



## Discussion

## DISCUSSIONS

The Alismatidae classically known as Helobiae have been considered to be the most archaic group of Liliopsida because of polymery of the flowers, which have little or no fusion. Family Alismataceae is further considered to be the most primitive monocot family ( Takhtajan, 1980; Dahlgren, 1980; Cronquist, 1981 ). Being a most primitive group of monocotyledons, the members of Alismatidae in general and family Alismataceae in particular have received considerable attention.

The current taxonomic treatment lists 13 genera and about 70 species. The genera of Alismataceae are assigned into 7 tribes largely on the basis of gynoecial character (Pichon, 1946) which is also supported by pollen morphology and basic chromosome number (Argue, 1976).

Genus **Wiesneria** alone constitute the tribe Wiesneriinae. It is considered to be a highly specialized alismataceous genus with submerged flowers (Eams, 1961). It is represented by 3 species viz. **W.filifolia**, **W.schweinfurthii** and **W.triandra**. All the three species are represented in Africa however, **W.triandra** also occurs in India. **Wiesneria triandra** has been recently reported as a rare species from South-India (Joseph and Chandra, 1980; Sivadasan, 1986). It grows in almost every ditch on laterite of Konkan area of Maharashtra during monsoon and is in no way rare and vulnerable as stated by C.D.K.Cook (1980) of Zurich botanical Garden in his monitoring on the status of some Indian endemic plants.

Observation on morphology revealed that **W.triandra** is specialized through process of reduction. The flowers of **W.triandra** are held up well above water and are wind pollinated, however, Eams (1961) mentions that the flowers in the genus are submerged. The leaves differ considerably from remaining genera of Alismataceae and other species of **Wiesneria**. They are erect and well distinguished into petiole, and lamina with distinct joint which differed in anatomical characters. **W.schweinfurthii** has linear leaves with distal part slightly flattened without morphological separation between lamina and petiole while in **W.filifolia** leaves show slight differentiation into lamina and petiole (Stant, 1966). There is a great variation in leaf form and venation pattern in Alismataceae. **Wiesneria** has the simplest leaf form in the family and **Sagittaria** the most complex (Stant, 1966). Although **Wiesneria** is advanced in many other character but retained simple form of leaf while in other genera there is gradual elaboration of the lamina.

Alismatidae exhibit trends toward sterilization of inflorescences (Wilder, 1975). In **Wiesneria triandra** it seems that there is general trend towards reduction. Observations on floral characters revealed that in **W.triandra**, variations in floral characters are more common. It is likely that the number of whorls per inflorescence is stabilizing at 6 rather than at 3 or 9. **Wiesneria triandra** shows functional unisexual flowers like in **Sagittaria** and **Lophotocarpus**. It further represents advancement over its allies in their reduction in carpel numbers, from 6 to 1 and stabilizing at three, as compared to numerous carpels of the Alismataceae members. Male flowers

of **Wiesneria triandra** show 3 stamen with 3 pistillodes. Sterilization of stamens is not considered as a conspicuous part of the evolution in **Lophotocarpus** and **Sagittaria** (Kaul, 1967), however, androecium indicates advanced nature than those having numerous spirally arranged and centrifugally developed stamens. In evolutionary modification of inflorescence reduction and condensation has played prominent role. Reduction primarily in flower number has taken place in many genera throughout angiosperms (Eames, 1961). Variations in number of petals, stamen number, and seldom occurrence of functional bisexual flowers support the view that **W.triandra** is specialized through process of reduction.

