally but becoming flattened epically. Teeth thin brown to white, drying or breaking off, leaving truncated margin of the sheath. Cones and rhizomes like those of subspecies *ramosissimum*.

Fr. : All the year round.

Icones : Roxburgh, Cat. Pl. East Ind. Comp. t. 1921. 1814; Roxburgh, Calc. Journ. Nat. Hist. 4: 468. t. 26. f. 2. 1844 (ed. W. Griffith); Milde, Monogr. Equiset. in Nov. Actorum Acad. Caes. Leop.-Carol. German. Nat. Cur. 32(2): 476-491. t. 26. 1867; Hauke, Beih. Nova Hedwig. 8: t. 2(c) 3(c). 1963; Baker and Posthumus, Varen Fl. Voor Java f. 81. 1939; Devol, Fl. Taiwan 1: t. 12, p. 57. 1975; Tagawa & Iwatsuki, Fl. Thailand 3(1): 34. f. 1-3. (p.13). 1979; Tagawa & Iwatsuki, Southeast Asia St. 5. 32. f. 1. 1-3. 1967 and Vaucher, Monogr. Prêles t. 10. 1822 (as *E. timorianum*).

Specimens examined : INDIA: Jammu & Kashmir : Kishenganga valley, road to Nanga Parbat, 6000 ft., R.R. & I.D. Stewart 17730 dt. 20.7.1939 (CAL); near Taubat, 7500 ft., R.R. & I.D. Stewart 17911 dt. 25.7.1939 (CAL). Punjab : Hoshiarpur, Aitchison s.n. 1878 (CAL); Gurdaspur, Tihri, Punjab Plain, U.C. Bhattacharyya 39320 (BSD); Bhatinda, N.C. Nair 27827 dt. 12.5.1963 (BSD); Tohana, Hissar district, N.C. Nair 24976 dt. 18.10.1962 (BSD); on Cho beds Punjab, T. A. Rao 10789 dt. 12.11.1959 (BSD). Haryana : Karnal, J.N. Vohra 9928 dt. 28.8.1959 (BSD). Uttar Pradesh : Garhwal Himalaya, G King s.n. 1849 (CAL); Bajahi, Kheri, Oudh, Inayat 22941 dt. 1.5.1898 (BSD); Dobeghat, Mussoorie, P.W. Mackinnon s.n. dt. Oct. 1900 (CAL); Mussoorie, P.W. Mackinnon s.n. dt. Oct. 1897 (CAL); Mussoorie range, G King s.n. 1869; Dehradun, G King s.n. 1869 (CAL); Ambara Kheri, Oudh, Inayat 22940 dt. 10.4.1898 (DD); Chuka head, Pilibhit, C.L. Malhotra 50510 dt. 28.8.1972 (BSD); Maldeo, Song river banks, 700 m, Dehradun, Y.K. Sarin s.n. (BSD); Rober's cave, Dehradun, C.L. Malhotra 38351 dt. 12.9.1968 (BSD); Saiya, Chakrata, 1500 m, O.P. Misra 38219 dt. 28.7.1968 (BSD);

Rajpur, Dehradun, 1000 m, *T.A. Rao* 1121 no date (BSD); Sahasradhara, Dehradun, *S.K. malhotra* 30771 dt. 6.11.1963 (BSD); Lansdowne, Banghat, Garhwal, *J.N. Vohra* 11236 dt. 26.2.1961 (BSD); Robber's cave, Dehradun, *U.C. Bhattacharyya* 15252 dt. 13.8.1961 (BSD); Ghilmodyaset Sultan, Corbett National Park, *P.C. Pant* 43165 dt. 12.11.1970 (BSD). Himachal Pradesh : Simla, 8000 ft., *A. Meebold* 8683 dt. 10.1907 (CAL); Sangi village, Bashahr *N.C. Nair* 22546 dt. 7.6.1962 (BSD). Madhya Pradesh: Jashpurnagar, Bilaspur, *C.M. Arora* 7296 dt. 28.12.1964 (BSA, CAL), Kutumsar, Bailadila, Bastar district, *G Panigrahi* 1184 dt. 19.2.1963 (CAL); Panchmarhi, *J.F. Duthie* 10682 dt. 19.2.1891 (CAL); Kalirchabutra to Pendra via Amar Kantak, *G. Panigrahi* 15286 dt. 2. 1972 (CAL); Kisli, Mandla district, *J.K. Maheswari* 4732 dt. 14.3.1962 (CAL); S. Mandla, *J.K. Maheswari* 4732 dt. 9.3.1962 (CAL); Rajpurghat, Raigarh district, *N.C. Rathakrishnan* 21310 dt. 4.10.1974 (BSA); Jashpur Nagar, N. Bilaspur, *C.M. Arora* 7296 dt. 28.12.1967 (BSA). Maharashtra : Gargaon-Mala river, Pune, *A.S. Rao* 79344 dt. 24.12.1961 (BSI); Junnar, Kukudi river Pune, *Hemadri K.* 10431 dt. 31.10.1964 (BSI); Sangam bridge, Pune, *B.M. Wadhwa* 64207 dt. 2.9.1961 (BSI). Rajsthan : Tordi Sagar, Tonk district, *R.P. Pandey* 4821 dt. 19.5.1977 (BSI). Kerala : Changana Cherry, *N.C. Nair s. n* dt. 5. 1970 (CAL). Tamil Nadu : Coonoor, Nilgiri district, 6000 ft., *J.S. Gamble* 13256 dt. 11.1883 (CAL); Perumal, Madras, 5000 ft., *Rev. van Maldaren* 1341 dt. 2 no Mth. Yr. (CAL); Nilgiri Mts., S. India, *Rev. E. Johnson s.n.* no date (CAL); Culhatty, Nilgherries, 5000 ft., *C.B. Clarke* 11250B dt. 26.3.1870 (CAL); Combai river, Madurai district, 3500 m, *K.M. Sebastine* 12580 dt. 14.6.1961 (MH, CAL); Combai River, Madurai district, Madras state, 333 m, *K.M. sebastine* 12920 dt. 16.9.1961 (MH, CAL); Marapallam, Nilgiri district, *K.M. Sebastine* 2121 dt. 20.1.1957 alt. 1666 m (CAL); Over Aravancodu, Nilgiri district, 2333 m, *K. M. Sebastine* 4093 dt. 29.7.1957 (MH, CAL); on way to Anaikatty from Eband, Nilgiri district, *G V. Subba Rao* 41561 dt. 27.7.1972 (MH); Manjukottai, Yarcaud, 1200 m, *D.B. Deb* 31406 dt. 15.2.1969 (MH); Segur River bank, Nilgiri district, *GV. Subba Rao* 35630 dt. 20.8.1970 (MH). Andhra Pradesh : Araku valley, *D.C.S. Raju s.n.* dt. 12.1956 (CAL); Araku Inspection Bungalaw, 950 m, *GV. Subba Rao* 21571 dt. 11.10.1964 (MH); Araku valley, Visakhapatnam district, 950 m, *N.P. Balakrishnan* 1073 dt. 3.8.1960 (MH). Orissa : Karalpet, Kalahandi, *N.C. Nair* 50319, 50316 dt. 8.9.1972 (CAL); Jeypore, Koraput, *D.C.S. Raju* 2424 dt. 14.8.1965 (CAL); Khandwar, Dongra, near Sagada, Kalahandi, *N.C. Nair* 51356 dt. 1.11.1973 (CAL); Sagada, 360 m, *N.C. Nair* 50343 dt. 9.9.1972 (CAL); Gurguria to Jena bil, *G Panigrahi* 12415 dt. 16.2.1958 (ASSAM). Bihar : Manbhum, *Rev. J. Campbell* 8200 no date (CAL); Ranchi, *J.J. Wood* 1040 dt. 30.10.1875 (CAL); Tholkobad, Singhbhum, *GV. Subba Rao* 23208 dt. 6.1.1961 (ASSAM); Shyampur, Champaran district, *V. Thakur s.n.* dt. 8.11.1958 & 4.11.1960 (CAL); Singhbhum near shady stream, *H.H. Haines* 429 dt. 28.9.1902 (CAL); Bhikhuna, Thoree, N. Bihar, *J.G. Srivastava* 49083 dt. 16.3.1958 (LWG). West Bengal : Ayodha, Kudna, Purulia district, 2000 ft., *U. Chatterjee* 296 dt. 21.7.1963 (CAL); Ayodhya Forest, Purulia, *K.C. Malick* 584 dt. 22.4.1968 (CAL); Purulia, *K.C. Malick* 771 (CAL); Rajabhatkhawa, Jalpaiguri, *V. Narayanaswami* 2481 dt. 14.5.1949 (CAL); Simulbari, Tindharia, Darjeeling district, *K. Biswas* 8682 dt. 16.11.1948 (CAL). Sikkim : Sikkim, 1560 ft., *Anon s.n.* 25.8.1874 (CAL); *T.T. s.n.* (CAL); *Kalét s.n.* dt. 7.11.no year (CAL); Sikkim, Terai, *Anon s.n.* dt. 9.2.1867 (CAL). Assam : Foot Hill Camp., 800 ft., *G Panigrahi* 5854 dt. 22.3.1957 (ASSAM); On way to Motherguri, 300 m, *R.S. Rao* 9955 dt. 12.7.1957 (ASSAM); Baghmara R.F., Assam, *G Panigrahi* 22571 dt. 16.12.1961 (ASSAM); Deboka R.F., Deboka village, Buriganga river, Nowgong district, *N.P. Balakrishnan* 39452 dt. 26.8.1964 (ASSAM); Bichimori, left bank of Kulshi river, Kamrup district, *A.S. Rao* 38964 dt. 19.6.1964 (ASSAM); Bijni, Goalpara district, *U.N. Kanjilal* 5061 dt. 28.1.1915 (ASSAM); Kalloi R.F., *G Panigrahi* 11503 dt. 23.11.1957 (ASSAM); Rangsha, Athiabari Gaon, Halim near Singra river, Kamrup district, *A.S. Rao* 39078 dt. 24.6.1964 (ASSAM); Assam, *Jenkins s.n.* (CAL); Nilgirting river silt, Assam,

Dr. Bourne s.n. dt. 2.1.1901 (CAL). Arunachal Pradesh : Hill slope, West of Tuting, Political colony, 2300 ft., *R.S. Rao* 17308 dt. 2.11.1958 (ASSAM, CAL); Left bank of Diong river, Dirang, *A.S. Rao* 41475 dt. 30.10.1970 (CAL); Kharom to Wakhro road, Lohit district, *A.S. Rao* 47750 dt. 9.9.1967 (CAL, ASSAM); Ipi Pani river, on way to Dambuk from Roingi, Lohit district, *A.S. Rao* 48232 dt. 4.10.1969 (CAL); Nampong to Pangshu Pass, Tirap district, 1000-1600 m, *R.S. Rao* 20040 dt. 12.10.1959 (ASSAM); on way to Hapoli to Ziro, Subansiri F.D., *G.V. Subba Rao* 24685 dt. 2.6.1961 (ASSAM); Laju, *G. Panigrahi* 14735 dt. 25.8.1958 (ASSAM); Dahung, 10 km from Rupa towards Dedza, Kameng district, 1300 m, *J. Joseph* 40468 dt. 3.10.1964 (ASSAM); Kalaktang, Kameng district, *G. Panigrahi* 15552 dt. 14.5.1958 (ASSAM); Sadiya, Abor Expd., Assam 1911-12, *I.H. Burkill* 35779 dt. 23.11.1911 (CAL). Meghalaya : Jowai, Shillong, *G.K. Deka* 5011 dt. 22.1.1957 (ASSAM); Khasya, *C.B. Clarke* s.n. (CAL); Khasia, *G. Mann* s.n. (CAL); Khasi hill, Shillong, 5000 ft., *H. Collett* 19 dt. 8. 1870 (CAL); Mauskhai, Khasia, 3500 ft., *C.B. Clarke* 16207 B dt. 21.10.1871 (CAL); Prubara, Khasia, 4500 ft. and Lailankite, Khasia, *C.B. Clarke* 5828 dt. 14.10.1867 (CAL). Manipur : Manipur, *R.D. Dixit* 58984, 58985 dt. 18.2.1978 (CAL); Karang, *R.D. Dixit* 58941 dt. 14.2.1978 (CAL); Lingl village, Eastern ranges, 4000 ft., *G. Watt* 6674 dt. 1.1882 (CAL). Nagaland : Below Narune, Naga hills, 2-3000 ft., *A. Meebold* 7414 dt. 12.1907 (CAL); Manipur, Naga hills, *S.K. Mukherjee* 3412 (CAL); Kohima, *Prain* s. n. dt. 8. 1886 (CAL); Moirang to Nongkhlow, 5200 ft., *G.V. Subba Rao* 28081 dt. 22.3.1962 (ASSAM); Dimapur, Naga hills, *S.N. Bal* 392 dt. 9.10.1925 (BSIM).

Distrib : The subspecies *debile* has a restricted distribution within the region from 30° N to 23° S lat. and from 70° E to 140° W long (Hauke, 1963). It is co-occurring with the subspecies *ramosissimum* in S.E. Asia. Pichi Sermolli (1979) also has shown its distribution along with subsp. *ramosissimum* which is a predominant *Equisetum* in S.E. Asia. It occurs in Sri Lanka, India, Nepal, Myanmar, Southern China, Taiwan, Hainan, Indo-China, Philippines, Indonesia, New Guinea, New Hebrides, New Caledonia and Fiji.

Anatomy : Milde (1867a) studied the anatomy in great detail. He first gave anatomical characteristics for diagnosis separately and then elaborately the anatomy of the subspecies.

Hauke (1963) and Sen and Sen (1973) observed that stomata were sunken below surface of the stem and arranged in one line on either side of the groove.

The recent studies show that the internal structures of the stem and root of subsp. *debile* are very similar and comparable to those of *E. diffusum*. Only difference in case of root structure is that its vascular bundles is diarch and in case of stem structure the vascular bundles are surrounded by individual endodermis (Sen and Sen, l.c.).

Gametophyte : Detailed works from the spore germination, to the growth and development of the prothallus and gametophytes of the subspecies both in single spore axenic culture to the wild condition have been studied by Kashyap (1914, 1917), Sethi (1928), Mahabale (1945), Campbell (1928) and Duckett (1979). In his work, Duckett (1979) compiled and assessed the observational data of Kashyap (1914, 1917) and Sethi (1928) and added his new observation derived from a single spore axenic culture from the material of subsp. *debile* obtained from New Guinea. In axenic culture of spore grown on Parker medium he observed that of 324 gametophytes, 27 percent were male and 73 percent were female and percentage of male gametophytes were always higher than bisexuals which

were initially male but in course of time during growth and development turned bisexual. It was observed that up to 50 days of gametophyte growth since sowing of spore, 70 percent of the gametophytes were female, but then their percentage came down gradually and after 400 days, female gametophytes of the lot appeared to be 20 percent only. Similarly, gametophytes initially female up to 50 days of growth, turned bisexuals which reached 60 percent of total gametophytes after 400 days or at the end of the culture period. And initially bisexual gametophytes which started with an humble percentage, settled at 30 percent of the total gametophytes in culture after 400 days.

