1972

Use Of Hydropterldales In Teaching Botany

Dale D. Sutton
University of Nebraska

Robert C. Lommasson
University of Nebraska

USE OF HYDROPTERIDALES IN TEACHING BOTANY

Dale D. Sutton and Robert C. Lommasson
Botany Department, University of Nebraska

ABSTRACT

In most instances the Hydropteridales receive little if any attention in the high school biology class or general botany class at the college level. Information regarding these plants may even be rather sketchy in the college level morphology class and morphology text books. Special emphasis should be used in studying this group because they illustrate the following points. Their general morphology is unique in many respects and their habitat is unusual among the ferns. These plants are very good for illustrating the relation between physiology and morphology. The sporocarps produced in this group are unique among all plants. Because of the above features the Hydropteridales seem to be a natural group with which to terminate a study of the ferns.

The Hydropteridales, "water ferns", are seldom mentioned in general botany text books, and information is also likely to be meager in the general morphology text. It is recognized that not all plants can receive detailed study in an undergraduate morphology course. For instance, *Marchantia* and *Riccia* receive considerable attention in dealing with liverworts but *Targionia* and *Corsinia* will likely receive very little attention. With the above statement in mind, it might seem just as logical to ask; why study the Hydropteridales when there are so many other ferns to be treated? It is hoped that the following discussion will show why this often neglected group needs special attention.

The Hydropteridales are a small order consisting of five genera and about ninety species. The taxonomic arrangement of this group is rather artificial. The group can be treated as a single order on the basis of all the members being heterosporus, leptosporangiate, aquatic to semi-aquatic and having sporangia produced in sporocarps. When treated as a single order these ferns are further separated into two families, the Marsileaceae and Salviniaceae. The separation into two families is based on characteristics of the sporocarps, type of vernation, number of nuclei in the neck canal cells, and the number of sperm cells produced in each antheridium. The same characteristics which are used by some morphologists (Campbell, 1918, p. 365; Eames, 1936, p. 197 & 231) for grouping the water ferns into one order and two families are used by others (Sporne, 1966, p. 168 & 171) for grouping into two orders and as many as four families. When divided into two families, the Marsileaceae seem to be a more homogeneous family than the Salviniaceae (Campbell, 1918, p. 396; Scagel, 1966, p. 451 & 454). For the sake of convenience, the water ferns are treated as two families in this article. Tables 1 & 2 contain information regarding the taxonomy, morphology, and distribution of the five genera of Hydropteridales.

If it is accepted that a students attention and interest is more likely to be gained with unusual encounters, the water ferns are sure to be just such an attention getter. We have never seen a student fail to take the second and third look when he encountered the water ferns for the first time (Fig. 1 & 2). It can also be mentioned that most of the students have had no prior experience with these plants. The general morphology of these plants can be used to show the extent to which variation occurs, even within a relatively small group (Tables 1 & 2).

The ecological aspects of this group are different than any other ferns. It can be shown that they are capable of growing completely submerged, floating, or amphibiously, and still have the capability of withstanding prolonged drought. Few botanists doubt that these are plants which have returned secondarily to an aquatic habitat. This change of habitat seems to be borne out by the reduction of leaves, roots, stem vasculature, and reproductive mechanisms.

The ferns would likely be the last group studied prior to a treatment of the seed plants. The water ferns are unique in being heterosporous and offer an excellent opportunity for an in depth study of heterospory and its consequences. Coupled with the occurrence of heterospory is the common phenomenon of sporocarp formation in all genera of water ferns.

Sporocarps are unique to the Hydropteridales but even within the order there is considerable variation in sporocarp morphology (Tables 1 & 2). The sporocarps of Marsilea are exceptional in their ability for maintaining viable spores, even after dormancy of thirty years or more. Even though the sporocarp may remain dormant for such long periods, germination starts within thirty minutes after exposure to water. As pointed out by Foster and Gifford (1959, p. 311) the events which follow the splitting of the sporocarp wall (Fig. 1-B) have interested many a student. The entire gametophyte cycle in Marsilea is completed within less than twenty-four hours, and a macroscopic sporophyte is visible within forty-eight hours (Eames, 1936, p. 220).

There are many features which relate physiology and morphology in this group, some of the more important ones being:

1. The ventral leaves of *Salvinia* which function as roots.
2. The previously mentioned hard sporocarp walls of *Marsilea* which allow for long dormant periods and survival under drought conditions.
3. The positively geotropic sporocarp stalks of *Pilularia* which thrust the sporocarp into the mud as a sort of self-planting mechanism.
4. The gelatinous sheath of the Marsileaceae is highly hygroscopic and when fully expanded is likely to be 15-20 times longer than the sporocarp.