Female flowers of **Wiesneria triandra** show 3 sepals, 3 petals, 3 staminodes and 3-6 carpels. Data on carpel and achenes per fruit (Table 2. fig.2) indicate the process of reduction in number of carpels is still in progress and it seems that it is stabilizing at 3. According to Kaul (1976) carpel closure and stigmatic localization in the Alismatales have accompanied decreases in carpel size and numbers of ovules per carpel and increases in carpel number per flower, while in **W.triandra** reduction in carpel number is also accompanied by reduction in ovule number. The most specialized carpels in Alismataceae are uniovulate and indehiscent (Kaul, 1976). Thus **W.triandra** represents most specialized carpels. Further more, functionally unisexual flowers represent advanced nature of **W.triandra**. Thus from morphological studies, it is clear that **W.triandra** is one of the most advanced genus in Alismataceae as also stated by Eames (1961). Our studies supports Pichon (1946) classification in placing **W.triandra** into a separate advanced tribe Wisneriinae.

Reference must be made to the anatomical study of Alismataceae by Stant (1964). In her studies of all the genera of the family, it has been shown that **Wiesneria schweinfurthii** has a low degree of correlation with all other members of the Alismataceae. Morphologically **W.triandra** is showing reduction in stamen, carpel and ovule number and functionally unisexual flowers which indicate its advanced nature in Alismataceous genera.

It has been revealed from cytological studies of **Wiesneria triandra** (Photoplate IV. Fig.3) that karyotype is reasonably asymmetrical and indicated advancedness in general. Sharma and Chatterjee (1967) in their extensive taxonomic studies of Helobiae showed that in various genera of Alismataceae (Excluding **Wiesneria**). Butomaceae and Hydrocharitaceae, the first pair of chromosomes is distinctly larger than the rest of the chromosomes and this pair has a median primary constriction and regarded as a marker chromosome for all those genera. However, in **Wiesneria**, this marker is of submedian type and other two long chromosomes are of median type and thus differs from all those genera of Alismataceae. These structural alterations of chromosomes may be attributed to the evolution of species.

Absolute symmetrical karyotype has not been found in any of the Alismataceae species. Only in the genus **Alisma** considerable amount of symmetry in karyotype has been noted in comparatively long chromosomes (Harada, 1955). Similar trend of symmetry is observed in **W.triandra** in its 3 long chromosomes. It is admitted on cytological grounds that Alismatales is having highly advanced

taxa evolving in divergent directions (Sharma and Chatterjee, 1967). Present investigation of **W. triandra** also supports this view.

In Alismataceae basic chromosome number ranges from 5-13 (Darlington and Wylie, 1955). Such a great diversity in basic numbers indicates that polyploidy and aneuploidy have played a major role in the evolution of these members. **Wiesneria triandra** support this view by having  $n=10$  which might have easily arisen as a multiple of 5, a primary basic number for the family. However, a thorough investigation into cytology of remaining two species of **Wiesneria** may provide confirmation to this assumption. From the foregoing discussion it seems reasonable that **Wiesneria triandra**, a specialized taxon of Alismataceae, is still in the process of stabilization with the help of chromosomal alterations as the prime mechanism.

Pantoporate pollen grains with elaborate apertures of **Wiesneria** are markedly unlike the monosulcate type of the monocotyledons, Argue (1976) studied pollen morphology of 280 specimens including 12 genera and 55 species of Alismataceae and distinguished two pollen type viz. Type 1 with lense shaped grains with 2(0-3) pores on each flattened side, Type 2 with polyhedral or spheroidal pantoporate grains with 9-29 apertures. Type 2 was again divided into 2 subtypes on the basis of pore number, occurrence or not occurrence of pore on pentagonal or hexagonal area and presence or absence of mid-interporal structural bands. He has assigned pollen grains of **W. triandra** to type 2, subtype b. Our results on study revealed that there are ca 24 pores and the pores are present on pentagonal area.

Therefore the pollen grain of **Wiesneria triandra** could be well fitted in subtype **2a**. He also maintains that the genera **Wiesneria**, **Burnatia**, some species of **Echinodorus**, and **Caldesia parnassifolia** are more or less intermediate in pollen-morphology between pollen subtypes **2a** and **2b** and depending upon the morphological characters could be assigned with other. Similarly as stated in discussion on cytology that **W.triandra** possesses  $X=10$ , whereas the other genera viz. **Caldesia**, **Limnophyton**, **Echinodorus** and **Sagittaria** have  $X=11$ .