Micromorphology : Page (1972) has studied the ultrastructure of the stomatal aperture of subsp. *debile*. The subspecies differs from subsp. *ramosissimum* in some ultrastructural elements, particularly in their orientation.

Cytology : Mehra and Bir (1959) and Ninan (1955) have studied cytology of the subsp. *debile* and its chromosome count is similar to those of other species of the genus *Equisetum* i.e. $2n = 216$ and $n = 108$.

Chemistry : The subspecies is reported to have contained a saponin, equisetonine, a light yellow amorphous substance which, on hydrolysis, yields a sapogenin, equisetogenin ($C_{27}H_{48}O_6$) and fructose and arabinose, two monosaccharide glycones (sugar). The subspecies also contains ascorbic acid (Vitamin C).

Teratology : Kashyap (1930) and Sinha (1956) have reported of abnormal cones in some specimens of the subspecies collected from the bank of Ravi river, Lahore and that of Kali river, Meerut respectively. Kashyap noted two cones in one specimen, one above the other separated by leaf sheath, in another specimen one normal cone at the top of the stem, below a whorl of four modified cones and in another, two cones one with normal annuals made of three whorls, each of considerable distance from each other. Sinha noted three cones, one above of the other serially in a fertile stem.

Hybridity : Duckett (1979b) has reported intergametophytic crossing between the specimens of subsp. *ramosissimum* (obtained from Lincolnshire, England) and subsp. *debile* (obtained from New Guinea and Rhodes, Greece), along with intragametophytic and intergametophytic selfing with same Lincolnshire and New Guinea specimens of subsp. *ramosissimum* and *debile*. The hybridity between these two subspecies (subsp. *ramosissimum* $\times$ subsp. *debile*), however is not found in the wild condition.

Ecology : Works of Gammie (1875), Burkill (1924), Schelpe (1954) and Sharma & al. (1969, 1970) have shown various ecological adaptation of subsp. *debile* in different region of India and its ability to co-exist with varied plant communities.

Ethnobotany and Uses : Santhals call it "Buru-katkon charec" and in Punjab, rural folks call it *Matti*, *Skinung*, *Bandukei*, *Nari*, *Trotak* or *Buki*. The plant is administered as a cooling medicine for gonorrhoea (Watt, 1890; Kirtikar and Basu, 1933). Its use as a cattle fodder and for cleaning the surface of nails by natives is also reported.

Discussion : Selection of a type of *E. ramosissimum* subsp. *debile* has created a dispute due to conflicting opinions. Hauke (1963) cited Griffith's collection of a specimen from Serampore, near Calcutta as the type, which according to him is in the De Candolle Herbarium, Geneva. But Morton (1974) had discounted Hauke's contention saying that "this is obviously impossible, since Griffith was only about 11 years old at that time *E. debile* was described in 1821 or 1822; he did not begin collection in India until 1835". Meanwhile, Geneva Herbarium was sought by me for having a xerox/photocopy of Griffith 919 but Dr. P. Giéssler, Keeper of Cryptogams informed that the said specimen could not be found there. When Morton's comment of his typification and unavailability of Griffith 919 at De Candolle Herbarium was referred to Prof. Hauke, he commented: Typification of *Equisetum debile* Roxb. ex Vaucher by a specimen of Roxburgh's in the De Candolle Herbarium is probably the best we can do. Since the name was published by Vaucher, copying an unpublished description by De Candolle, of a name given by Roxburgh but not described by him, the type should be a specimen in the De Candolle Herbarium known to Roxburgh. Milde's designation of Griffith 919 as lectotype predates Morton's annotation label. However, if that specimen no longer exists, then the specimen annotated by Morton can be considered as type (R. L. Hauke, Professor of Botany, University of Rhode Island, Kingston, U.S.A., Official Commun.).

What prompted Prof. Hauke to select Griffith 919 as the type of the species as Milde's note on the 14th of 29 collection of *E. debile* Roxb. made from different places of Asian countries (Monogr. Equiset. p. 486) as follows: *E. debile* Roxb. specim. orig. herber. De Candolle No. 919 Serampore bei Calcutta (Griffith).

Hauke stated in his monograph (1963) that although Vaucher (1822) first published the name of *E. debile* with a description, he apparently never saw a specimen but rather copied De Candolle's unpublished description, listing as type "*E. debile* Roxb. Ind. Orient.". According to him, the type Griffith 919 cited by Milde as the original specimen was collected by Griffith from Pir Panjal, Kashmir for the British East India Company anytime after 1810 since he started collecting the area which was included by Roxburgh in his publication of a catalogue of the plants in the East India Company's Botanic Garden at Calcutta in 1814.. So it is possible, Hauke stated that Roxburgh's name during cataloguing of Griffith's collection was applied to *E. debile*.

This is unlikely as Morton pointed out that when Vaucher published the species in his monograph, Griffith was a boy of 11 or 12, and did not reach India. Roxburgh was in India from 1793 to 1813 (Burkill, 1965) and prepared a list of his collection before 1813 and gave his manuscript *Hortus bengalensis* to William Carey of Serampore for publication. After his leaving India in 1813, it was published in the following year (1814) by Carey. So when this catalogue was prepared Griffith was a mere child of 3 (Lanjouw & Stafleu, 1957; Stafleu & Cowan, 1976). Therefore, there could not be any possibility that Griffith's collection was mixed with that of Roxburgh and during cataloguing Roxburgh's name was mistakenly applied to Griffith's collection.

Roxburgh never went out of Calcutta for collection; he used to send collectors, two of them being his sons, William and John. The initials of W.R. and J.R. could be found in *Hortus bengalensis*. The collectors' name usually were published on the fourth column from left, where no collector's name was given, only "indigenous" was printed and that collection could be imagined of Roxburgh's own. In the work, *Equisetum debilis* R. clearly points out that it was his collection. Still,

a possibility could be imagined that Roxburgh's collection of *E. debilis* R. might be the actual collection of William Carey instead of Griffith who assuredly sent dried plants from Serampore to Roxburgh mixed with his own, but proof is lacking (Prain, Bengal Plants, preface p. 18. 1903).

Another anomaly which was evident in Hauke's selection of Pir Panjal, Kashmir as the type locality is significant. How could he reach this decision is not clear, because Milde cited in his monograph only Hügel's collection (Hügel 1021) from Pir Panjal, Kashmir (Monogr. Equiset. 486. 1867) and none of Griffith's collection cited by him was from that place. Four collections of Griffith cited by Milde were all from India Orientalis. Griffith's collection no. 919 accepted by Hauke as per remark of Milde as the original specimen was from Serampore. In that case, citation of type locality being Pir Panjal, Kashmir does not arise.

Let us quote that last two lines of Hauke's discussion about this species "Milde, the author of the name *E. huegelii* himself made it a synonym of the name *E. debile*, citing it as the most northwesterly locality of that species. The type locality is Pir Panjal, a mountain of Kashmir". By this, what is meant is that, Hauke wanted to mean that as Hügel collection was made a species by Milde earlier, *E. huegelii* (1861) but later included into a synonym of *E. debile*, was taken by him as the same place- Pir Panjal, Kashmir.

Equisetum* subg. *Hippochaete* sect. *Hippochaete

Basionym : *Hippochaete* sect. *Euhippochaete* Farwell, Mem. New York Bot. Gard. 6: 463. 1916.

Subsect. ***Perennantia*** (Doell) Hauke, Amer. Fern Journ. 52: 57. 1962.

Basionym : *Equisetum* II *Sclerocaulon* b. *Perennantia* Doell, Gesäsz-Krypt. Baden. 67. 1857.

Lectotype : *Equisetum hyemale* L.

Etymology : The meaning of the Latin epithet of the subsection come close to English word, 'Perennial'. Actually *E. hyemale* with its varieties var. *affine* representing the only species of this subsection are perennial in the sense that the plants of both the varieties are persistent not less than for at least two years (Hauke, 1963).

Taxonomy : Hauke (1963) recognised the only species *Equisetum hyemale* L. with its two varieties *E. hyemale* var. *hyemale* and *E. hyemale* L. var. *affine* (Engelm.) A.A. Eat. under the subsection *Perennantia*. The subsection is represented in India by *E. hyemale* var. *hyemale*.

3. *Equisetum hyemale* L. var. *hyemale*

E. hyemale L., Sp. Pl. 2: 1062. 1753.

Synonym : Hauke in the first paper of his series of "Resume" (1961) discussed the early works on *Equisetum* and its classification. He mentioned about Milde (1867a), Börner (1912), Farwell (1916) and Rothmaler (1944) who recognised *Hippochaete* as separate genus. Though Milde never made any specific combination under *Hippochaete*, the other authors did. So Farwell's *Hippochaete hyemalis* or

Börner's *Hippochaete hiemale* (L.) C. Börner also accepted by Rothmaler (1944) may be cited as its synonyms.

Taxonomy : Milde (1867a) placed the species *E. hiemale* under the group *Equiseta hiemalia* of the independent genus *Hippochaete*. He, however, never attributed the generic name to the species binomial under it and described the species under the common generic epithet, *Equisetum* (*Equiseta*). Farwell (1916) placed the species *H. hyemalis* under the section *Euhippochaete* or true *Hippochaete* of the genus *Hippochaete*. Rothmaler (1944) followed Börner (1912) in treating *Hippochaete* as a genus, placed the taxon *H. hiemale* (L.) C. Börner under his new combination of section, *Stichopora* (A. Br.) Rothm. and subsection *Hiemalia* (A. Br.) Rothm. along with two other taxa, *H. ramosissimum* (Desf.) C. Börner and *H. trachyodon* (A. Br.) C. Börner, the last one, however, is a hybrid of *E. hyemale* and *E. variegatum* (cf. Hauke, 1961).

General morphology : Erect, unbranched evergreen stem 30(50)-100(125) cm long, perennial, at least biennial, glaucous with slightly inflated internodes, grooves, 10-30. The ridges have two rows of silica tubercles with a medium furrow separating them making them bituberculate in the stem cross section. These rows of tubercles continue into the sheath segments which are 4-ridged or quadricarinate. The leaf sheaths are about as long as broad/wide, whitish, ashy grey in colour, girdled with black band at the top and bottom, the abscission layer formed at the base of the teeth. The sheath teeth are slightly appressed to the stem, pushed off during the stem elongation and may be found at the top of the stem as a series of superposed cones resembling a small pagoda. The stem has a double common endodermis and individual endodermis in rhizome. The carinal collenchyama is absent. The cones are prominently apiculate, 8-15 mm.

Type : In Linnaean Herbarium (LINN) in the packet no. 1241, the specimen no. 7 (*i.e.* 1241.7) consisting of two stems are designated as the type of *E. hyemale* (Savage, 1945). But as Hauke states (1962), quoting Savage (*l.c.*) that the specimen of *E. hyemale* in the Linnaean Herbarium in London was not present in 1753, hence it can hardly be the type. However, in the absence of a holotype, this specimen may serve as a neotype. Cullen (1965) cites Herb. Linn. 1241/7 and Ilgin (1934) states that the type is in London.

In *Flora Lapponica* (1737) Linnaeus cited under *E. hyemale* Rudb. Elys. 1 p. 124 f. 10 and in *Species Plantarum* (1753) he referred to Fl. Lapp. 394 (*i.e.* *E. hyemale* in Fl. Lapp.- 394 may either be serial or species number) and below it in parenthesis (*Equisetum* Cam. Epit. 770. f. A).

In *Flora Lapponica* Linnaeus clearly referred to the plate no. 10 in page 124 of the first volume of Rudbeck's *Campus Elysius* published in 1702. In Sp. Pl. he referred to Fl. Lapp. 394 *i.e.* *E. hyemale* but carried a plate 770 f. A. perhaps of same *Campus Elysius* of revised, compiled edition where the plate number was different.

As *Flora Lapponica* was first published and Linnaeus clearly referred to the plate in Rudbeck's *Campus Elysius* with *E. hyemale*, I think the plate no. 10 in page 124 of Vol. 1 in Rudbeck's *Campus Elysius* published in 1702 may be considered as the holotype of the species in absence of authentic specimen for typification.

Icones : Fl. Dan. 8: t. 1409. 1810; Fl. U.S.S.R. 1: t. 5, fig. a. b. 1934; Roles, S.J., Brit. Fl. Illustr. 1: t. 11. 1957.

Distrib. : *E. hyemale* had its origin presumably from a common ancestor with the *ramosissimum*-complex in south Western North America and flourished throughout North America. It migrated to Europe through North Atlantic Land-bridge and then spread out to many corners of Asia, segregating its variety *Hyemale* in Siberia and producing a hybrid (with *E. ramosissimum* subsp. *ramosissimum*) *E. × moorei* Newm. in West Asia, near Caspian sea. It has also spread in Asiatic Russia, Anatolia to Sinkiang and China eastward (*l.c.*). It is recently reported from India.

Specimens examined : INDIA: Jammu & Kashmir : University campus, Hazratbal, Srinagar, Botany Deptt. Garden A. Datta 58101 dated 10.8.1983 (CAL); Same locality, A. Datta 58219 dated 2.9.1983 (CAL). Manipur : Kankui forest, Ukhrul, Manipur, B. Ghosh & party 16544 dated 18.5.1984.

Anatomy : Bierhorst (1958b) studied the vessels of subterranean rhizomes and stems and Dute and Evert (1977) studied them in the roots of *E. hyemale*. Bierhorst observed that the lateral xylem of the internodal bundle of *E. hyemale* in large stem is composed of metaxylem. Wagner and Hammitt (1970) studied the natural proliferation of the floating stems of scouring rushes.

Gametophyte : Earlier, Jeffrey (1889) and Ludwigs (1911) studied the prothallus and gametophyte of the species. They were of opinion that the gametophyte of *E. hyemale* is strictly dioecious or unisexual. But it is noted that under unfavourable conditions *e.g.* low light, nutrient depletion, draught or crowding only male gametophytes were produced and that old female gametophytes occasionally produced antheridia. Ludwigs (*l.c.*) stressed upon the unisexuality of gametophytes and described them either male or female initially and reaffirmed the observation that the old female gametophytes regularly produced antheridia. He reported the formation of archegonia on initially male individuals. It was noted that under unfavourable conditions only unisexual males were produced. Light is one of the external environmental factors affecting the growth and development pattern in *E. hyemale*. Clopper and Pearson (1934) showed that blue and red light affected the gametophytes of *E. arvense* and *E. hyemale* and increased percentage of male sexuality. Red light with an intensity of 20,000 ergs/cm²/sec. increased maleness of the gametophytes upto 95 and 68 percent in *E. arvense* and *E. hyemale* respectively.