Fig. 1

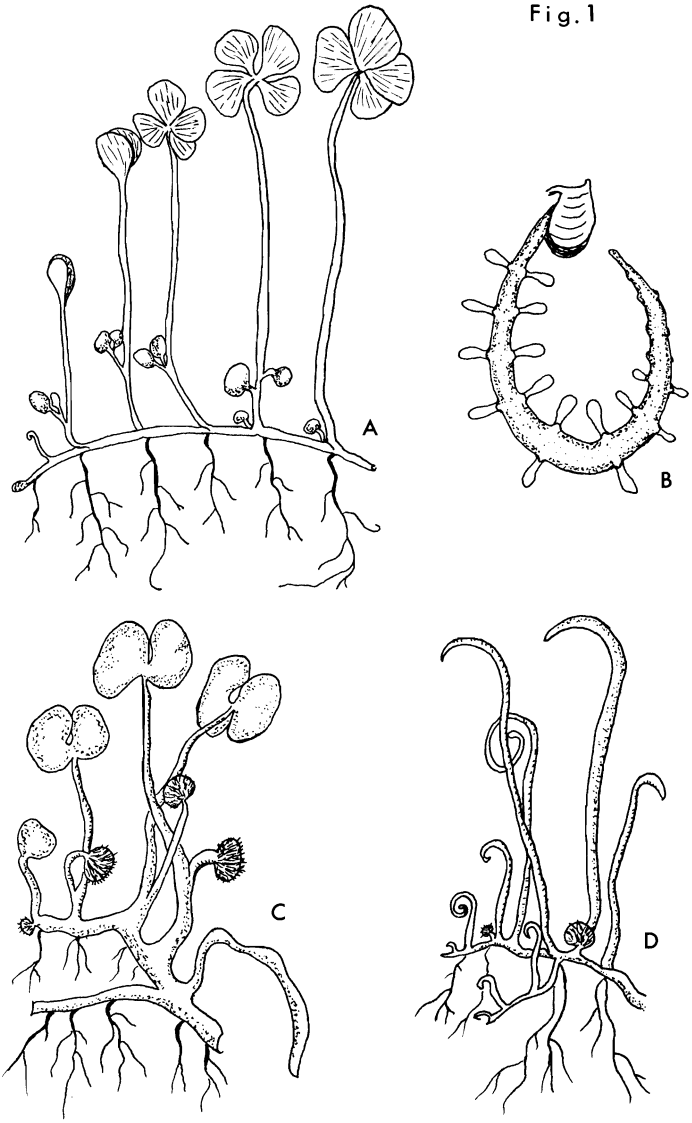
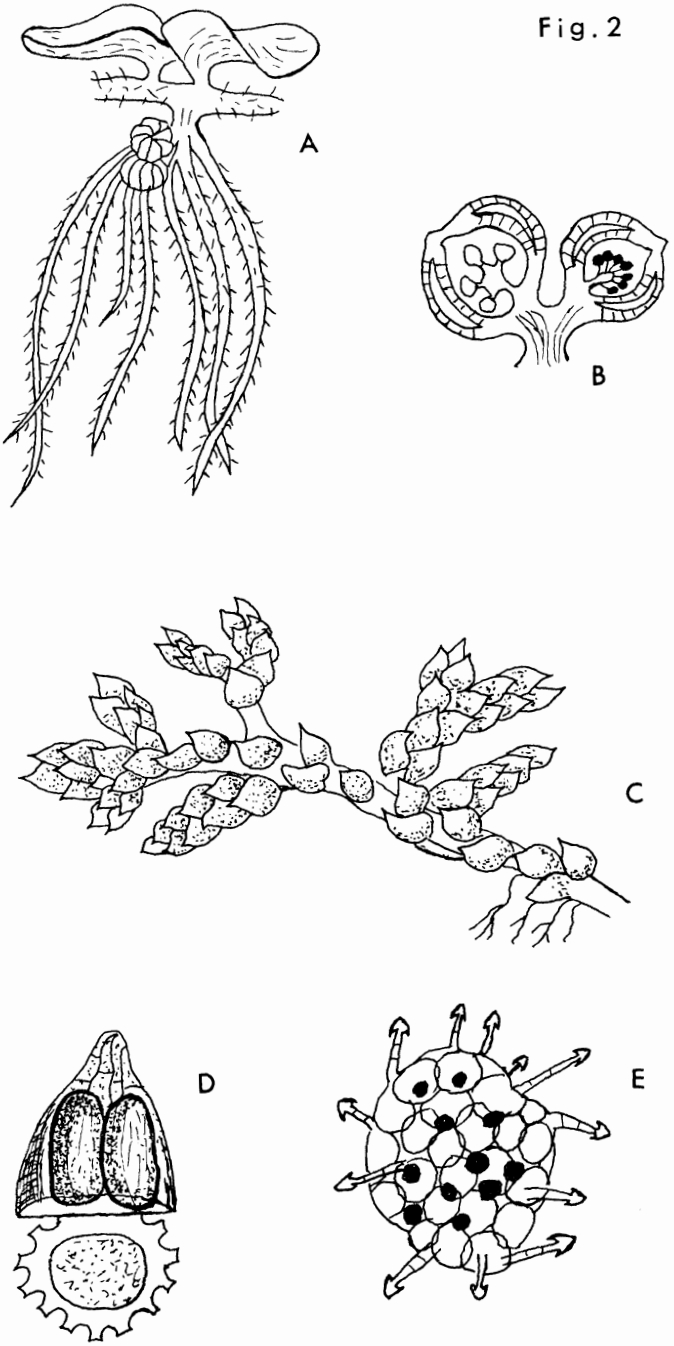