In **Wiesneria triandra** trinucleate condition of pollen grain at the time of shedding may relate to its aquatic habit. Trinucleate pollen typically requires specialized condition for germination, and a disproportionately high number of aquatic angiosperms have trinucleate pollen. The trinucleate condition should probably therefore be regarded as preadapted to surface pollination, rather than as evolved in response to it (Cronquist, 1981).

In **Wiesneria triandra** the rhizome (Stem axis) is greatly condensed and the vascular tissue is organised in such a way that the analysis of anatomical structure is scarcely possible. The central ground tissue consists of numbers of vascular bundles irregular in course with parenchyma sheath. vascular tissue consists of xylem tracheids with annular thickening and phloem is indistinguishable.

The ground tissue lacks secretory canals as well as tannin cells. The general structure of rhizome is very similar to **W.schweinfurthii** (Stant 1966). The ground tissue contains starch grains. The cortical tissue is lacunose with few diaphragms as observed in **Limnophyton Ranalisma** and **W.schweinfurthii** (Stant, 1966, Tomlinson, 1982). Endodermis is indistinct.

Roots are devoid of hairs and are unbranched. In young root, The cells of middle cortex become polyploid and 2-3 nucleate. The zone containing multinucleate cells differentiate into lacunose parenchyma. From this it seems that polynucleation is primary stage in development of lacunose parenchyma. Mature root consists of 2-3 layered cork and lacunose cortex traversed with diaphragms. Endodermis is made up of thick-walled cells. Vascular tissue consists of central vessels surrounded by undifferentiated tissue or about 4 metaxylem tracheids alternating with phloem. However, in **Wiesneria schweinfurthii** xylem elements around vessel are obscure (Stant,1966). Stant (1966) observed laticifers in exodermis of roots of **Limnophyton** and **Wiesneria schweinfurthii**, however, they were not observed in roots as well as rhizome of **Wiesneria triandra**.

The leaf sheath is provided with sheathing wings. The ground parenchyma is lacunose and vascular tissue is fairly well developed as compared to **Wiesneria schweinfurthii** (Stant 1966). Anatomy of petiole shows single layered epidermis, 1-3 layered hypodermis, lacunose parenchyma traversed with diaphragms and 1-2 large central vascular bundle and small peripheral bundles. Vascular tissue consists of few metaxylem tracheids. laticifers are found in hypodermis as well as at places where septa of lacunae meet.

the petiole and lamina is lined by distinct joint which shows differences in anatomical characters from that of petiole. T.S. of petiole is bluntly triangular in outline. Joint shows great reduction in amount of lacunose parenchyma. Septa between air chambers is



1-4 layered as, against single layered in petiole. There is single central large vascular bundle and 3 smaller peripheral bundles. Laticifers are found in lacunose parenchyma as well as in hypodermis. Xylem is surrounded by 2-3 layers of thick walled cells. Xylem consists of 2-3 tracheids. Thus joint of **Wiesneria triandra** is morphologically as well as anatomically very distinct from petiole, however, Stant (1966) observed no such joint in **W. schweinfurthii**. In **W. schweinfurthii**, she observed submerged leaves without lamina and floating leaves with petiole and lamina.

The leaves in **Wiesneria triandra** are isobilateral and amphistomatic as observed in **Wiesneria schweinfurthii** and **Sagittaria sagittifolia** (Tomlinson, 1982). It relates to its almost erect lamina raised well above water-level. Transverse section of lamina shows thick midrib region with lacunose parenchyma, large midrib bundle and lateral wing like blades. Epidermis is heterocellular made up of small and large cells. In blade region there are 2-3 layers of somewhat vertically elongated palisade on either side of leaf containing abundant chloroplasts while the central portion of blade in T.S. consists of somewhat longitudinally elongated cells consisting of chloroplast and small vascular bundles. Laticifers are found in palisade layer of leaf in midrib region. Thus **Wiesneria triandra** shows more elaboration of lamina than **W. schweinfurthii**.