Hauke (1971) stressed upon the impact of light intensity and light quality upon the sex expression of *Equisetum* species. It was found that while the gametophytes of *E. arvense* was strongly affected by light intensity, gametophytes of *E. hyemale* were affected by light quality only. He showed that when white light with an intensity of 40000 ergs/cm²/sec. could induce 86 percent male sexuality in *E. arvense*, the same intensity could induce 45 percent maleness in *E. hyemale*. He observed that the increasing of male sexuality due to the effect of red light upon the gametophytes of *E. hyemale* was, in fact, a response to the absence of blue light. He also observed that sucrose enrichment of the medium did not affect gametophytes of *E. hyemale* grown under white light but did significantly increase the number of males grown under a modified spectrum (blue or red). But when the medium was enriched with glucose, male sexuality increased in the gametophytes of *E. hyemale* (Hauke, 1977).

Equisetum spores are viable for short period to produce gametophyte for a brief period in a year. Whittier (1996) extended the viability of spores of *E. hyemale* for more than a year keeping them frozen at -70°C.

Ecology : The specific epithet “hyemale” denotes, ‘occurring on land followed during winter’ (hyemalis or hiemalis pertaining to winter) (Stearn, 1973). This means that the species occurs in most cold climate. The species, discovered so far in India is found occurring in Kashmir Himalaya and Kumaon hills where moist cold climate remains throughout the year and is found to have occasionally eco-morphological variation of having slight irregular feeble branching in some part of the stem. For its recent discovery and very restricted occurrence in northern mountain tract, the ecological studies of the plant has not been recorded, but elsewhere, a unique correlationship between moisture and selective occurrence of *Equisetum* species has been revealed by Dowding (1929).

Micromorphology : The silica deposition pattern of the epidermal system in *Equisetum* is a taxonomic marker in subgeneric level. For instance, *E. hyemale* (subg. *Hippochaete*) is taxonomically different in respect of having uniform silica deposition in stomatiferous areas from *E. arvense* (subg. *Equisetum*) where silicification of the same areas are in discrete knobs and rosettes (Kaufman & al., 1971).

Again, while in *E. hyemale*, the furrows of the stems may be plain or are provided with silica bars of rosettes, the ridges possess double rows of tubercles and their features may persist as perennial structures for several years in natural population, in contrast to the annual stems of *E. arvense*, which contain much less silica.

La Roche (1968, 1969a, b) and La Roche & al. (1970) studied by SEM, the silica deposition pattern in *E. arvense* and *E. hyemale*. From the investigation, it is noted that the polymerized opaline silica ($\text{SiO}_2, \text{H}_2\text{O}$) in *E. arvense* is deposited below the cuticle but essentially on the outside of the outer epidermal cell wall in positions corresponding to the knobs and rosettes, detected by the SEM. It might be possible in *E. arvense* that the accumulation of ectodesmata in the wall take the corresponding positions of knobs and rosettes on the wall. This process secrets excess silica on opal which is absorbed by the plant and transported to the shoot system. This presumably offers such a weak distributional pattern of silica in *E. arvense* that the cell wall does not get enough strength. On the other hand, in *E. hyemale*, silica is uniformly distributed within and on the other epidermal cells both periclinally and anticlinally. Silicic acid is distributed both on the surface and inner wall and ectodesmata is evenly distributed within the cell wall. The overall effect gives strength to the cell wall of *E. hyemale* and makes the plant erect.

Chemistry : The species is known to contain two secondary metabolites, cinnamic acid derivatives. Caffeic acid (3,4-Dihydroxycinnamic acid, $\text{C}_9\text{H}_8\text{O}_4$) and Ferulic acid (3-Methoxy, 4-Hydroxycinnamic acid) ($\text{C}_{10}\text{H}_{10}\text{O}_4$), Nicotine ($\text{C}_{10}\text{H}_{14}\text{O}_2$) and Dimethylsulphone ($\text{C}_2\text{H}_6\text{O}_2\text{S}$) and alkaloid palustrine ($\text{C}_{17}\text{H}_{29}\text{H}_3\text{O}_2$) and silicic acid (Hegnauer, 1963, Raffauf, 1970).

Economic Uses : Uphof (1959) states that due to the high silica content of *E. hyemale* L., the plant stalks are extensively used in Japan for polishing, especially in the villages of Waka-mori of Tambon province. Barton and Castle (1877) and Lindley (1856) reported the extensive use of *E. arvense* and *E. hyemale* (Dutch rush) for having large quantity of silex in the stem were used in Europe for polishing hard wood, ivory, brass for scouring and cleaning pewter dishes and plates, milk pails and other culinary articles. Muenscher (1951, 1955) reports that the plant is toxic to grazing cattle and horses in United States. But it is used in Mexico as diuretic and antibleorrhagic (Uphof, 1959).

The species has insecticidal properties- when injected to cockroaches, they fall victim to unrecoverable paralysis and their mortality varies from 20 to 50 percent, sometimes 100 percent (Heal & *al.*, 1950).

Hybridity : Borg (1967), Duckett (1974) and Hauke (1963) report that four interspecific hybrids occur in wild by the cross between the two varieties of *E. hyemale* and the three species, *E. myriochaetum*, *E. laevigatum* and *E. variegatum* all in the subg. *Hippochaete*. The American variety *E. hyemale* var. *affine* (Engelm.) A. A. Eat. hybridizes with *E. myriochaetum* Schlecht & Cham. and with *E. laevigatum* A. Br. to produce *E. × mexicanum* Wilde and *E. × ferrissii* Clute respectively which are distributed in S. America and N. America. The taxon *E. hyemale* L. var. *hyemale* on the other hand, hybridizes with *E. ramosissimum* Desf. subsp. *ramosissimum* to produce *E. × moorei* Newm. which is distributed in Europe and Japan. It is not yet reported from S.W. Asia and India. Another hybrid *E. × trachyodon* A. Br. of putative parents *E. hyemale* and *E. variegatum* is wild in N. America and Europe.

Discussion : The taxonomic ranking of *Equisetum hyemale* L. through a century from Braun (1844) to Rothmaler (1944) is an interesting story. Braun who first made taxonomic study of North America *Equisetum* and classified them before Milde placed *E. hyemale* along with *E. variegatum* and *E. laevigatum* in a subgroup of the group *Homophyadica* under his section *Stichopora* which subsequently became the subg. *Hippochaete* (Baker, 1887).

In his earlier work, Milde (1861) placed *E. hyemale* in the subsection *Equiseta monosticha* of the section *Equiseta cryptopora* (*E. hiemalia*) which are grouped in subg. *Hippochaete*.

In 1864, Milde provided *Equiseta cryptopora* a subgeneric rank as subg. *Cryptostoma* Milde and the species grouped in section *Cryptopora* remained as before.

Next year, Milde (1865) recognised his two sections as two separate genera: *Equisetum* and *Hippochaete*, and *E. hyemale* with other species previously grouped in sect. *Stichopora* A. Br. and *Cryptopora* Milde were ranked in this genus *Hippochaete*.

In his monograph, Milde (1867a) mentioned all the synonyms viz. *Equiseta hiemalia* A. Br., *Equiseta stichopora* A. Br. and *Equiseta stichopora* Milde under *Hippochaete* which had been divided into three sections one of which was *Equiseta monosticha* that contained four subsections one of which was subsect. *Equiseta hiemalia* Milde where *E. hyemale* was placed.

Börner (1912) recognised *Hippochaete* as a separate genus and made generic recombination of the species such as *Hippochaete hiemale* (L.) C. Börner.

Rothmaler (1944) followed Braun's classification and merged Börner's *Alloselites* (Börner created this new genus) into the sect. *Homophyadica* A. Br. of the genus *Equisetum* L. But regarding the classification of *Hippochaete*, he made new combination with Braun and Pfitzer regarding sect. *Univaginata* and subsect. *Homocormia*. He made new combination of sect. *Stichopora* (A. Br.) Rothm. and subsect. *Hiemalia* (A. Br.) Rothm. in which he placed *H. hiemale* (L.) C. Börner, *H. trachyodon* (A. Br.) C. Börner and *H. ramosissimum* (Desf.) C. Börner.

Equisetum subg. *Equisetum* Baker, Handb. Fern. Allies 1. 1887.

Basionym : *Equisetum* L. restr. Milde Bot. Zeit. 23: 297. 1865.

Lectotype : *Equisetum fluviatile* L., Sp. Pl. 1062. 1753.

Though Milde did not attribute a taxonomic ranking as subgenus *Equisetum* within the genus *Equisetum*, Baker (1887) first used the taxonomic rank as subgenus *Equisetum* within the genus *Equisetum* and accordingly he is considered as the author of the subgenus.

Taxonomy : Hauke (1978) reviewed the taxonomic classification of the genus *Equisetum* adopted by various authors and furnished his own. He divided (*l.c.* 1978) subg. *Equisetum* to two sections: sect. *Equisetum* and sect. *Heterophyadica*. Of eight species of the subgenus *Equisetum* distributed in the world, only four species including one hybrid, namely *E. diffusum*, *E. palustre*, *E. arvense* and *E. × wallichianum* are reported from India. The first two belong to the section. *E. × wallichianum* is a natural hybrid between *E. diffusum* and *E. arvense*.

Note : Raizada and Chowdhury (1954, 1961) and Chowdhury (1973) have mentioned of the occurrence of *E. maximum* in India. I have not detected any specimen of the species in the *Equisetum* collection of different herbaria of India. Chowdhury (*l.c.*) has mentioned the restricted occurrence of the species in Malhot of Dehradun district at an altitude of 3000 feet and referred to the collection J.S. Gamble 24575. I have not come across that specimen in Calcutta Herbarium nor I have detected any specimen of the species in BSD and DD at Dehradun.

According to current taxonomic views, Lamarck's *E. maximum* lacks a systematic taxonomic position. Hauke (1978) has treated it as synonym of both *E. fluviatile* and *E. telmateia*. He has discussed in detail the reason of this confusion (1978).

From the description and synonym of the species that Chowdhury has provided it appears that *E. maximum* reported as occurring in India is *E. telmateia* Ehrh. So far as its distribution is concerned, it is old world species and among its distribution areas Asia, Syria, Iran and Southern USSR closed to Northern frontier of India are recorded (Hauke, 1978). So it is likely that the species migrated to North-West Himalaya of India from those places and Gamble collected it from Dehradun. But, I presume it is now rare in India as no collection of the species in the area has been reported in the recent times.

Equisetum subg. *Equisetum* sect. *Equisetum* Hauke, Nova Hedwig. 30: 410. 1978.

Note : Milde (1867b) reduced two genera *Equisetum* and *Hippochaete* he created earlier (1865) to a single genus *Equisetum* and divided it into two sections using the same epithet *i.e.* sect. *Equisetum* and sect. *Hippochaete*. Novak (1971) and Holub (1972) in their infrageneric classifications used sect. *Equisetum* under subg. *Equisetum*. Hauke (1974) earlier did not create any section under the subg. *Equisetum* and kept it as such but later (1978) created the section *Equisetum*.

Type : *E. fluviatile* L., Sp. Pl. 1062. 1753 being in the section of the subg. *Equisetum*.

Synonym : Novak's (1971) section *Equisetum* subsect. *Singulivaginata* (Pfitzer) Novak, section *Homophyadica* A. Br. emend Novak, subsect. *Palustria* Novak and section *Heterophyadica* A. Br.

emend Ascherson *pro parte* and Holub's (1972) section *Limnosetum* Holub and section *Heterophyadica* A. Br. restr. Holub *pro parte*.

Taxonomy : The section *Equisetum* consists of five species: *E. fluviatile*, *E. palustre*, *E. bogotense*, *E. diffusum* and *E. telmateia*. The section is represented in India by two species *E. diffusum* and *E. palustre*.

4. *Equisetum diffusum* D. Don, Prodr. Fl Nepalensis 19. 1825.

Synonyms : *E. diffusum* var. *caespitosum* Milde, *E. diffusum* var. *ramosum* Milde, *E. diffusum* var. *nudum* Milde, *E. diffusum* var. *polystachyum* Milde in Monogr. Equist. 307. 1867; *E. diffusum* var. *paucidentatum* Page, Fern Gaz. 11(1): 31. 1974; *E. mekongense* Page, Fern Gaz. 11(1): 36. 1974.

Milde stated that although in 1825, D. Don described *E. diffusum* in Prodr. Flora Nepalensis, still in many herbaria *E. diffusum* was not designated in its right name; sometimes it was designated as *E. arvense*, sometimes as *E. palustre* or often as *E. debile* (In den Herbarien findet man Sie fast nirgends mit ihrem richtigen Namen, sondern bald als *E. arvense*, bald *E. palustre* bald als *E. debile* bezeichnet. (Monogr. Equiset. 309-310. 1867).

General morphology : The species is endemic to the Himalayas and long recognised as distinct from the more widespread species of *Equisetum*. It resembles *E. palustre* in general habit and size, having an invariably monomorphic type of shoot, the fertile ones of which terminate in typically long-ovoid cylindric cones. Most shoots bear regular whorls of long, green branches of spreading or ascending habit from all the nodes in the lower 1/3! to 2/3! of the shoot, although as in *E. palustre*, occasional unbranched shoots occur often bearing cones.

Stems generally monomorphic or homophyadic or very scarcely heterophyadic or dimorphic due to unusual morphological plasticity, 24-65 cm tall with internodes, 1.7-5.0 cm long, 1.5-2.5 mm in diam., with 6-10 ridges, these being grooved to flat topped.

Internally there is only carinal collenchyama and the chlorenchyama is continuous around the stem. Central canal is absent to obscure with only partial break down of the pith tissue. Endodermis outer common. Sheath urceolate, 4-7 mm × 2.0-4.5 mm with teeth 2-4 mm long, narrow, dark; the stem ridge grooves and branch internode grooves continuing up the centre of each sheath segment and to the end of the teeth (Page has termed it as biangulation of the stem and branch internode ridges). Branches ascending in regular whorls or irregular, sometimes absent on coniferous stems, with first internode about equalling the subtending stem teeth, teeth 3-7 mm long, ridges 4, these prominently grooved and bearing a silica profile of 2 rows of closely set, blocky sawteeth. Sheath segment grooved, grooves continuing into triangular narrowly pointed teeth, commissure to 0.6 mm long with prominent furrow of anchor cells. valleys rounded with stomata scattered throughout. Silica pilules covering stomata and distinctly outlining them. Stomata lined with a single row of somewhat rod-like pilules. Mamillae transversely aligned, usually distinct.