FIGURE DESCRIPTIONS, Fig. 1

Fig. 1-A Habit sketch of *Marsilea quadrifolia.* X 1.
1-B *Marsilea* sporocarp with expanded gelatinous sheath. X 3.
1-C Habit sketch of *Regnellidium diphyllum.* X 2/3.
1-D Habit sketch of *Pilularia blobulifera.* X 2. (Figures A, C. & D, redrawn from Eames)

Fig. 2



5. The massulae which surround the megaspores and microspores of the Salviniaceae are ideal structures for flotation of the spores in an aquatic environment (Fig. 2-D & 2-E). The massulae surrounding the microspores of *Azolla* are also equipped with barb-like hooks (Fig. 2-E) called glochidia. Once these massulae make contact, the glochidia hook onto massulae bearing the megaspores holding together the two spore-bearing structures. Eames (1936, p. 257) points out that the megaspore of *Azolla* with its massulae and other parts is "one of the most remarkable of plant reproductive structures" . . .
6. The unwettable hairs of *Salvinia* and *Azolla* provide an excellent method for maintaining proper orientation on the surface of the water.
7. The gross morphology of these plants seems to be based on survival in seasonal habitats.

In conclusion, the relationship of physiology and morphology, and rapid completion of the life cycle of *Marsilea* make it the best known plant for direct observation of a complete life cycle. An additional strong point for use in the laboratory is the ease with which these ferns can be cultured in the green house. Some suggested laboratory activities are listed at the end of this article. It seems that the water ferns are a natural group with which to conclude a study of the ferns. The points which have been mentioned will offer an excellent opportunity to review and tie together much of the morphological information covered in the Bryophytes and the Pteridophytes, and will also give excellent background for introducing the seed plants.

SOME SUGGESTED LABORATORY ACTIVITIES

1. Construct a key to the five genera of water ferns.
2. Compare and contrast a seed and a sporocarp.

FIGURE DESCRIPTIONS, Fig. 2

Fig. 2-A Habit sketch of *Salvinia natans.* X 2.

2-B Microsporocarp (right) and megasporcarp (left) of *Salvinia.* X 5.

2-C Habit sketch of *Azolla filiculoides.* X 2.

2-D Megaspore and surrounding massulae, *Azolla filiculoides.* Upper massulae in optical view and megaspore in median section showing pits of the surrounding, lower massula. X 40.

2-E Massula with microspores and many glochidia, *Azolla caroliniana.* X 250.

(Figures A & B, redrawn from Campbell; Figure C, redrawn from Dittmer; Figures D & E, redrawn from Eames)

Table 1. Summary of information related to Marsilaeceae.[1]

Genus, number of species, distribution.	*Marsilea,* 65 species, world wide, centered in tropical Africa & Australia.
Habitat	Aquatic or amphibious.
SPOROPHYTE	
Vegetative organs, stem, habit.	Herbaceous, rhizomatous, creeping.
Leaf morphology.	Compound, 4 leaflets, circinate vernation, dichotomous venation.
Roots	Adventitious, borne at the nodes.
Stele	Amphiphloic solenostele.
Sporophylls	Sporocarps which are modified pinnae with many marginal sori. Number of indusia is equal to number of soral sacs.
SPORANGIUM	Leptosporangiate development with numerous micro-sporangia and megasporangia produced within the same sporocarp.
Sporangium wall, annulus, tapetum.	Wall is a single layer of cells, no annulus, 2-3 layered tapetum formed from archesporial cell.
Spore output.	1 megaspore per megasporangium and 64 microspores per microsporangium.
GAMETOPHYTES	Both the male and female gametophytes have endosporic development, prothallus is not green.
Color and position of the prothallus.	
ANTHERIDIUM	Two antheridia are produced by each male gametophyte. Each antheridium produces 16 spirally coiled, multicilliate sperms.
ARCHEGONIUM	Each female gametophyte produces a single archegonium having a short neck, two cells in height, with two neck canal nuclei.