Cuticle consists of longitudinal files of rectangular parenchymatous cells. Stomata are paracytic with subrectangular subsidiary cells and long narrow guard cells. Stomata are arranged in longitudinal rows oriented parallel to long axis of leaf. The stomatal

density was almost same on abaxial and adaxial surface view-of leaf. It varied from 12-34 mm<sup>2</sup>. Argue (1976) observed correlation between stomatal distribution and leaf orientation in various genera of Alismaceae. The genera viz. **Alisma**, **Luronium**, **Damsonium**, and **Baldelia** show horizontal leaf orientation and stomata are mostly found upper surface while in **Limnophyton**, **Sagittaria** **Lophocarpus** and **Echinodorus** with erect leaves have equal distribution on both the surfaces or higher number on abaxial side. Present investigation also supports this correlation. Stant (1966) failed to observe stomata in material of **Wiesneria schweinfurthii**, however, Meyer (1936) recorded them in laminate leaves of the species. Hydropoten observed in many genera of Alismataceae (Mayer, 1915) was not seen in the species under investigation.

Vascular anatomy of peduncle was found to be very similar to vascular anatomy of upper portion of petiole. Petiole showed presence of diaphragms, tannin cells as well as laticifers.

Developmental anatomy of achene of **Wiesneria triandra** is very peculiar, and characteristic to the species. Achenes are somewhat laterally compressed and passes slit-like openings on flat lateral surfaces. Thus although fruit wall is hard, permeable to water because of slits.

Ovary wall consists of 5-9 layers of cells. After fertilization, drastic changes takes place in the cells of ovary-wall. The epidermis enlarges to great extent without any inclusions, while the cells of remaining layer and then act as starch storing tissue.

Undergo irregular outgrowths forming starchy sclereids which fit in each other like zipper. They become thick wall and develop pit-canals. The starch is utilized by developing embryo and at maturity of achenes, the fruit wall layers are devoid of starch or only with few starch-grains. During this development, lateral sides remain unthickened and form slits. The integuments remain as thin papery layers inside the fruit wall.

When seeds are shed, they remain floating for quite long time due to large parenchymatous epidermal cells which facilitates dispersal of seeds with water currents. After settling down of seeds, and drying of ponds, the unthickened parenchymatous tissue in slit region dries off and decay opening the slits. Then the seeds become permeable to water. The embryo is protected during summer and winter by sclereotic fruit wall. The seeds germinate in next monsoon season. Then the achene structure has definite correlation with dispersal and germination of seeds. Nayer and Sworupanandan (1978) studied morphology of the fruit and mechanism of seed dispersal of the *Limnocharis flava* of Limnocharitaceae of Alismatidae and found that effective reproductive mechanisms are responsible for high potentiality of the species as a dangerous weed. He also states that the effective mechanism of protection of fertilized carpels and seeds dispersal, coupled with its ability for extensive vegetative multiplication by means of detachable bulbils make it a potential threat to water ways. Except vegetative propagation, *Wiesneria triandra* have other potential and thus as stated earlier, it is found in almost every ditch on laterite of Konkan area of Maharashtra and is not a rare species.