Branches solid; cones 25-60 mm long, narrow, on stalk or peduncles 20-30 mm long. Rhizomes shiny, brown, covered with hairs, occasionally bearing tubers. Spores 30-41 µm in diam.

Fr. : Coning from July to November.

Taxonomy : *E. diffusum* is endemic to the Himalayas and has a very stable taxonomic character unlike all other *Equisetum* species except *E. bogotense*. Hauke (1978) states this species distinguishes itself from other species with regard to its stems that stand out above ground all the year round. The two species in many respect are alike, but one is endemic to a restricted zone of the Old World (*E. diffusum*) and the other is similarly restricted to a zone of New World (*E. bogotense*). Milde in his monograph (Monogr. Equiset. 302-310 [*E. diffusum*], 311-319. 1867a [*E. bogotense*]) of the genus treated the two in subsequent order under "Equiseta Homophyadica" and gave the diagnostic features of the two species (p. 302-303, 311-312) some of which are common to each other but in stem character, ridge number, teeth morphology etc. the two species differ. The most distinctive features of the two are that both the species have branches and rhizome solid, in *E. diffusum* central canal of the stem is almost obsolete or very narrow, but in *E. bogotense* central canal is lacking (*lacuna centralis nulla*). In *E. diffusum* stem is uniform, deeply grooved, sometimes rough (stengel eingestaltig, tief gefurcht, etwas rauh) whereas in *E. bogotense* stem is tight, but looks corrugated or rugose, deeply grooved or sulcate (stengel dicht querrunzelig, tief gefurcht). Due to its specific taxonomic entity, *E. diffusum* is confused very little with other species and it does not entail many synonyms.

Lectotype : Wallich s.n., Nepal collected by Wallich in 1820 (BM) designated by Hauke (1978) as the lectotype. He has discussed about the typification of the species and has ignored Wallich's other specimens collected from Nepal particularly Nr. 398 assuming that it may be catalogue number and not the field number.

Icones : Milde, Monogr. Equiset. 1867 t. XI. f. 1-3, 4-18, Hauke, Monogr. Subgen. Equiset., Nova Hedwig 30: 1978 t. 5(p. 447), t. 17, 18 (p. 449), t. 33 (p. 551), t. 44 (p. 452), t. 55.56 (p. 453); Page, New Phytol. 71(2): 355-369, t. 3. (No. 4-7). 1972; Page Fern Gaz. 11(1): 37. 1974 f. 7 a-d, 2a, b.

Distrib. : This species is distributed in the Himalayan belt of India from Kashmir to Assam, including Sikkim with neighbouring countries, Bhutan, Nepal, Burma and China. It is distributed on an elevation from 450 to 3000 feet from sea level.

Milde (1867a) reported the distribution of *E. diffusum* in the Himalayan region of India and adjacent Nepal and Tibet. He referred to Fischer's collection from Alpine Nepal including Kathmandu covering from 27° 35' North lat. to 97° 28' East long. He referred to the specimen of Strachey and Winterbottom, of the Himalayan Herbarium (*Strachey and Winterbottom* 2) and also to Alexander Braun's collection from Assam and Tibet. Griffith's collection from the Himalayas, Hügel's collection from Mussoorie, T. Anderson's collection from Eastern Himalaya and Griffith's collection from Mishmee hills.

Specimens examined : INDIA: Jammu & Kashmir : Near Khir Bhawani, 1500 m, Ram Lakhan 10823 dated 26.5.1954 (LWG); Pandit Monmohan Nath Koul, Governor I dated 30.10.1908 (BSIS); Sonmarg, A. Datta 58109 dated 12.8.1983 (CAL); way to Amarnath, 3000 m, A. Datta 58119 dated 14.8.1983 (CAL); Kangan (Pushkar), Anukul Datta 58136 dt. 17.8.1983 (CAL); Gulmarg, near sports ground, A. Datta 58159 dt. 19.8.1983, A. Datta 58164 dt. 20.8.1983 (CAL); Tangmarg, A. Datta 58169 dt. 21.8.1983 (CAL); Khillan Marg, A. Datta 58170 dt. 22.8.1983 (CAL); Allapathri, above Khillan Marg, 4200 m, A. Datta 58171 dt. 22.8.1983 (CAL); Pahalgam, A. Datta 58191 and 58192 dt. 26.9.1983 (CAL); Aru valley, beside Liddar valley river, A. Datta 58206 dt. 28.8.1983 (CAL). Punjab : Bathri, Dalhousie,

1200 m, *Ravi s.n.* dt. 29.9.1971 (ex Herb. Punjab Univ., Patiala, CAL). Himachal Pradesh : Naggar, Kulu valley, *J.G. Srivastava and party* 60206 dt. 25.5.1959 (LWG); Water falls, Simla, 1500-1717 m, *J.S. Gamble* 5773 C & E dt. 16.9.1877 (DD) & *J.S. Gamble* 5773 B & F (CAL); Simla, 2400 m, *A. Meebold* 8684 dt. 10.1907 (CAL); Pangi village, Bashahr, *N.C. Nair* 2254 dt. 7.6.1962 (BSD); Chhatru, Lahul, 3325 m, *N.C. Nair* 16589 dt. 3.9.1961 (BSD, CAL). Uttar Pradesh : Dehradun, *J.F. Duthie s.n.* dt. 10.1890 (DD); Dehradun, *J.F. Duthie* 6872 dt. 21.9.1887 (DD); Tehri Garhwal, *J.F. Duthie* 2256 dt. 10.1881 (DD); Kumaon, *J.F. Duthie* 3729 dt. 4.10.1884 (DD); Aglur valley, above Balah, Tehri Garhwal, *J.F. Duthie* 2256 dt. 24.9.1881 (DD); Jumna valley, Tihri Garhwal, near Bhula, *J.F. Duthie* 25 dt. 10.1877 (DD); Dehradun, *J.F. Duthie* 7676 dt. 21.9.1887 (DD); Mantaogarh, Tihri Garhwal, 180 m, *J.S. Gamble* 27354 dt. 10.1898 (DD) and *J.F. Duthie* 2404 dt. 9.1882 (DD); Lukwar, Garhwal, *G. A. Gammie s.n.* dt. 1891 (DD); Between Sitabani and Ramnagar, Garhwal, *Inayat* 26049 18.8.1902 (DD); Robber's Cave, Dehradun, *M.B. Raizada s.n.* dt. 9.1944 (DD); Kumaon, *Col. Davidson s.n.* dt. 1875 (DD); near Almora, Kumaon, 2400 m, *Col. Davidson s.n.* 10. 1857 (DD); Dehradun, *Falconer s.n.* (DD); Dehradun, *M.A. Rau* 14588 dt. 2.4.1961 (BSD); Gangotri, Tehri Garhwal, 3300-3600 m, *J.F. Duthie* 2256 dt. 10.1881 (DD); Mattiana, *T.R. Drummond s.n.* dt. 1885 (DD); Khomi, 1800 m, *N.L. Bor* 16043 dt. 19.7.1942 (DD); Kathi-Divali, Kumaon, 2000-3500 m, *T.A. Rao* 4322 dt. 12.7.1957 (BSD); Chowbattia, Kumaon, 2000-2300 m, *T.A. Rao* 4808 dt. 5.10.1957 (BSD); Baldi Nadi, Sahasradhara, Kumaon, *Y.K. Sarin* 7957 dt. 4.11.1956 (BSD); Kalimatu, Garhwal, *M.A. Rau* 8761 dt. 3.10.1958 (BSD); Lansdowne, Sat Puli, Garhwal, *M.A. Rau* 11220 dt. 26.2.1960 (BSD); Sirkote, Almora dist., 1800 m, *J.N. Vohra* 58004 dt. 17.10.1975 (BSD); Almora, *Kaul and party* 19206 dt. 23.2.1955 (LWG); Ganai, Almora, *D. Hooper* 39032 A dt. 20.10.1912 (BSIS). West Bengal : Teesta river bed, Kalighora, Darjeeling dist., *B. Krishna* 315 dt. 22.3.1973 (BSIS); Tiger Hill, 2400 m, Indo-Russian Expedition, E. Himal. and N. Bengal No. 178 dt. 20.4.1961 (CAL); Lloyd Botanic garden, Darjeeling, *R.D. Dixit* 52565 dt. 26.4.1975 (CAL); Kalimpong, Darjeeling dist., *K. Biswas* 8532 dt. 10.11.1948 (CAL); Bambakabashi, Kalimpong, 1200 m, *K. Thothathri* 9439 dt. 6.11.1960 (CAL); Llyod Botanic Garden, Darjeeling, *J.K. Maheswari* 4963 dt. 20.11.1962 (CAL); Darjeeling, 2400 m, *C.B. Clarke* 9742 B dt. 10.1877 (CAL); Simaria forest, Darjeeling dist., *R.D. Dixit* 52893 dt. 9.5.1975 (CAL); Mungpoo, 900 m, *W.W. Smith s.n.* dt. 17.4.1908 and *W.W. Smith* 391 dt. 5.10.1908 (CAL); near Lloyd Botanic Garden, *M.B. Raizada* 18913 dt. 11.11.1944 (BSD). Sikkim : Gangtok, 1500 m, *R.K. Ghosh* 50226 dt. 25.5.1972 (CAL); Sitong, *W.G. Craib* 664 dt. 11.12.1908 (CAL); Rakti river, *J.S. Gamble* 7370 dt. 11.1879 (DD). Arunachal Pradesh : Ankling, Kameng dist., *P.K. Hajra* 54146 dt. 16.10.1973 (ASSAM); North of Bomdi-La road, towards Dirang, Kameng dist., *A.S. Rao* 49398 dt. 28.10.1970 (ASSAM); Khuni Pahad to Pete Podi, Subansiri dist., *G. Panigrahi* 19642 dt. 26.9.1959 (ASSAM); Shoeliang to Paya, 360-750 m, *R.S. Rao* 10613 (ASSAM, CAL); Krishna, 8 km. to Sessa, Kameng F.D., *J. Joseph* 39717 dt. 10.9.1964 (ASSAM, CAL); Zorum, Subansiri dist., *G. Panigrahi* 19734 (ASSAM, CAL); Khola, Tirap dist., 450 m, *G.G.K. Murthy* 12969 dt. 15.3.1958 (ASSAM); Sissini, Kameng dist., 1215 m, *G. Panigrahi* 6097 dt. 26.3.1957 (ASSAM); Between Krishna and Sessa, on way to Bomdi-La, Kameng dist., *A.S. Rao* 49238 dt. 24.10.1970 (CAL); Dafla hills, *Badul Khan* 135 dt. 1.1890 (CAL); Janakmukh, Abor Expedition, 1911-12, *I.H. Burkill* 37157 dt. 15.12.1911 (CAL); 25 km. north of Bomdi-La, Dirang, near Dirang bridge on Dirang river, left bank, on moist hill slope, Kameng dist., *A.S. Rao* 49498 dt. 30.10.1970 (ASSAM, CAL); North of Bechum river, suspension foot bridge, Kameng dist., *A.S. Rao* 50633 dt. 23.11.1970 (ASSAM, CAL); Kothong, Tirap F.D., *D.B. Deb* 26103 dt. 25.6.1961 (CAL); Sissini to Jabrang, *K.S. Srinivasan s.n.* dt. 7.5.1955 (BSIS). ASSAM: Nonai, Darang dist., *U.N. Kanjilal* 4993 dt. 15.1.1915 (ASSAM); Nunai, Darang dist., 345 m, *B.K. Nath* 13313 dt. 18.2.1957 (ASSAM); Motherguri, *R.S. Rao* 9955 dt. 12.7.1957 (ASSAM). Meghalaya : Jowai road, K. & J. hills, above Umkhin river, *I.H. Burkill & S.C. Banerjee* 19 dt. 13.6.1911 (CAL); Mao Daw, Khasia, 1050 m, *C.B.*

Clarke 15255 dt. 9.11.1871 and 10.11.1871 (CAL). Manipur : Mukhu village, on Seeka river, 750-900 m, *G Watt* 5058 dt. 1. 1882 (CAL); Ching Sow, 1800-2100 m, *G Watt* 5942 dt. 1.1882 (CAL); Seeka river, between Khongal and Nuagba, 750 m, *G Watt* 6645 dt. 1.1882 (CAL). Nagaland : Kohima, *D. Prain s.n.* dt. 5.10.1886 (CAL); Mao bat, *R.D. Dixit* 58911 dt. 13.2.1978 (CAL); Naga hills, *N.L. Bor* 22070 (6757) no date (CAL).

Anatomy : Milde (1867a) has made a critical anatomical study of the species. Sen and Sen (1973) record that the tracheids are with annular and helical thickenings that form veins; ridges in stem are composed of sclerenchymatous cells with heavily silicified walls, stomata occur in the valleys between the ridges, flush with epidermal layer of stem and occur in multi-lined bands, peripheral cells of cortex below ridges and valleys are chlorenchymatous and have conspicuous intercellular spaces. Development of stomata is characteristic of the species in which there are two successive longitudinal divisions of the initial, the two innermost cells developing into a pair of guard cells and the outermost into a pair of subsidiary cell. Cortex and stele are separated by an endodermis. Vascular bundles are endarch, protoxylem elements are replaced by carinal canals in which a few lignified rings are visible. On either side of the phloem, a few metaxylem elements can be seen, that lie to the outside of each carinal canal.

Root stele is triarch, consists of an axial metaxylem element with three peripheral protoxylem elements. Space between protoxylem elements are completely filled by phloem. Pericycle absent but endodermis is 2-celled thick. Bir (1978) has studied the anatomy of its tubers.

Gametophyte : Cones of *E. diffusum* contain several whorls of sporangiophores borne on an axis, the tip of which also ends in a sporangiophore. At maturity, it attains deep brown colour and a length of about 2-4 cm. Sporangiphore is peltate and has a hexagonal disc. Each sporangiophore bears 5-8 sporangia. Spores are alete, thin walled and chlorophyllous. Wall consists of smooth exine and a thin perine, the latter forms a band-like or ribbon-like elements attached to a single point. A spore is about 32 μ in diameter (Sen and Sen, 1973). The spore, at maturity, in suitable medium produces the prothallus, the gametophyte.

The study by Hauke (1980) shows that the gametophytes of *E. diffusum* are similar to those of other species of *Equisetum* in basic form. For instance, sexual dimorphism, cessation of growth in sporophytes and bearing gametophytes and production of numerous sporophytes per gametophyte are all seen in other species.

