

# ***Azolla*: Botany, Physiology, and Use as a Green Manure<sup>1</sup>**

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*This is a comprehensive review of literature pertaining to the aquatic fern *Azolla* and its nitrogen-fixing algal symbiont, *Anabaena azollae*. The preceding decade has witnessed an explosive growth in research on *Azolla*, and hopefully this paper will facilitate those efforts.*

*The paper is broken into three major categories: botany, physiology and biochemistry, and agriculture. The botany section includes a world distribution map and reference tables for the 6 *Azolla* species, and includes the first review of literature on *Anabaena azollae*.*

*The physiology and biochemistry section covers the range of topics from environmental factors to life processes and nitrogen fixation. Tables on the effect of growth regulators and on the rate of nitrogen fixation measured by acetylene reduction are presented.*

*The agriculture section draws extensively from literature published in the People's Republic of China and in the Democratic Republic of Vietnam. The major focus of this section is on the history and management practices for *Azolla* cultivation as a green manure for rice. The effect of weed suppression, use as a fish food and animal fodder, and the insects and diseases of *Azolla* are also discussed.*

*Azolla* has been of traditional interest to botanists and Asian agriculturists because of its symbiotic association with a nitrogen-fixing blue-green alga. Stimulated by the recent energy crisis, the interests of these two groups have merged, resulting in the publication of numerous articles in popular magazines and extension bulletins. These articles have focused on the green manure, nitrogen fixation, and hydrogen production qualities of *Azolla* (Galston, 1975; Newton, 1976; Brill, 1977; Singh, 1977b).

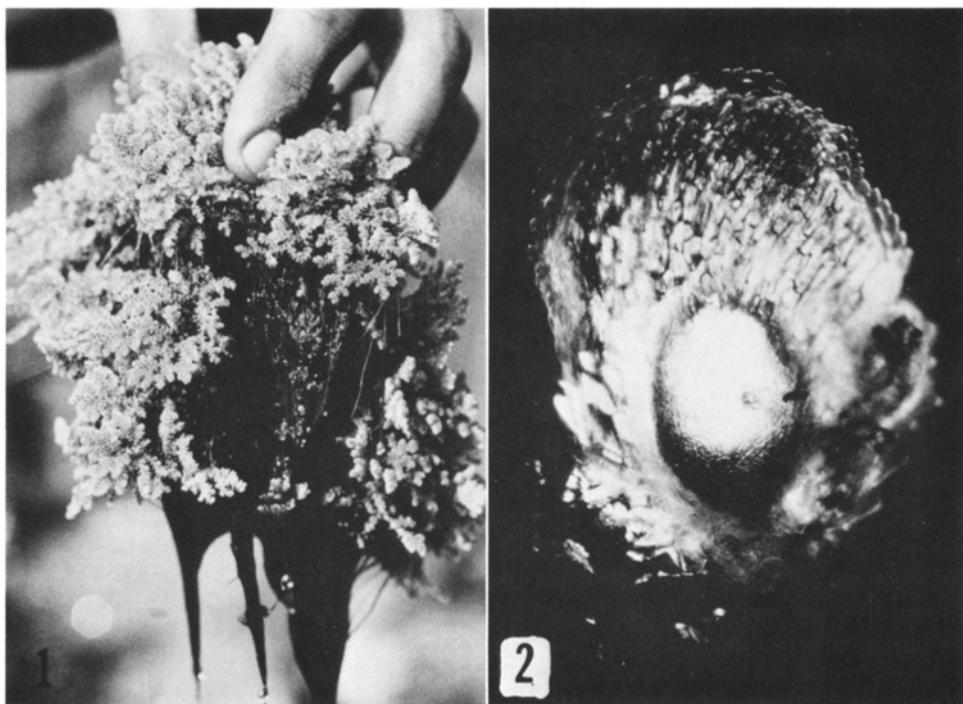
The intent of this paper is to provide a current and comprehensive survey of all available literature on the *Azolla*-*Anabaena* symbiosis, essentially up-dating and expanding the excellent review by Moore (1969). Some of the included references were published prior to 1969 but were hitherto unavailable (e.g., those from Vietnam and China).

The most remarkable characteristic of *Azolla* is its symbiotic relationship with the nitrogen-fixing blue-green alga (cyanobacterium), *Anabaena azollae*. The delicate *Azolla* (Fig. 1) provides nutrients and a protective cavity in each leaf (Fig. 2) to *Anabaena* colonies in exchange for fixed atmospheric nitrogen and possibly other growth-promoting substances (Schaefer, 1947; Ashton and Walmsley, 1976). The rate of nitrogen fixation in the *Azolla*-*Anabaena* symbiosis rivals that of the *Rhizobium*-legume symbiosis. Talley et al. (1977) reported a daily fixation rate

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**Fig. 1-2.** Fig. 1. *Azolla filiculoides* mats, growing in Hawaiian taro fields, contain approximately 70 kg N/ha. Fig. 2. *Anabaena azollae* filaments are visible within the ovoid leaf cavity of an *Azolla pinnata* dorsal lobe.

of 1.2 kg N/ha and Dao and Tran (1966) reported an annual nitrogen yield of 864 kg N/ha.

#### BOTANY OF AZOLLA

##### *Taxonomy and stratigraphy*

The genus name, *Azolla*, is a conjugation of two Greek words, *Azō* (to dry) and *ollyō* (to kill), suggesting the fern is killed by drought. Some of the fern's vernacular names are: water velvet, mosquito fern (English); Algenfarn (German); Helechito del Agua (Spanish); Lu P'ing, Ho P'ing, Man Chiang hung shu (Chinese); Akaukikusa, Koaukikusa, Ooaukikusa (Japanese); Chak pos kra bey, Chak krahan (Khmer); Nae harnghern (Lao); Beo hoa dau, Beo giao (Vietnamese).

*Azolla* belongs to the Salviniaceae which is closely related to the Hymenophyllaceae (Copeland, 1947; Bierhorst, 1971). Lamarck established the genus *Azolla* in 1783 after examining specimens brought from Chile (Griffith, 1845). The genus was originally included in the Salviniaceae Sadeb., a family of heterosporous free-floating ferns (Sadebeck, 1902) (Fig. 3), but recently taxonomists have assigned *Azolla* to a monotypic family, Azollaceae C. Chr., separate from the genus *Salvinia* (Christensen, 1938; Reed, 1954; Sculthorpe, 1967; Konar and Kapoor, 1974; Martin, 1976).