Studies on floral anatomy of **Wiesneria triandra** revealed that there is gradual reduction in vascular supply to various parts of flower. Peduncle axis consists of 1-3 vascular bundles which form a plexus at node giving rise to bundles to involucre and usually 3 bundles to three pedicels of flower in each whorl. The bundle of pedicel also forms a plexus at the base of floral organs. The plexus of vascular tissue gives vascular traces to sepals, petals, staminodes and carpels in female flower. Such condition of vasculature is observed in many species of Alismataceae such as **Lophotocarpus**, **Sagittaria** and **Limnocharis** of Buttomaceae (Kaul, 1967). Further in female flower, vascular traces were absent for some of the petals and staminodes. Vascular supply to carpels is very much reduced. The plexus at the base of female flower first gives out three prominent traces to three carpels of lower whorl and 1-3 traces to upper whorl depending upon the number of carpels in upper whorl. As discussed under morphology, there is gradual reduction in carpel number and probably the number of carpel is stabilizing at 3 or even further reduction is expected during evolution. Each vascular tract to carpel, bifurcates at base, one ending at base of funiculus and supplying to ovule, while other forms a dorsal bundle of carpel. Ventral bundles of carpel are absent in **Wiesneria triandra**. Similar very simple vasculature to carpel is observed in **Sagittaria montevidensis**, **S.latifolia**, **S.guayanesis**, **S.sagittifolia** and **Luronium natans** (Kaul, 1976). The simplicity of carpel vasculature is due to reduction and thus the uniovulate carpels of **Wiesneria triandra** presents most specialized carpel.

In male flowers, the general plan of vasculature is similar to female flower, however, the rudimentary pistilodes do not receive any vascular supply. Vascular supply ends at base of pistillodes.

In *Wiesneria triandra*, perianth lobes especially sepals possess regular system of secretory canals. The carpels of *W. triandra* lack secretory canals, however, their presence in carpels wall is reported in *Alisma*, *Baldelia*, *Limnophyton* and *Sagittaria* (Singh, 1976).

Events during anther development, microsporogenesis and male gametophyte development in *Wiesneria triandra* are very similar to several other members of Alismataceae (Tischler, 1915; Clausen, 1927; Johri, 1935). Anthers are tetrasporangiate. The primary archesporium cut off parietal layer which divides into an outer endothecium layer and inner layer. The inner layer divides again giving rise to middle layer and tapetum. Anther development is of monocot type. The tapetum is of amoeboid type which is reported in several members of Alismataceae (Davis, 1966). Development of male gametophyte shows close similarities with other Helobial members. Young pollens are small with, centrally placed nucleus. During enlargement of pollen, shifting of nucleus to one side of pollen with appearance of vacuole opposite to nucleus takes place. Nucleus then divides to form vegetative and generative nucleus. Generative cell divides inside pollen grain giving rise to 2 sperm and the pollen grains are shed in 3-celled condition. Trinucleate pollens are observed in several members of Alismataceae viz. *Sagittaria latifolia* (Schaffner, 1897), *S. sagittifolia* (Schurhoff, 1928), *Limnophyton*

**obtusifolium** (Johri, 1935a), **Sagittaria guayanesis** and **S.latifolia** (Johri, 1935b). In **Elisma natans**, Narsimha Murthy (1933) reports that the male nuclei have a definite sheath of cytoplasm around them and are therefore male cells.

The ovules are anatropous, bitegmic. Each integument is 2 cell in thickness except at apical ends. There is single hypodermal archesporial cell which directly functions as megaspore mother cell without cutting parietal cell. This seems to be common feature in Alismataceae viz. **Alisma plantago**, **Damsonium alisma**, **Echinodorus ranunculoides** (Dahlgren, 1928); **Limnophyton obtusifolium** (Johri, 1935a); (Narsimha Murthy, 1933) **Sagittaria sagittifolia** (Dahlgren 1934; Johri, 1935), **Echinodorus macrophyllus** (Dahlgren, 1934); **Sagittaria guayanesis** and **S.latifolia** (Johri, 1935b). Megaspore mother cell divides unequally into small micropylar cell and large chalazal cell. The micropylar cell degenerate and is seen as cap over bi or 4 nucleate embryo sac. The lower dyad cell develop into the embryo sac. The development of female gametophyte is of **Scilla** type as also observed in other members of Alismataceae.