Certain features of *E. diffusum* gametophytes, however, indicate that they are relatively primitive and more closely allied to *E. telmateia* than any other species. Basing this study, Hauke (*l.c.*) presented an evolutionary sequence among the species of subg. *Equisetum* using his own observations of the gametophytes and of the morphological characters of the same described by Duckett (1973).

Cytology : Mehra and Bir (1959) have studied the chromosome number in the species $n = 108$ and noted that the spore mother cells of the species as well as of *E. ramosissimum* var. *ramosissimum* (the authors, however, used old name, var. *altissimum*) are slightly granular and take stains quicker than usual. Their chromosome size and shape are variable and sometimes appear in multivalent pairing.

Chromosome appear so brittle that there is every possibility that they can break during karyotype analyses, leading to faulty counting. So the authors stated that for exact and correct counting, the results were confirmed from large number of spore mother cells in each case. The size of bivalents at diakinesis, they recorded, were smaller and more contracted in both the species.

Micromorphology : Page (1972, 1974) has made SEM studies of the ultrastructures of the branch internode of the species along with other species of *Equisetum*. He (1974) presented four scanning electron micrographs of var. *diffusum* of the species, two of which were of a Chinese specimen (Forrest 28928) and the other two of an Indian material (Strachey and Winterbottom 2) showing structural variation and position of difference of mamillae and pilulae and stomatal cells areas from each other. The ultrastructure of the Chinese material denotes its more alignment to *E. palustre* var. *palustre*, whereas that of Indian material shows its more closeness towards *E. arvense*. According to the author, *E. mekongense* (which has been reduced to a synonym of *E. diffusum* by Hauke) shows strong indications of relationship with *E. diffusum* in micromorphology. The arrangement of peripheral pilulae and distribution of them along the stomatal aperture is similar to that of *E. diffusum*.

Hybridity : *Equisetum* × *wallichianum* Page is a natural hybrid of putative parents *E. arvense* and *E. diffusum* var. *diffusum* occurring in wild condition in Sino-Himalayan region (Page, 1974).

Ecology : *E. diffusum* occurs in varied types of ecological conditions in this country from upper temperate to subtropical regions. Its occurrence in different plant communities and ecological habitats reported by Sharma & al. (1969, 1970), Dhir and Sheera (1975), Awasthi and Sharma (1980) deserve mention. This author has also seen its occurrence in diverse habitats- in the shallow, sandy river bed under flowing water at Sahasradhara, Dehradun at the foothills of Siwalik, in the sprawling rice fields and at the banks of canal and in the ditches in the flowing water at Kangan, Kashmir in comparatively lower elevation and warmer climate to the high altitude at Sonmarg, Kashmir, in the Sind valley along the bank of Indus and at Pahalgam and Aru valley, in the Lidder river in the crevices of boulders submerged under the fast flowing ice-cold water. Also in Kashmir, high above Khillanmarg, at Allapathri, in the Pir Panjal range, in open and in comparatively drier soil having no water course near by, this species is found to grow. On the other hand, in Eastern Himalaya, in subtropical and temperate wet evergreen and dry deciduous forests in open and in shade, in river valleys and in crest of mountain ridges it grows luxuriantly.

Discussion : Milde (1872) grouped *E. diffusum* with *E. bogotense* under the group *Equiseta homophyadica* A. Br. subgroup *Equiseta bicylindrica*, both having solid branches (*rami solidi*) as their common characteristics. The former is endemic to Himalaya and the latter endemic to Central America. Geographically they are wide apart but taxonomically closed to each other. *E. palustre* had also been put by him under the same subgroup but the species differ from the former two species in having branches hollow (*rami fistulosi*). In his monographic work of the species (1867), Milde mentioned of four varieties of it, but they "all seem to have environmentally-induced growth habits of little taxonomic importance" (Page, 1974). Page, however, in the same paper (1974) recognised a variety *E. diffusum* var. *paucidentatum* on the basis of branch internode ridges, lacking both the longitudinal groove and ridge tubercles or nearly so (*Carinae internodiorum ramorum truncatae, et sulco et tuberculis absentibus vel fere absentibus*) and cited specimens from Simla and Garhwal, India and from Nepal. Hauke (1978) opined that this variation "does not seem a sufficient basis for the recognition of a taxonomic variety"

Similarly Page's new species *E. mekongense* (1974) faces bitter criticism as "one character, one specimen taxonomy" (Hauke, 1978) because the "new" species is based upon a single collection of J. Lile no. 1496 collected in April-May, 1899 from Nekou in Mekong valley in north west Yunnan. This plant, as Page examined, is with vegetative stems like *E. diffusum* but heterophyadic like *E. arvense*. However, micromorphologically, it is indistinguishable from *E. diffusum*. Page defends the establishment of his new species by stating that the combination of these micromorphological features with the presence of 2-keeled sheath-teeth allow *E. mekongense* to be clearly distinguished from both *E. arvense* and *E. diffusum* even in the absence of information on the type of fertile shoot.

But Hauke (*l.c.*) states that he finds no character other than fertile shoot by which *E. mekongense* differs from *E. diffusum*. To him, this so-called fertile shoot seen only in a single collection like an ephemeral spring shoot of *E. arvense* type carries actually no taxonomic importance, because similar heterophyadic shoot has been found occurring in some unusual cases in *E. fluviatile* as reported by Van Hoek (1976) and some degree of dimorphism in *E. pratense* with regard to its coniferous stems are reported. Also in *E. sylvaticum* it is found that the coniferous stem when young and before shedding of spores appear somewhat "ephemeral" but after shedding of the spores become green, branched, persistent and typically vegetative. It is also commonly found in *E. diffusum* an incipient tendency towards heterophyadicity as the sheaths immediately below cone of the plants are commonly enlarged and swollen, a character associated with coning stem in heterophyadic species. Perhaps that is why, Page in his earlier work (1972) has attached no importance to heterophyadic vs. homophyadic shoots as a taxonomic character at the sectional level of *Equisetum*. Hauke believes that the type specimen of *E. mekongense* is merely an aberrant specimen of *E. diffusum* and so it may be treated as a synonym of the species.

5. *Equisetum palustre* L., Sp. Pl. 1: 1061. 1753; 2: 1516. 1763.

Synonyms : *E. nodosum* Hoppe, Botan Täschenbuch. 65. 1794; *E. tuberosum* Hectot ap. De Candolle, Fl. Franç. 6: 245. 1815; *E. veronense* C. Pollini, Hort. Et prov. Veronens., 27. 1816; et Fl. Veronens 3: 260. 1824; *E. arenarium* Opiz, Kratos 14: 9. 1819; *E. pratense* de Schlechtendal non-Ehrh., Fl. Berolin., 1823-24; *E. tenellum* Fries, Summa Vegetab., 59. 1846; *E. ramosum* et *E. umbrosum* in Payot. Cat. Des Fougères, 50, 52. 1860; *E. telmateia x palustre* Zabel, Arch. Vereins Freunde Naturgesch. Meeklenb., 13: 268. 1863; *Equisetum palustre brevioribus setis*, Bauh. Pin. 15, 16; *Equisetum palustre linariae scopariae folio*, Bauh. Prodr. Theatri botanici 14. 1671; *E. palustre minus polystachion* Bauh. Prodr. Theatri botanici 14. 1671; *E. palustre* var. *americana* Vict., Contrib. Lab. Bot. Univ. Montreal 9: 51. 1927; *E. palustre* var. *szechuanense* Page, Fern Gaz. 11: 34. 1974.

Taxonomy : Due to its enormous plastic nature, *E. palustre* varies in shape and size from region to region. In North American regions, some populations of the species were determined as a distinct variety. For instance, Victorin (1927) determined some populations of the species as a variety of it as *E. palustre* L. var. *americana* Vict. on the basis of their sheath teeth being longer, more pointed and with narrower, scarious margins. Hauke, however, has invalidated the variety (Hauke, 1978) for this reason of plasticity of the species and Holub (1972) questioned the taxonomic justification of the variety which according to him is nomenclaturally invalid (Die taxonomische Berechtigung von var. *americana* Vict. als eines Vikarianten ist strittig; der Name von Victorin ist nomenklatorisch ungültig).

So in the history of taxonomic treatment of *E. palustre* done by various authors at different times, it is observed that the species due to its significant plasticity like other species of *Equisetum* is either wrongly identified with *E. diffusum* D. Don, *E. ramosissimum* Desf. or is treated as varieties of *palustre* or of different species such as, *E. palustre* β *altissimum* Lapeyr (Lapeyrouse Picot de, Hist. Ab. Des. Pyrenées 82, 150. 1818) or *E. pratense* β *simplicissimum* Al. Braun (cf. Milde, 1867) in addition to the innumerable varieties cited in the synonym.

General morphology : Stem homophyadic, 20-80 cm tall, with internodes, 2.5-5.8 cm long and 1-3(5) mm in diam., having 5-1 ridges; both the branch and stem internodes having characteristic simple rounded angles and furrows, first internode of the branch being very short, usually less than half and often only 1/4 the length of the adjacent stem sheath, 2-5 mm long with 4-6 ridges, the silica profile or irregular tubercles; stems with usually less than about 9 sides, but often of 5-6 sides recorded. Branches spreading in irregular whorls, from middle nodes only or sparse or absent. Sheath elongated, 4-9 $\times$ 2-5 mm, green with long, narrow, black teeth with scarious white margins, sheath segments and teeth with slight central grooves, branch teeth resemble stem teeth with less obvious scarious margins, commissure with long furrow of anchor cells, they may be broad, short or more or less close-pressed to the stem or may be relatively long, free spreading and not closely appressed to the stem; similarly stem teeth may be short, broadly triangular, nearly equilateral with conspicuous scarious margins or long, having each segment distinctly 2-keeled and more or less without broad scarious margins. valleys rounded, with stomata scattered throughout. Internally there is only carinal collenchyma and the chlorenchyma is continuous around the stem. Central canal small, ca 1/6- 1/3! diam. of stem and vallecular canals nearly as large. Endodermis outer common. Silica pilulae scattered over surface of stomata intermeshing across the pore, but not outlining the stomata, as away from the pore, pilulae become progressively more sparse. Mamilliae prominent, frequently transversely aligned. Branches hollow. Cones distinctly ovoid-cylindric, 9-35 mm long on peduncles, 5-32 mm long. Rhizomes shiny black to dark-brown, except on sheaths, occasionally bearing tubers; spores 30-45 μ in diam.

Type : The sheet number 5 in the Linnaean Herbarium (LINN) contained in Packet 1241 and labelled, "*Equisetum palustre*" is generally recognised as the type of the species (Savage, 1945; Cullen, 1957). But the sheet 5 actually contains two specimens both of which, Hauke (1978) claims, are found to be *E. arvense*. I have also seen the microfiche reproduction of Linnaean sheet 1241/5 (LINN) and I have not marked the most distinguishing character of *E. palustre* such as first internode to the branch very short which is much less than the length of adjacent stem-sheath in the specimens in reproduction.

On the other hand, the specimen in Hortus Cliffortianus (p. 471-72, 1737) listed by Linnaeus under *E. arvense* is claimed by Hauke (*l.c.*) to be actually *E. palustre*. Linnaeus identified with *Equisetum minus terrestre* after Bauhin (Hist. 3: 730. 1650-51) meaning its habitat being less terrestrial. It seems Linnaeus faced difficulty in distinguishing *E. arvense* from *E. palustre* although his description in Species Plantarum makes clear that *E. arvense* is heterophyadic implying *E. palustre* as homophyadic (Hauke, *l.c.* 1978). His diagnosis of the species (*E. palustre* L.) as "Caule angulato frondibus simplicibus", published in Flora Suecica (2: 928. 1755) (vide Milde, Die Diagnose in der Flora Suecica 1755 lautet *E. palustre* Caule angulato, frondibus simplicibus (Monogr. Equiset. 335. 1867) and its habitat being in "Europae aquosis" (Sp. Pl. 2: 1516. 1763) and "*Equisetum minus*

terrestre" meaning "Occurrence in European marshland" and less terrestrial respectively, the taxonomic identity of the species has been established. Hence as per description Linnaeus clearly indicates only one species, the plant presently known by his name and therefore it should be the type for the name of *E. palustre* (vide also Hauke, l.c. 1978).

It is pertinent to note here that from the mention of Amman against species *arvense* and *palustre*, it is known (vide Savage, 1945) that the plants were collected by Heinzelmänn in 1736 for Flora Tatarica Orebürgensis from S.E. Russia and a small portion of Siberia. Its catalogue was originally prepared by J. Amman who was Linnaeus's correspondent in Russia and presumably the duplicates of the specimens were sent to Linnaeus by him before 1741 in which year he died. Later through his pupil P. Kalm and diplomat Baron Sten. Bjelke, J.G. Gmelin and Prince Grigorij Demidov, Linnaeus received large collections of Russian specimens, the collection of Steller, Heinzelmänn, Weber, Gmelin, Demidov and others between the year 1744 and 1750. But it seems none of these collections contained truly *E. arvense* or *E. palustre*. Because the specimen in sheet no. 3 in packet 1241 which Linnaeus designated *E. arvense* is also not *E. arvense* actually, but *E. sylvaticum* (vide Hauke, 1978). With sheet no. 3, Linnaeus cited about additional information of the species from Gmelin, but in Flora Siberica of the latter I have found no reference of either *E. arvense*, *E. sylvaticum* or *E. palustre*. So as discussed earlier, the type of the species (*E. palustre*) is to be found from European collections. Linnaeus's Hortus Cliffortianus and Flora Lapponica were published in the same year, 1737, but the former was published later than the latter. So in Hortus Cliffortianus Linnaeus made reference of Flora Lapponica in *E. arvense* and *E. palustre* along with others. Correspondingly, in Flora Lapponica (p. 309), among other references, Linnaeus cited against all *Equisetum* species, Rudbeck's illustration (O.S. Rudbeck and C.C. Rudbeck, Campus Elysium Vol. I, 1702) of the species at respective places. For both *E. arvense* and *E. sylvaticum* Linnaeus referred to Rudbeck's fig. 9 though pagination of the work in two cases have been given differently which appears to be wrong, for *E. palustre* Rudbeck's fig. 3 has been cited. After checking the illustrations, I presume an attempt of the typification of the species can be made.

Icones : Bolton, Fil. Brit. t. 35. 1790; In Fl. Danica 7: t. 1183. 1797; Schukuhr, Crypt. Gewach., t. 169, 170. 1798; Smith, Engl. Bot. 2021. 1810; Bischoff, Crypt. Gewach. t. 3. f. 1, t. 5 f. 46-61. 1828; Newm. Brit. Ferns p. 43, 47, 59, 50. 1844; Milde, Gefäss. Crypt. Schles. t. 36. f. 57, t. 37 f. 61. 1858; Duval-Jouve, Bull. Soc. Bot. Franç., 516 t. 5. 1858; Hooker, Brit. Ferns t. 63. 1861.