EMBRYO (young (sporophyte)	The first cell division of the zygote is vertical. There is no suspensor.
MAJOR DIFFERENCES BETWEEN THE GENERA OF MARSILEACEAE	The genus *Regnellidium* is monotypic and found in Brazil. *Regnellidium* leaves have two reniform segments. Sperm cells are only slightly coiled. Six species of *Pilularia* are scattered in Europe, America, N. Africa, and Australia. *Pilularia* has an awl-shaped leaf with no blade. Each sporocarp contains only four marginal sori and produces one to a few megasporangia and two to a few microsporangia. In some cases there may be traces of an annulus. Sperms are only slightly coiled.

Information is given for *Marsilea* with major differences summarized in the last item of the table.

Table 2. Summary of information related to Salviniaceae.[1]

Genus, number of species, distribution.	*Salvinia,* 10 species, chiefly African, but also found in U.S. and Europe.
Habitat	Floating aquatic.
SPOROPHYTE	Herbaceous, branching, rhizomatous.
Vegetative organs, stem, habit. Leaf morphology.	Numerous leaves in 4 dorsal and 2 ventral rows, 1 vascular bundle per dorsal leaf, ventral leaf is greatly disected.
Roots	Not present, replaced by ventral leaves.
Stele	Ectophloic siphonostele.
Sporophylls	Sporocarps which are modified indusia with one marginal sorus.
SPORANGIUM	Leptosporangiate development, gradate maturation, megasporangia produced in megasporocarps and microsporangia in microsporocarps. All sporangia stalked.
Sporangium wall, annulus, tapetum.	Wall is a single layer, annulus is vestigial or absent. Tapetum is 1 cell thick.

Table 2. continued:

Spore output.	1 megaspore per megasporangium and 64 microspores per microsporangium.
GAMETOPHYTES Color and position of the prothallus.	Both the male and female gametophytes are endosporic, prothallus is bright green.
ANTHERIDIUM	Two antheridia are produced by each male gametophyte. Each antheridium produces 4 slightly coiled, multicilliate sperms.
ARCHEGONIA	Each female gametophyte produces 3 to several archegonia with short necks 3-4 cells in height, 1 binucleate neck canal cell is produced.
EMBRYO (young sporophyte)	The first cell division of the zygote is vertical. There is no suspensor.
MAJOR DIFFERENCES BETWEEN GENERA OF SALVINIACEAE	The genus *Azolla* is made up of 5 species which are scattered throughout warm temperate areas, Europe, and the U.S. *Azolla* has numerous two-lobed leaves in two alternating rows along the upper surface of the stem. Adventitious roots are produced at the nodes. *Azolla* has a protostele and dichotomous branching veins in the leaves. The prothallus is slightly green. Each antheridium produces 8 slightly coiled, multicilliate sperms.

Information is given for *Salvinia* with major differences summarized in the last item of the table.

3. File the wall of a *Marsilea* sporocarp and observe the expansion of the gelatinous ring.
4. Study and describe heteroblastic leaf development in the genus *Marsilea.*
5. Compare the "sleep" movements of the leaves of *Marsileas* in constant darkness for 72 hours, in alternating periods of light and dark, and in 72 hours of constant light.
6. Compare the venation patterns of *Marsilea, Regnellidium, Salvinia,* and *Azolla* with other vascular plants.
7. Study the effects of temperature on the viability of the sporocarps of *Marsilea.* Such a study could also be expanded to include the effects of temperature on the time required for sperm release and archegonium formation.
8. Make a study of the time required for formation of a macroscopic sporophyte in *Marsilea.*

REFERENCES CITED

Campbell, D. H. 1918. Mosses and Ferns: London, The Macmillan Company, 708 p.

Eames, A. J. 1936. Morphology of Vascular Plants. New York and London, McGraw-Hill Book Company, 433 p.

Foster, A. S., and Earnest M. Gifford, Jr. 1959. Comparative Morphology of Vascular Plants. San Francisco and London, W. H. Freeman and Company, 555 p.

Scagel, R. F., Bandoni, R. J., Glenn, E. R., Schofield, W. B., Janet, R. S., and Taylor, T. M. C. 1966. An Evolutionary Survey of the Plant Kingdom. Belmont, California, Wadsworth Publishing Company, 658 p.

Sporne, K. R. 1966. The Morphology of Pteridophytes. London, Hutchinson & Co., 192 p.