The nucleus of lower dyad cell divides forming 2 nuclei of which one moves to micropylar end and other to chalazal end separated by vacuole. Both these nuclei divide and form 4 nucleate embryo sac. Third division is regular in nuclei of micropylar end but not in chalazal end. The four nuclei formed at micropylar end soon organise forming 3 celled egg apparatus and polar nucleus. The 2 nuclei of chalazal end may or may not divide, of which one behave as polar nucleus and other as antipodals. Therefore occurrence

or non-occurrence of third mitotic division divides the number of antipodals in chalazal end. The number of antipodals ranges from 1-3 in number. Such variation in antipodals is observed in many member of Alismataceae. Alismataceae members have usually 6-nucleate embryo-sacs, however, 7 or 8 nucleated embryo sac have been found occasionally in **Sagittaria sagittifolia** (Dahlgren, 1928; Johri 1936b), **S.guayanensis** and **S.latifolia** (Johri, 1936) **Limnophyton obtusifolium** (Narasimha Murthy, 1934, Johri 1936) **Alisma aquatica** (Johri 1936b), **Alisma plantago** (Johri, 1936b). Similarly there are also indications that sometimes the number of the antipodal nuclei may increase by fragmentation of tetranucleate stage as reported in **Limnophyton** (Johri 1935a) and **S.sagittifolia** (Johri, 1935b).

The pollen tube enters in one of the synergid where it release its sperms. The sperms are easily recognisable by their dark staining ability and shape. These sperms bring about double fertilization on embryological characteristic of all Angiosperms. Double fertilization has been reported in **Alisma plantago** (Nitzschke, 1914; Dahlgren, 1928), **Sagittaria sagittifolia** (Schaffnar, 1897), **Limnophyton obtusifolium** (Narsimha Murthy, 1933), **Echinodorus macrophyllus** (Dahlgren, 1934) and **Sagittaria guayanesis** (Johri, 1935).

The endosperm development in **Wiesneria triandra** is of typical helobiales type as found in **Sagittaria sagittifolia**, **Echinodorus macrophyllus** (Dahlgren, 1934), **S.guayanensis** (Johri, 1935) and **S.gramina** (Johri, 1936) while it is reported to be nuclear type in some member of Alismataceae viz. **Alisma plantage**, **Damsonium alisma**, **Elisma natans** (Dahlgren, 1928), **Alisma plantage-aquatica** (Johri, 1936).

Embryogeny of **Wiesneria triandra** shows close similarity with embryogeny of other members of Alismataceae viz. **Sagittaria guayanensis**, (Johri, 1935) which corresponds to *Alisma* type. The zygote divides transversely giving - rise to large basal cell and small apical cell. The basal cell does not divide further but enlarges and develops into large polyploid suspensor cell. The terminal cell divide transversely forming 3-celled embryo. Next transverse division forms linear embryo of 4-cells. The terminal cells undergoes two vertical divisions at right angle to each other forming quadrant and octant stage. Apart from this regular development, several variations in number of cells in linear embryo, number of vertical division in terminal cells were observed. After octant stage, periclinial division give rise to globular embryo. With further division, the embryo gradually gets differentiated into plumular part, radicle and single massive U shaped cotyledon. This development is in accordance with the observations of Schaffnar (1897), Souges (1931), and Johri (1935).

From forgoing discussion, especially on morphology, cytology, floral vascular and palynology, it may be said that **Wiesneria triandra** with pantoporate 2a type of pollen (Argue, 1976), different karyomorphology, uniovulate carpels and functionally unisexual flower and highly reduced vasculature to carpel is specialized through reduction and represents an advanced member of the family. Eams (1961) mentions that **Wiesneria** is one of the most specialized genera of Alismataceae. Present investigation supports, Pichon (1946) is placing **Wiesneria** under separate well advanced tribe **Wiesneriinae**. It shows



combination of various characters of all the 13 genera of Alismataceae but can not be said that it is closely related some single genus of Alismataceae. Extensive anatomical studies of stant (1966) on Alismataceae also revealed that **Wiesneria** has a low degree of correlation with all other members of the family. She further points out that morphologically, **Wiesneria** is perhaps the member of the Alismataceae closest to **Butomus** and the two genera have many anatomical characters in common. According to her, **Wiesneria** show least degree of elaboration. This also supports that **Wiesneria** is specialized through reduction series.