Distrib. : The species is distributed both in the Old and New World, generally in the Northern Hemisphere, in Asia, Europe and Northern America. In India, the species is distributed only in Kashmir.

Specimens examined : INDIA: Jammu & Kashmir : Srinagar, V.N. Kaul 012 dt. 6. 1964 (CAL); Dachigam Game Sanctuary, 1650 m, B.M. Wadhwa 66874 dt. 7.9.1979 (BSD); Ganderbal, Sind valley, 1560 m, Ludlow and Sherriff 8165 dt. 12.6.1940 (growing in 2 ft. of water, submerged) (BM); Barpu Glacier, Oblation valley, right bank, Karakoram Mts. (between Kashmir and Sinkiang), 2700-3300 m, R. Scott Russell 1151 dt. 10.7.1939 (BM); Pahlgaon, near the bridge over Liddar river, west bank, from the submerged rock crevices in the river bed, in fast flowing water, A. Datta 58191 & 58192 dt. 26.8.1983 (CAL); Aru valley, 12 km. North of Pahlgaon, in the grassland beside Liddar river situated little above river bed, A. Datta 58206 dt. 28.8.1983 (CAL); Sikkim : Dikeeling, 900 m,

C.B. Clarke 9742 B dt. 22.10.1869 (CAL); South of Gangtok, *Thothathri s.n.* dt. 10.1951 (CAL); Uttar Pradesh : Gugiani, Kumaon, Almora dist., 1200-1500 m, *B.M. Wadhwa* 57650 dt. 15.10.1975 (BSD).

Anatomy : Milde (1867), Duval-Jouve (1864) and Vaucher (1821) have studied the details of the anatomical features of *E. palustre*. Apart from their works, anatomical studies of this species have been done by a number of authors. Of them, Browne (1912) and Barratt (1920) have studied the details of the anatomical features and vascular structures of the cone and fertile stem of *E. palustre*. According to Barratt, the way of the development of xylem in young cone and vegetative axis of *E. palustre* is different from each other. In the latter several protoxylem strands of each internode above and below are subsequently connected by the nodal tracheids. In the cone, however, the protoxylem strands develop uninterruptedly from the base to the apex of the cone; there is no disjunction at the nodes, though some of the strands may terminate at or near the point of insertion of the sporangiophore. Leaf-traces and sporangiophore traces arise into two different ontological manners. Also the differentiation and development of tracheids of the traces of the two organs are different. Browne (1912, 1915, 1920) reached the conclusion after studying the vascular structure of the cone of *Equisetum* species that there is a gradual reduction of vascular system in them in the order as follows: *E. arvense* → *E. hyemale* → *E. palustre* → *E. giganteum* → *E. maximum* → *E. limosum*. But she warned that the order of reduction should not be taken as a phylogenetic sequence. In another work (1920) she considered the phylogenetic affinity among the *Equisetum* species basing upon her observation on their vascular system of the internodes. In her later work (1933) she observed that taking into account the decreasing trend of anastomosis among metaxylem and protoxylem system of vascular bundle of the cone, *E. palustre* remains always somewhat in the middle position of *Equisetum* species complex. Bierhorst (1958b) studied the tracheary elements of the *Equisetum* species. In the internode of the vegetative stem, he found carinal protoxylem elements were all annular and the rings of the annular tracheary elements of carinal protoxylem are thicker in rhizome than in the aerial stem. Vidal (1912) noted the transition from the annular to reticulate thickening in trans-nodal region of protoxylem in *E. palustre*. Bierhorst (1958a) aligned *palustre* with *laevigatum*, *sylvaticum*, *arvense* and *pratense* on the basis of a type of vessel found only in their subterranean stems and in lateral xylem of the internodal bundles.

Gametophytes : Rumberg (1932) and Hurel-Py (1949, 1959) have studied the gametophytes of *E. palustre* along with other species of *Equisetum*. From the study it appears that the gametophytes of the species are bisexual and are strictly male and initially female but the latter in unusual condition can produce male antheridia especially when fertilisation fails to take place. Hurel-Py also states that the gametophytes of the species are bisexual and protogynous. Elaborate single spore axenic culture and gametophyte growth and development and sex expression of the species have been studied by Duckett (1970, 1973, 1979). He agrees with Rumberg in some aspect of growth and development of the gametophyte of *E. palustre* especially in regard to the formation of the flat lamellae of the archegonial branch with round lobes (Duckett, 1973). In regard to early stage of lamellar and archegonial growth and development of the gametophytes, *E. palustre* resembles those of *E. fluviatile*, *E. arvense* and *E. sylvaticum*. In all 4 species the growth of lamellae from archegonial branches consists of filaments 1-4 irregular files of cells joined laterally. Early development of antheridia is also identical in all the species of subgenus *Equisetum* and it is only in final stage of development when spermatogenesis takes place that the specific difference become apparent. *E. palustre* resembles *E. fluviatile* in respect of well developed corona in the antheridia and *E. pratense* and *E. sylvaticum* in opercular cell number and

cavity shape of the antheridia. But in respect of longest antheridia and highest opercular cell number *E. palustre* is grouped with *E. fluviatile* and *E. bogotense*. *E. palustre*, however, is distinct from other species in regard to the pyriform shape of the opercular cells, which comes into being due to the development of a large central papilla after dehiscence. Its antheridial opercular cell number is larger than those of *E. sylvaticum*, *E. telmateia* and *E. arvense*. Further study of Duckett (1979) throws light on the sex expression of the gametophytes of *E. palustre*. The gametophytes were initially female, grown from spores, produced antheridia much more slowly than of *E. arvense* which means that the gametophytes of *E. palustre* have inherent tendency to remain female. It has been seen that even after remaining in culture for one year, a few individuals still retained some branches of the prothallus in their original archegonial condition. Similarly in subculture, the cushion meristem remained female for prolonged time before switching to antheridial production.

Micromorphology : Duval-Jouve (1864) and Milde (1867) studied the silica deposition pattern in the stomatal cell areas of the species. Recently Page (1972, 1974) has made SEM studies of the ultrastructure of the stomata and stomatal cell areas: the silica mamillae and the pilulae arrangement and ornamentation. It is found that the silica ornamentation in *E. palustre* varies directly with the geographical distribution of the species. Because it is marked that the typical *E. palustre* (var. *palustre*) occurring in China is markedly different in silica ornamentation from the same occurring in Western Europe. Similarly, the Chinese material of var. *palustre* differs less from *E. telmateia* complex but differs from *palustre* material from the West European part of its range. On the other hand var. *szechuanense* of the latter differs significantly and consistently in its micromorphology from var. *palustre* as stated by him (1974) and the Chinese material of the former variety is virtually indistinguishable from those of *E. telmateia*. But elsewhere in the same work (1974) Page observed *E. palustre* var. *palustre* and var. *szechuanense* were themselves clearly closely interrelated in the Western China area both in overall structure and micromorphology. According to Hauke (1978) the pattern of mamillae arrangement in typical *E. palustre* is not different from that of var. *szechuanense*. So he has not recognised the variety. Hauke (1978) adopting a new simple non-SEM technique studied the silica micromorphology of stomatal cell area of *E. arvense*, *E. pratense* and *E. palustre*, where the transversely aligned confluent mamillae scattered over the stomata of the latter though not as sharp as SEM resolution, can be well identified.

Cytology : Like other Equisetums, *E. palustre* has also the diploid number of chromosome, $2n = 216$ and haploid number, $n = 108$ (Manton, 1950, Chiarugi 1960; Löve and Löve, 1973).

Ecology : Holub (1972) briefly gives an account of ecology and plant association of *E. palustre* in Europe. The species has great adaptability for different ecological conditions and occurs as geophyte, mesophyte and hydrophyte from north of Poland to Afghanistan through Eurasian land mass at different elevations. The species forms an association with *Carex fusca*, *C. davalliana*, *Molinia* and *Phragmites* species. I have seen it occurring in the river valley of Kashmir at Pahalgam, in the river bed of Liddar in submerged and under water condition and also at rock crevices besides river bed, at Aru valley, occurring with *Pteridium aquilinum* near river bed rocks and in a meadow over Liddar river with grass, weeds and herbs.

Chemistry : The species yields a number of chemicals, the main constituents of which are alkaloids, namely Palustrine ($C_{17}H_{31}N_3O_2$) and Palustridine ($C_{18}H_{31}N_3O_3$). Details of other chemical

constituents isolated from the species are given by Raffaui (1970), Geissman and Heinreiner (1952) and Hegnauer (1962).

Hybridity : The species forms three intra subgeneric hybrids: *Equisetum* × *rothmaleri*. C.N. Page with *E. arvense* reported by Page from Isle of Skye, Scotland (1973), *Equisetum* × *font-queri* Rothm. (previously named as *E. × torgesianum* Rothm. (Rothmaler, 1944) with *E. telmateia* (1973) from the same place and the unnamed hybrid, *E. fluviatile* × *E. palustre* Page from Hebrides (1963). Recently, however, Page named the hybrid (1981) as *Equisetum* × *dycei* Page. The only inter subgeneric hybrid between *E. palustre* (subg. *Equisetum*) and *E. variegatum* (subg. *Hippochaete*) is reported by Duckett and Page from Switzerland (1975) but its existence is doubtful. Because inter subgeneric hybrids in *Equisetum* are very rare or almost absent (Duckett, 1979).

Toxicity : The species is reported to be highly toxic to the grazing cattle, horses and sheeps, causing equisetosis or Equisetum-poisoning due to its chemical content aconitic acid, palustrine (alkaloids), equisetonin (saponin) and high silica content (ca 25.3%) (Rapp., 1954; Muenscher, 1951; Ballard, 1966; Timell, 1964).

Mineral indication : *Equisetum* species particularly, *E. arvense* and *E. palustre* are well known as mineral indicators. They can accumulate gold from the soil in their plant body. That is why, it is generally believed that their occurrence in an area indicates its underground gold-deposit. *E. palustre* has been reported as having high gold-accumulating capacity as Ward and Brooks (1978) quoted Nemec & al. (1936) who reported an extraordinary high gold content (610 µg/gm, ppm) in the ash of *E. palustre*.

Discussion : Page (1972) on the basis of micromorphological characters of the species of the subgenus *Equisetum* classified them into 3 sections, 2 of which he created new: section *Equisetum* sect. nov. in which he put *E. fluviatile* and *E. arvense* and section. *Palustria* sect. nov. in which he included *E. bogotense*, *E. palustre*, *E. diffusum* and *E. telmateia*. The other two species *E. pratense* and *E. sylvaticum* remained in the section *Subvernalina* A. Br. as such. In regard to the new section *Palustria*, according to the author, *E. bogotense*, *E. diffusum* *E. palustre* are particularly similar to one another in most characters of mamillae and pilulae. Page found the American material of *E. telmateia* and those of *E. palustre* were so similar micromorphologically that they were virtually indistinguishable. Similarly in his work on Sino-Himalayan materials of *Equisetum* (1974) he found the Chinese material of *E. palustre* var. *szechuanense* as virtually indistinguishable from those of *E. telmateia*. Of the *E. bogotense*, *E. diffusum*, *E. palustre*, *E. telmateia* species complex. *E. palustre* links all other species morphologically and is widespread rather than the restricted geographical range of other members. It also shares micromorphological characters of the co-species under this section. So Page argued that in the light of new information on surface micromorphology, the traditional sectional classification of the subg. *Equisetum* based on cone-shoot morphology should be replaced by his new classification based on silica micromorphology. But Duckett (1979) on the basis of gametophyte and antheridial morphology of the species of subgenus *Equisetum*, support its traditional taxonomy and classification. Duckett (l.c.) reviews Page's classification also in the light of intra subgeneric hybridization. The retention of the section, *Subvernalina* A. Br. by Page has been justified according to Duckett as there is successful synthesis of hybrids between the two constituent species of this section proving that they are sexually compatible to each other and so very close

together. But Page's grouping of *E. fluviatile* and *E. arvense* in a redefined section *Equisetum* and of *E. palustre*, *E. telmateia*, *E. diffusum* and *E. bogotense* in a new section *Palustria* are not justified as because the production of successful synthetic hybrid between the two of the group of these species are not frequent. In this regard *E. arvense*, *E. fluviatile* and *E. palustre* form a closely linked complex whereas *E. telmateia* is distantly related to them.

Equisetum subg. *Equisetum* sect. *Heterophyadica* A. Br. emend. Hauke, Nova Hedwig. 30. 415.
1978. *Equisetum* sect. *Heterophyadica* A. Br. Flora 22: 307. 1839.

Basionym : Hauke has emended Braun's *Heterophyadica* because it contains elements of both the sections, section *Equisetum* and *Heterophyadica*. Braun (1839) built his group *Heterophyadica* with two subgroups: A. Ametabola (*Equiseta vernalia*) containing *E. arvense* and *E. telmateia* and B. Metabola (*Equiseta subvernalia*) containing *E. pratense* and *E. sylvaticum*. *E. telmateia* is an element of section *Equisetum* which Hauke (1978) has discarded from Braun's *Heterophyadica* and thus emended it. Holub (1972) however, kept *E. telmateia* under the section, *Heterophyadica*.

Etymology : The word "Heterophyadica" means different (Hetero) or unlike or dissimilar forms of stems (Phyadica). It is applied upon a group of plants whose fertile stems are of different form from those of the barren stems.

Type : *Equisetum arvense* L. selected by Rothmaler (1944).

Distrib. : Of the three species under sect. *Heterophyadica*, *E. arvense* is the most common, widespread and ubiquitous species in the Northern Hemisphere. It is distributed from 80°N lat. to about 30°N lat. *E. pratense* and *E. sylvaticum* are restricted to 40-50°N lat. and 70°N lat. and the two are distributed only in Western Hemisphere. *E. arvense* is wide spread in both the New and Old World of Western and Eastern Himalaya.

The section is represented in India by only one species *E. arvense* L.

6. *Equisetum arvense* L., Sp. Pl. 1061. 1753.

Synonym : Milde (1867a, b), Vaucher (1821) and Duval-Jouve (1864) reported a large number of synonyms. Hauke (1967) records a list of synonyms. In his monograph of the subg. *Equisetum* (1978) he, however, mentions only three, two of which are more recently built viz. *E. boreale* Bong., *E. saxicola* Suksdorf and *E. calderi* Boivin. The last one however, has recently been found to be a hybrid of the putative parents, *E. arvense* and *E. pratense* (Duckett, 1979).

Taxonomy : *E. arvense* is probably the most worked-out species in the genus *Equisetum*. One of its remarkable features studied by a large number of authors is its forms to look so different in gross appearance without really being different. In the past many authors could not realise that these forms were actually morphological variations. The extent to which some authors have gone in describing infraspecific taxa of the species is remarkable. Hauke (1967) mentioned of Klinge who assorted these various forms of *E. arvense* into 6 level of subdivisions. Hauke (*l.c.*) has made further mention of Schmidt, Junge and Gandoger who listed 34, 57 and 62 forms and 11 and 12 monstrosities respectively. Hauke (*l.c.*), asserts "I have not waded through this morass of nomenclature to eliminate

invalid taxa but I estimate that there are probably over two hundred properly published infraspecific names in *E. arvense*".

Actually, as Duval-Jouve hinted, all these infraspecific taxa and segregate species based on seasonal and ecological variations, trivial morphological variations such as branch angle (3 or 4-angled), intermediacy of fertile and sterile stems and monstrosities or teratological malformations, therefore, are discounted. After their de-recognition, there remains no variety nor any infra-varietal taxon of *E. arvense*.

General morphology : Stem heterophyadic or dimorphic; vegetative stems are morphologically unlike the fertile stems which bear cones or the reproductive organs. Vegetative stems are 2-100 cm tall, 0.8-5.0 cm in diam., internodes 1.2-4.5 cm long, sheath almost square, 1-9 mm long, 1-8 mm wide with short (1-4 mm long) narrow dark teeth often remain attached in pairs. Sheath segments often with slight central groove. The stomata are in bands on each side of the valley and a mass of collenchyma tissue are found under both ridges and valleys. Branching is very regular from the middle and upper nodes. Branch ridge number is 3-4. The cone-bearing coniferous stems are precocious, non-photosynthetic (without chlorophyll unlike vegetative stems) and unbranched. They appear succulent and nodal sheaths are enlarged. The coniferous stems die back when spores are shed. But in exceptional cases it has been seen that occasionally coniferous stems persist and become unbranched, so also the vegetative stems occasionally produce cones. The aerial stem is richly branched and the stem and branches are centrally hollow. Rhizome system is elaborate and grow horizontally with profuse branching deep under the surface sometime below 6-7 feet the surface of the soil. The cone bearing fertile branch develops from the rhizome in autumn and subsequently appears during winter or spring.

Type : Linnaeus coll. Packet 1241 sheet No. 4 (LINN). Hauke (1966, 1978) has designated the specimen as the type and concludes that sheet no. 3 of the same packet 1241 pinned and labelled by Linnaeus himself as *E. arvense* is wrongly made and is actually *E. sylvaticum*. I have seen the microfiche of Linnaeus 1241.4 as the type of *E. arvense* and agree with him. Actually Linnaeus suffered a confusion in identifying the real species from among the three: *E. arvense*, *E. palustre* and *E. sylvaticum*. This confusion is evidently portrayed in Sagave Catalogue (1945). In sheet no. 3 which bears misidentified *E. arvense* is written "[+ addit. Gmel.] [Sm.]? pinned to sheet no. 4" which means that the specimen which was sent by Amman from Russia was originally designated by Linnaeus as *E. arvense* but when an additional specimen of the same species was sent from the same country later by J.G. Gmelin, it was mentioned under *E. arvense* but was pinned to sheet no. 4 which remained unidentified. This clearly shows Linnaeus's confusion about the identity of the species.

The type designated is a specimen *Loefler* 713 from Spain, Linnaeus kept in sheet no. 4 of his packet 1241.

Icones : Schkuhr in Linné's Pflanzensys. Kryptogamische Gewächse 1: 1809. t. 167. f. a-j; Vaucher in Monogr. Prêles 1822, t. 1, f. 1, 2, 3, 4, 5 & 6. p. 392; Milde in Monogr. Equiset., Nova Acta Caes. Leop. Carol. 32(2): 219-1867. t. I, II & III, f. 1-24, 25-38 & 39-46 and in Martius Fl. Brasil 1(2): 1872 t. 71 f. 1-4, 18; Makino, J. in Illustr. Fl. Japan t. 2924 p. 975. 1887-91; Fl. Dan. 11: t. 1942. 1829; Roles, S. J. in Brit. Fl. Illustr. 1, t. 19. 1957.

Distri. : The species is distributed throughout Canada and the United States except its southeastern States. In the Old World, it is distributed throughout Europe. In Asia, its occurrence is reported from South of Turkey, Iran, the Himalayas covering Northern India, Nepal, Bhutan, China excluding its southern part, Korea and Japan. Pichi Sermolli shows that the species is not found in two regions: Sahara-Arabian and Macronesian region (1979), but distributed in northwestern Europe and Alaska and of circumpolar regions of the world (Hulten, 1950 and 1963).

Specimens examined : INDIA: Jammu & Kashmir : Srinagar, W. Gilton 9127 dt. 12.10.1889 (DD); Janbotha, N.W. Frontier, Capt. Harris 16894 dt. 5.5.1895 and Chitral, Bundai, Capt. Harris 16892 dt. 5.5.1895 (DD); Zearat, Chitral, N.W. Frontier, Capt. Harris 16893 dt. 13.6.1895 (DD, CAL); Kagan valley, Hazara, 900 ft., Inayat 20445 dt. 24.5.1896 (DD); Nila, Kagan valley, Hazara, Inayat s.n. dt. 22.7.1899 (DD, CAL), Marel, Baltistan, N.W. Himalaya, 9-10,000 ft., A. Meebold 526 dt. 8. 1905 (CAL); Kishen-Ganga valley and road to Nanga Parbat, R.R. Stewart and I.D. Stewart 18525 dt. 14.8.1939 (CAL); Kula Pam, Gilgit, 10,500 ft., G.M. Giles 123 dt. 1805 (CAL); Kalarus forest, Pohru basin, Jhelum valley, 6500 ft., Kesavanand 572, dt. 6.10.1906 (DD); Thajwas mountain, Glacier area, near Sonmarg, T.A. Rao 9562 dt. 18.6.1959 (CAL, BSD), Sonmarg, 2800 m, M.A. Rau 50219 dt. 24.8.1972 (BSD); Desu Rakh, T.A. Rao 9803 dt. 1.7.1959 (BSD); Yarikshah, 2500 m, T.A. Rao 21 & 89 no date (BSD); Sankoo, Ladakh, 3100-3300 m, B.M. Wadhwa 59855 dt. 33.8.1976 (BSD). Himachal Pradesh : Sanch valley, Pangl, Chamba, 8500 ft., Harsukh s.n. dt. 9.8.1899 (DD, CAL); Simla, N.W. Himalaya, 8500 ft., K.N. Druar 1080 dt. 10.5.1881 (CAL); Herb. Schlangintweit from Indian and high Asia, Koksar to Kardong, Lahol, Gen. Cat. No. 4146 dt. 11.12.1856 (CAL); Chhot, Garang, Bashahr Himalaya, 8000 ft., J.H. Lace 937 dt. 16.6.1881 (BSIM); Chhatru, Lahul, N.C. Nair 16589 dt. 3.9.1961 (BSD); Thumla, Spiti, 4200 m, U.C. Bhattacharyya 49191 dt. 1.8.1970 (BSD); Sissoo, Lahul, 2000 m, U.C. Bhattacharyya 40688 dt. 8.8.1970 (BSD); Between Kilar and Dharwas, Pangl, Chamba dist., 2800 m, N.C. Nair 32732 dt. 21.7.1964 (BSD); Sissoo, Lahul, 10500-11000 ft., S.P. Sethi & R.P. Negi 183 dt. 6.6.1958 (DD); Koksar, Lahul, 10500 ft., N.L. Bor 14582 dt. 1.6.1941 (DD). Uttar Pradesh : Bogdwar-Martoli, Kumaon, 300-4500 m, T.A. Rao 6822 dt. 14.6.1958 (BSD); Simlasu, Tehri dist., 700 m, A.K. Goel 64689 dt. 18.2.1979 (BSD); Harke Dun, Tehri Garhwal, B.B. Osmaston s.n. dt. 6. 1897 (DD); Harke Dun, Tehri Garhwal, 11000 ft., W.C.G. Rogers s. n. no date (DD); Badrinath near river bank in field near Mana village, L.D. Kapoor and party 70279/D (LWG); Vingkar range, Kumaon, 12-13000 ft., J.F. Duthie 11069 dt. 19.5.1892 (DD); Bireti forest, Phulal Dara, Tehri Garhwal, 11000-12000 ft., J.F. Duthie 378 dt. 18.8.1893 (DD). Punjab : Muree Hill, Punjab Agricultural college, Lyallpur, Rawal Chand s.n. dt. 20.4.1932 (CAL); Pathankot, P. Chandra & party 71621 dt. 26.6.1963 (LWG). West Bengal : Darjeeling, Herb. G Watt 14338 dt. 1900 (BSIM).

Anatomy : Milde (1867), Duval-Jouve (1864) and Vaucher (1821) have studied in detail the anatomical features of *E. arvense*. Milde illustrated tissue system in transverse sections of sterile and fertile stem and Duval-Jouve's illustration of anatomical features of the species deserve mention. Both the authors have shown the silica ornamentation of the stomatal and internodal structure though they appear to be not that much correct. Anatomical studies of this species have been done by a number of authors. Browne (1912, 1915, 1920, 1933) and Barratt (1920) studied anatomical features of the species. Golub and Wetmore (1948a, b) have studied the vascular structure of *E. arvense* in relation to the development of its vegetative shoot system. In the two works, the author have described in detail the growth and development of shoot system from apical meristem and primordial leaf sheath to the initiation and development and course of the protophloem, metaphloem, protoxylem and metaxylem. The initiation and function of the intercalary meristem and its effect on the organisation of the mature

tissue of the plant has been described. The variation of the number and position of their corresponding 'leaves' have been studied and the explanation has been furnished in terms of the loss or addition of one or more procambial strands. The reports of the previous workers regarding origin of lateral branches have been confirmed and the origin and development of vascular supply of the lateral branches from the parent axis has been described. The internodal vascular strand on the basis of unitary nature of procambial strands, the unitary nature and course of phloem and the order of differentiation of the protoxylem and metaxylem have been interpreted as single integral vascular strands and the nodal vascular strands have been shown to be devoid of any cambium. In *E. arvense*, leaf trace tracheids have spiral and annular thickenings and in transnodal protoxylem of the species, the presence of spiral and spiral-reticulate thickenings have been observed.

Bierhorst (1958a) studied the vessel of *Equisetum* and marked two types of vessels in this genus. The first type is common to all the species including *E. arvense*. It is at most 2-celled long and occur above and below nodes connecting the nodal metaxylem and the carinal canals or the median protoxylem lacunae of the internodes. At the upper and lower end of carinal canals, isodiametric cells differentiate with thick secondary walls in the form of a much open reticulum as described by Baratt (1920) and others. These abut directly on the nodal metaxylem elements as well as the internodal inner protoxylem elements. Some of them form large and conspicuous elements and internodal carinal protoxylem. In the second type of vessel which is seen in *E. pratense*, insufficient number of critical sections of end walls was seen. The perforation plates were quite elusive and could be identified only by critical examination. Those type of vessels were found only in subterranean stems and lateral groups of xylem of the internodal bundles. In his other observation of tracheary elements of *Equisetum*, Bierhorst (1958b) marked that internal thickenings of carinal protoxylem elements of *E. arvense* along with many other *Equisetum* species were all annular without exception and agreed with Hofmeister (1862) and Vidal (1912) but disagreed with Goebel (1887), Golub and Wetmore (1948) and Johnson (1933) who reported the presence of helical thickenings in them. The structure of annular thickenings, however, vary in structure within species. Trans-nodal protoxylem in *E. arvense* along with other major species of *Equisetum* which are structurally composed of elements that are similar to those of protoxylem elements of the leaf-trace are somewhat reticulate than occasional helical or annular, whereas in lateral xylem of the internodal bundles of *E. arvense* along with *E. palustre* and *E. pratense*, thickenings are annular in part and helical in part according to the author.

Foster and Gifford (1959) and Bold (1978) have presented the overall anatomical features of the species derived from contemporary works on the species.

Gametophytes : The gametophytes of *E. arvense* have been studied by a large number of authors. It is known that the prothalli of *E. arvense* occurring in the wild are extremely few and are only from their habitats which are damp, recently explored and free, at least initially from much competitions (Page, 1967 and Hauke, 1967) of the naturally occurring population of gametophytes of *E. arvense*. Scharz (1928) who made conclusion on the occurrence of wild *E. arvense* gametophytes recorded that the prothallia of *E. arvense* when grown under unfavourable conditions resulted in most of them becoming male plants. Of the earlier workers, Duval-Jouve (1864), Hofmeister (1862), Buchtien (1887), Jeffrey (1899), Sadebeck (1900), Ludwigs (1911), Mäkel (1924) and Walker (1931) studied the growth and development of various gametophyte organ components of *E. arvense*. Of them Mäkel (*l.c.*) and Scharz (*l.c.*) described the gametophytes of the species as male or female initially but also

found that old female gametophytes regularly produced antheridia. Bischoff (1853), Hofmeister (*l.c.*), Buchtien (*l.c.*), Jeffrey (*l.c.*) and Sadebeck (*l.c.*) and others described the gametophytes were strictly dioecious and noted that under unfavourable conditions (*e.g.* low light, nutrient deficiency, draught and crowding) only male gametophytes were produced and old female gametophytes occasionally produced antheridia. Schartz found that even under favourable conditions over 50 percent of the gametophytes of *E. arvense* were still male and these could not be induced to form archegonia. Walker (1931) observed that the antheridia of *E. arvense* protruded from the surface of the thallus more than did other species. The author also detected that the first formed gametophytes were archegonia and then masses of antheridia were formed in the upturned extensions of the main axis of meristem.

Many authors studied the gametophytes of *E. arvense* by growing them axenically on chemically defined media. Castle (1953) grew gametophytes of *E. arvense* under axenic conditions and presumed, like Walker, that archegonia were produced after the antheridia but never saw them.

Other reports on *E. arvense* gametophytes in axenic culture (Wollersheim, 1957; Hurel-Py, 1949, 1958, 1959; La Roche 1967) state that these are initially either male or female. The females all developed antheridia later but only Wollersheim reported male gametophytes later producing archegonia.

Duckett (1970) grew gametophytes of *E. arvense* in Beijerinck agar and observed that a minority of the gametophytes from all populations produced archegonia initially but all developed antheridia later. It was further observed that the gametophytes destined to become female were larger, more vigorous and tended to remain longer in a vegetative state and produced much broader cushion and many more lamellae than those becoming male.

Duckett (1973) confirmed Walker's observation of marked antheridial protrusion from the surface of the thallus and observed that the antheridial cavity might be up to three times as long as wide and regarding the archegonial development, defended La Roche's (1967) observations. He only found that the terminal neck cells were usually pointed and that subterminal neck cells were slightly elongated in *E. arvense*.