Present investigation is in famous of the Tomblinson view (1982) that the Alismataceae are a derived and highly specialized group which provide no useful evidence for the phylogeny of the monocotyledon, or for the evolutionary relationships between dicotyledons and monocotyledons. Thus Alismatidae is scarcely on main line of evolution but represent a specialized side branch of monocotyledons which has retained some very primitive characters .

**Aponogeton satarensis** (Aponogetonaceae)

The family Aponogetonaceae is represented by the genus **Aponogeton** consisting of some 40 aquatic herbs. Van bruggen (1990) in his most recent taxonomic treatment of Aponogetonaceae reports 43 species of **Aponogeton** from the old world. In a revision of Asiatic species of **Aponogeton** he records the distribution of 5 species from India and besides two other species confined to Sri Lanka (Van Bruggen, 1970). All these seven Asiatic species are characterized by bisexual floweres and one species are characterized by bisexual.

**Aponogeton satarensis** eighth Asiatic species with dioecious habit and biforked inflorescence is an unusual feature in Asiatic species of the genus. Two other dioecious species **A.dioecus** and **A.decaryi** are found in Madagascar (Van Bruggen, 1982). **A.satarensis** is closely allied to **A.decaryi** and according to Van Bruggen both probably had a common ancestor. Thus the species is important from phytogeographical point of view.

Morphological features are very similar to other species of **Aponogeton** except biforked spike and dioecious habit. It is an endemic and endangered species of Maharashtra restricted to mountain top plateaus of Sahyadri ranges of Maharashtra. It has been already included in Red-data book as an endangered species.

The underground tuber contains starch. The leaves and roots are produced from top of tuber. Old tubers are replaced by new tubers in every year. It perennates through underground tubers.

Anatomical features of **Aponogeton satarensis** include a well developed system of air lacunae in the petiole, inflorescence axis and roots. Roots are of diamorphic nature and produce unicellular hairs. The exodermis is one to three layered followed by well developed lacunose tissue, Endodermis and pericycle is well distinguished. Xylem is represented by single wide central tracheid as in **A.crispum** and **A.natans** (Singh, 1965a) or by single tracheid associated with 2-3 protoxylem.

The leaves in **Aponogeton satarensis** are floating. The petiole of leaf shows single layered epidermis, lacunose ground parenchyma with simple diaphragms and about 5 vascular bundles in a single arch with a wide median bundle and successively narrower lateral bundles as found in **A.natans** (Tomlinso, 1982). Anatomical characters of inflorescence axis are very similar to petiole.

The leaves are linear lanceolate and glabrous. Leaf venation shows 3 distinct orders of veins peculiar to Aponogettonaceae. The leaves are dorsiventral and epistomatic. The anatomical characters of **Aponogeton satarensis** of leaves are very similar to **A.spathaceum** (Tomlinson, 1982). The mesophyll of leaf is well distinguished into upper 1-3 layered palisade and lower mesophyll made up of spongy parenchyma with large intercellular spaces. The midrib region contains lacunose parenchyma with centrally places single vascular bundle. The lateral first order bundles are surrounded by parenchymatous sheath.

Stomata are found only on upper epidermis. They are arranged in regular rows and are paracytic. Stomatal density varies from 8-13 mm<sup>2</sup>, Lower epidermis is made up of polygonal cells. The anatomical characters of leaf observed in **A.satarensis** are very similar with floating leaves of other species described by Tomlinson (1982).

Tannin cells occur as an isolated cells in all plant parts including carpels. They are reported in other species of **Aponogeton** (Surgueef, 1907; Tomlinson, 1982). Starch grains are found in almost

all the tissues as observed in aquatic plants of many families. Articulated unbranched laticifers are found usually associated with large vascular bundles of petiole, leaf and inflorescence axis, which is common character in families of Alismatales (Eams, 1961).