In 1977, Duckett observed that subcultured female branches of gametophytes always produced antheridia as did intact female gametophytes. What he found in intact females, was that 50 per cent of female gametophytes produced some antheridia after 115 days and after 220 days every single individual was bisexual and after 260 days every single archegonial branch had switched over to antheridial production.

Hauke (1971) tested the effect of the light quality and intensity on sex expression of *E. arvense*, *E. hyemale* and *E. fluviatile* gametophytes. *E. arvense* developed a significantly higher number of male gametophytes under higher intensity of light of all qualities. He found that under 20,000-40,000 erg/cm²/sec intensity of white, blue and red light 86-95 per cent male gametophytes were produced. In a similar experiment Hauke (1977) found that spores in culture media required light in varying day-length for germination and growth of gametophytes. For significant growth of male gametophytes of *E. arvense* longer day-length was found necessary. So longer day-length and higher intensity of light

are the two factors inducing more male sexuality of *E. arvense*. Hauke further found that red-far red system had no effect on the sex expression of either of the above-noted two species but application of blue light-dark period-white light appeared to have effect on sex determination of *E. arvense* gametophytes. It was further noted that sucrose enrichment of the culture medium decreased the percentage of males in *E. arvense* but it had no effect on isolated culture. On the other hand glucose enrichment of the medium increased the number of male gametophytes of the species, so also the dilution of the medium had similar effect which was indicated by La Roche (1967).

Ultrastructure of spore : Olson and Gullvåg (1973) studied microbodies of *E. arvense* spore cells which consist of organelle peroxysomes, the dominant type of microbody necessary for photorespiration and glyoxysomes containing enzymes peroxidase concerned with glyoxylate-cycle. These two organelles which are morphologically similar although biochemically different, have a few common characteristics.

Micromorphology : Silica micromorphology of stomatal structure and adjacent stem internode of *E. arvense* have been studied by La Roche (1967, 1968, 1969, 1973), Kaufman & al. (1971) and Page (1972, 1974) using Scanning Electron Microscopy (S.E.M.) techniques and by Hauke (1978) following his own non-instrumental method.

In *E. arvense* Kaufman & al., observed that entire outer or paradermal surface of the epidermis was covered by small papillae or knobs and the cluster of knobs were designated silica rosettes. The silica rosettes are spaced more or less equidistantly in a ring surrounding each stomatal apparatus. The stomatal aperture consists of a slit, the margins or lips of which are bordered by distinct papillae-like teeth. La Roche discovered silica ornamentation of the epidermal surface of the species in a helical pattern with groups of silica pustules and observed similar arrangement of pustules along the slit margin or lips of stomatal aperture that Kaufman & al. later recorded. Page (1972) observed silica deposition called mammillae of moderate size scattered loosely within the branch furrow showing a weak tendency towards longitudinal or transverse alignment. In stomatal cell areas arrangement of mammillae and pilulae were nearly identical with that of *E. fluviatile* on the basis of which Page erected new section *Equisetum* nov with these two species. In later years, however, Page (*l.c.* 1974) found close alignment of Sino-Himalayan *E. arvense* with endemic *E. diffusum* in respect of the presence of a more distinctive peripheral row of pilulae to the stomatal cell areas and pilulae adjacent to the stomatal aperture having greater length in both the two taxa.

Cytology : Chromosomal count of *E. arvense* like all other species of the genus is the same as has been discussed separately $2n = 216$ and $n = 108$.

Ecology : The species has a wide adaptability to various ecological conditions. The habitat varies from wet meadows, arable land or cultivated field to arid area under xeric condition (Hauke, 1966). Mann (1939) has shown that root system of *E. arvense* can penetrate soil upto 5 feet, characteristic morphological feature of xeric habit. It is seen occurring in mountain valleys as well as in the plains. It occurs in both swampy areas, marshlands near ditches and river banks, as well as in open fields, on road sides and railroad embankments. It thrives well both in cooler climate in hill crests and in comparatively drier and warmer climate of the plains- under shade as well as in the open. Schelpe (1954) has studied the habitat of *E. arvense* in Pine-Spruce-Fir-Silver birch and Rhododendron-Juniperus zones of Kangra Himalayas (North-West Himalaya).

Chemistry : Many chemical constituents have been reported from *E. arvense*. These include a number of secondary metabolites as flavonoids, phenolics, saponins, alkaloids, fatty acids and oils. In addition, according to recent reports (The flavonoids, Advances in research ed. J.B. Harbourne & T.J. Mabry, Chapman and Hall, 1982, p. 351-358, 366, 373-377). *E. arvense* is reported to contain a flavonoid *Naringenin* (5, 7, 4' -trihydroxy flavonone) and a dihydroflavonol, *Aromadendrin* (5, 7, 4' trihydroxydihydroflavonol).

Hybridity : *E. arvense* hybridizes with five species of subg. *Equisetum*: with *E. fluviatile* (hybrid: *E. × litorale* Kühlew) with *E. palustre* (hybrid: *E. × rothmaleri* C.N. Page) with *E. pratense* (hybrid: *E. × suecicum* Rothm.), with *E. telmateia* (hybrid: *E. × dubium* Dostal) and with *E. diffusum* (hybrid: *E. × wallichianum* C.N. Page).

These hybrids are found occurring in wild condition and also can be synthesized by artificial means excepting cross between *E. pratense* and *E. arvense*.

For hybrids *E. × dubium*, *E. arvense* is a female parent, for *E. × rothmaleri*, *E. × litorale* and other species *E. arvense* is a male member of the two putative parents. Due to genetic conspecificity dominant in *E. arvense*, it is also observed that intraspecific hybridization between two population of the species from two different areas (North America and England) also occurs (Duckett, 1979).

Teratology : Occurrence of abnormal cones in *E. arvense* has been reported by Webster in the American population of the species (1973). The abnormal strobili show extensive lateral infusion of sporangiophores and in extreme cases, fusion becomes so compact or close that they form one or two complete circles around the cone axis.

Toxicity and Uses : Burkill (1935), Uphof (1959) and Wren (1932) mention of its medicinal uses in China, Malaya and Europe. Rapp (1954), Barton and Castle (1897), Muenscher (1951, 1955) and Ballard (1966) have reported its toxicity as a cattle feed but Lawson (1866) recommended it as a good cattle fodder. Corner (1977) also reported no ill effect of it when taken by the grazing cattle. The strobili of the species are eaten by the Japanese. Its expressed juice and extract are reported to be antimicrobial and insecticidal (Nickell, 1959; Heal & al. 1950).

Mineral Indication : The species is reported to be an excellent gold indicator. Benedict (1941) and Turrill (1963) state, the species has a special acquisitiveness for gold in solution and can accumulate in its tissue about 4½ oz. gold per ton whenever this metal is present in the soil, on which it grows.

Discussion : *E. arvense* is the most common and widespread species of the genus *Equisetum*. It is found circumboreally, covering both the Old and New World. It has enormous variations in morphological forms from country to country which led many taxonomists in the past to built its many varieties, forms and even to segregate new species from it.

But in Sino-Himalayan region, as Page (1974) states that *E. arvense*, *E. palustre* and *E. diffusum* show markedly a general tendency towards some morphological features common to one another such as more diffuse overall growth habit, markedly longer branches etc. which are not seen in these species generally occurring elsewhere. One of the reasons of this, as Page states is that Sino-Himalayn area is one of the "Coming-together of several distinct taxa with widespread hybridization and introgression resulting in a local blending of species characters".

Relevantly, *E. arvense* of all the species of subg. *Equisetum* hybridizes with maximum number of species. Duckett (1979) has recorded the wild interspecific hybrids of *E. arvense* and these species reported by various authors. The occurrence of these wild hybrids are found in Europe and North America except *E. × wallichianum*, the hybrid of putative parents, *E. arvense* and *E. diffusum* reported from Western Himalaya (Uttar Pradesh, India) by Page.

Page (1973), however, has discussed in detail the original discovery of the putative hybrid of *E. arvense* and *E. palustre* which was first described by Rothmaler, as *E. × torgesianum* Rothm. (Rothmaler, 1944).

In 1983 during August-September this author collected some specimens in Kashmir which appear to be the said hybrid taxon. The morphological features of the collected specimens have been examined and the long branchless terminal portion to the stem, ascending pattern of the branches, gradually tapering outline of the upper part of the shoot, black-tipped teeth on branch sheath and small vallecular and central canals and single common endodermis resembles *E. palustre*. On the other hand, it resembles *E. arvense* in having longest branches typically near the middle of the shoot, first internode of the branch being as long as or longer than the adjacent stem-sheath, branches with prominent acute ridges, separated by deep furrows and spreading teeth to the branch sheaths.

But the specimens collected have not been in fertile state. So the reported monomorphic habit of the hybrid, external morphology of small ovoid cones, spore character, etc. could not be verified. In England, as Page reported the hybrid bears mature cone in July but in Kashmir in August-September, this author came across no plant of the species particularly of subg. *Equisetum* in fertile state.

Equisetum × wallichianum C.N. Page, Fern Gaz. 11(1): 34-36. 1974. Putative hybrid of *E. arvense* L. × *E. diffusum* D. Don in wild condition.

Synonym : "*Equisetum scoparium*" Wallich *nom. nud.* Wallich in List of Plants No. 398. p. 13. 1828.

Taxonomy : The hybrid in apparent morphological features appear to be *E. diffusum*. So *E. scoparium* Wall. was quoted always by Milde (1867a, b) as synonymous to *E. diffusum* D. Don. But by the detailed study of the type specimens (Bourne and Wallich collections from China and Nepal) and of the recent collection of M.A. Rau from Grohna, Garhwal, Page (1974) confirms that it is a hybrid between *E. arvense* and *E. diffusum*, which are abundantly growing in Western Himalaya in close proximity to each other.

General morphology : Vegetative shoots diffuse, thin and weak; stems 20-25 cm or more, 1-2 mm in diam., green, annual; furrows 4-6 or more, shallow, rounded; ridges usually truncated, smooth; sheath with teeth 4.5-7.0 mm; free teeth half to half length of sheaths, narrow, acute, greenish or black, each sheath segment shallowly 2-ribbed. Branches abundant throughout middle 2/3! of shoot, 8-12 cm, spreading to suberect in ± regular whorls, simple, the lowest internode 1½-2 times the length of adjacent stem sheath, internodes mostly 4-angled, the furrows broad, shallowly V-shaped, each often with a very shallow central channel interrupting the distribution of the stomata across the furrow, the ridges acute but often truncated by a narrow flat top with a shallow length wise groove, branch sheath pale, 1.5-2.0 mm, free teeth, about 1/3-1/2 length of sheath in size, triangular, acuminate,

spreading, usually green throughout, each segment usually minutely 2-ribbed to about half-way along each free tooth, the ribs often with minutely dentate-serrulate tubercles. Rhizomes with rust brown tomentum.

Types : *Holotype*: Com. F.S.A. Bourne s.n., from Chung-Ching, Western Szechuan recd. 1/1886 (K, designated by Page as holotype, not seen) *Paratypes*: *Equisetum scoparium* Wallich 398, E. India, without detailed locality but probably from Nepal (K, Photo!); Grohna, along lake margin, Garhwal, N.W. Himalaya, India, M.A. Rau 10070, dt. June 1959 (K, BSD !).

Distrib. : Garhwal in North Western Himalaya in India, probably in Western Szechuan, Eastern Himalaya, in China and Nepal.

The hybrid thus present in those areas where both the two parents species *E. arvense* and *E. diffusum* overlap and so there is sure probability of higher frequency of wild cross between the two in nature. Page (1974) has pointed out that areas such as Garhwal and Punjab where both parents are abundant are the places of the occurrence of the hybrid and spread-over.

Micromorphology : Page (1974) has made SEM studies of the micromorphology structure of the hybrid along with those of the parent species. The ultrastructure studies show the distinct intermediacy of the hybrid between the two parent species:

<i>E. arvense</i> L.	×	<i>E. diffusum</i> D. Don	=	<i>E. × wallichianum</i> Page
1. Conical mamillae free and scattered in stomatal cell areas.		1. Relatively low conical mamillae transversely aligned and partly fused, sometimes irregularly scattered.		1. Conical mamillae free weakly transversely aligned.
2. Stomatal cell areas with inclined apertures, having elongate pilulae adjacent to the pore and around outer periphery.		2. Stomatal cell areas with either flat-profile or with rather high convex profile with exceptionally elongate pilulae adjacent to the pore.		2. Stomatal cell areas with flat profile with many closely set low pilulae.

Gametophyte : Nothing is known as yet. Hauke (1978) states that almost all hybrid species have abortive spores which means they are sexually sterile. However the hybrid species can produce vegetatively.

Discussion : *E. × wallichianum* named after Nathaniel Wallich is distinctly intermediate in morphology between the two parent species. The hybrid resembles *E. arvense* in respect of broad furrow, to the branch internode with a shallow lengthwise central longitudinal channel separating the stomata on either flank, narrow acute ridges between the angles and branch sheaths with spreading teeth. On the other hand, it resembles *E. diffusum* in having truncated or biangulate ridges to the branch internodes and 2-ribbed segments to the branch and main stem-sheaths.

The hybrid retains its own characteristic morphological features which differ from those of both the parent species, namely: the combination of truncated branch ridges and branch furrows with a central channel and broad V-shaped branch internode furrows with central channel.

Page (*l.c.*) confirms the determination of the hybrid on the basis of direct morphological intermediacy of *E. × wallichianum* between local material of *E. arvense* and *E. diffusum*, the presence of hybrid in areas where both parent species overlap for instance in Garhwal Himalayas or more widely in North Western Himalaya. These observations leave little doubt that *E. × wallichianum* is the hybrid between them.

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भारत में इक्विसेटेसी कुल

अनुकुल दत्त

भारतीय वनस्पति सर्वेक्षण, हावड़ा

सार-संक्षेप

इक्विसेटेसी - इस युनिजेनेरिक कुल के एकमात्र उपलब्ध जीनस इक्विसेटुम एल. की संसार में पन्द्रह जातियों एवं सत्रह संकर में भारत में छः जातियाँ एक इंटर-स्पेसिफिक संकर हैं। इस कुल के शोध पत्र में ऐतिहासिक टिप्पणियाँ, सबजेनेरिक से जाति स्तर तक सार वृत्त (key), टैक्सा की सामान्य आकार की, उनकी प्रसूय प्रशस्ति, विश्व एवं भारत में व्याप्ति, अन्तः रचना पर चर्चा एवं टिप्पणियाँ, कोशिका विज्ञान, गेमेटोफाइट, अणु आकार की, पारिस्थितिकी, रसायन शास्त्र एवं उपयोग दिए गए हैं।