The ovules in **Aponogeton satarensis** are anatropous, bitegmic and crassinucellate as in most of the Helobiae members, however, in **A. distachyon** and **A. quadrangularis**, the ovules are unitegmic (Afzelius, 1920).

Anther development in **Aponogeton satarensis** is monocotyledon type and the major events are very similar as described for **A. monostachyon** and **A. crispum** (Sane, 1940). However, few differences were observed. Cytokinesis during pollen formation is of simultaneous type as in **A. distachyon** (Suessenguth, 1919); **A. ulvaceous** (Stenar, 1925); **A. monostachyon** and **A. crispum** (Sane, 1940). The pollen tetrads are generally isobilateral or rarely tetrahedral, however, Sane (1940) describes former type of tetrad as common and latter of rare occurrence in **A. monostachyon** and **A. crispum** which needs re-investigation.

Development of male gametophyte is very similar to other Helobial members. Pollen grains are shed in three celled condition. Although 3-celled condition at the time of shedding is considered to be advanced in other taxa in Helobiae. Pollen grains are monosulcate and reticulate as found in other members of Alismataceae. It is considered to be an adaptation to aquatic habit (Cronquist, 1981). The development of male gametophyte is similar to members of Helobiae (Johri, 1935; 1936, a and b ) .

Essential events in megasporogenesis of **A. satarensis** are similar to other species of **Aponogeton** viz. **A. quadrangularis**, **A. monostachyon**, **A. ulvoceous**, **A. violaceous**, **A. guillotii** (Afzelius, 1920); **A. monostachyon** and **A. crispum** (Sane, 1940). Single archesporial cell give rise to a parietal cell and megaspore mother cell. The megaspore mother cell forms linear tetrad of 4 megaspores. The linear type of tetrad is of common occurrence in Helobiae (Schnarf, 1929) Afzelius (1920) did not see the micropylar dyad cell dividing in the species of **Aponogeton** that he investigated. An occurrence of linear tetrad has been reported for **A. distachys** (Scrgueeff, 1967) **A. crispum** and **A. monostachyon** (Sane, 1940).

The form, shape and structure of embryo sac of **Aponogeton satarensis** is exactly similar to **A. crispum** **A. monostachyon** (Sane, 1940). The development of embryo sac is of **polygonum** type, which occur in about 70 % of angiosperms (Davis, 1966). The antipodals are persistent for some time after fertilization. It has also been observed by Afzelius (1920) and Sane (1940).

The endosperm development in **Aponogeton satarensis** is of Helobial type which is characteristic of order Helobiales. Sergueeff (1907) described nuclear endosperm in **A. distachyos**, however, as pointed out by Afzelius (1920), Sane (1940) and present investigation, it is found that the endosperm development is of helobial type. Embryogeny in Aponogetonaceae is peculiar and generally variable. In the embryo of **Aponogeton crispus**, the hypocotyl is enlarged and radicle actually seems to abort (Yamashita, 1976b); Shah (1972) observed some peculiarities in embryogeny of **Aponogeton natans**.

The Helobian affinity of the Aponogettonaceae is not in doubt, on general evidence of their embryology. However, the position of the family within the Helobiae is not at all clear on the basis of present evidence, our observations on various aspects of **Aponogeton satarensis**, support the suggestion of Engler that the Araceae represent one line of affinity on the basis of inflorescence construction, leaf fenestration, presence of spath and laticifers. Similarly Singh and Sattler (1976b) in comparing the floral development of **Acorus** with that of **Aponogeton** point out that there are striking resemblances between the two genera. On the other hand, the strong resemblances between **Aponogeton** and **Scheuchzeria**. Suggested by Uhl on the basis of carpel vasculature, is further supported by the more detailed investigation of floral anatomy by Singh (1965c) continued in the developmental studies by Singh and Sattler (1977b).

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