AZOLLA: AN AQUATIC PTERIDOPHYTE WITH GREAT POTENTIAL
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Abstract
The concept of using aquatic plant for different purposes is receiving special attention nowadays. Because of its growth habitat, high multiplication rate, excellent source of protein for mono-gastric animals, high biomass production and increasing demand as organic food, Azolla has gained importance in recent years. Azolla is one of the aquatic Pteridophyte that may be used as animal food, as green manure, biofertilizer, for increasing soil fertility, bioremediation of waste water and reclamation of saline soils. Due to its high nutritional values and protein content Azolla is suitable for human consumption and as feed supplement for variety of animals like fish, ducks, cattle, poultry etc. to reduce feed cost. It also finds use in biogas and hydrogen production, as space food, in controlling weeds and mosquitoes.

Keywords: Pteridophyte, Bioremediation, Biogas, Reclamation, Sesbania, Desalinate, Sporulation and Fluctuations.

INTRODUCTION
The name Azolla is derived from Greek word azo (to dry) and allyo (to kill) meaning that plant dies when it dries. The genus Azolla established by J. B. Lamark as early as 1783 [1] was placed in the family Salvinaceae of the order Salviniales. However taxonomists have placed it now in monotypic family Azollaceae [2]. There are seven or eight extant and more than forty fossil species of Azolla known [3, 4]. The genus is further categorized into two sub-genera Euazolla and Rhizosperma [1]. Euazolla is characterized by the presence of three megaspore floats and consists of five new world species namely A. caroliniana, A. filiculoides, A. mexicana, A. microphylla and A. rubra. The sub genus Rhizosperma consists of two old world species namely A. pinnata and A. nilotica possessing floats in the megaspore apparatus. Azolla imbricata nakai has been reported as an independent species instead of a sub-species of Azolla pinnata [5]. The three Neotropical host species A. microphylla, A. caroliniana and A. mexicana are similar in vegetative morphology and eco physiology [6].

The small fast growing free floating fern has global distribution. Azolla is a dichotomously branched free floating aquatic fern naturally available on moist soils, ditches and marshy ponds. The shape of Indian species is typically triangular measuring about 1.5 to 3.0 cm in length, 1 to 2 cm in breadth. Fronds has tiny roots usually associated with rich microphylla [7], short branched stem called rhizome covered with small alternate overlapping leaves the sporophyte has dorsiventral organization [8] and each leaf is divided into dorsal and ventral lobe., the ventral lobe is thin almost colourless and distal half is only one celled thick. The aerial dorsal leaf lobe has multilayered mesophyll adaxial and abaxial epidermal tissues, numerous stomata and single celled papillae. In the dorsal leaf lobe there is an ellipsoidal cavity which is formed by the enfolding of the adaxial epidermis. The cavity largely filled with gases is lined with mucilage [9] which contains the cyanobiont Anabaena azollae [10] and a gram positive non-nitrogen fixing bacteria [11] identified as Arthrobacter species [12].
BENEFICIAL ASPECTS FOR PLANTS

The experiments have shown that Azolla can overcome nutrient limitation to plant growth by enhancing nutrient acquisition. According to the plant species and to the growing practices and conditions, Azolla provide different benefits to the plants and to the environment:

- Increase yields and crop quality
- Reduce disease occurrence
- Enhance flowering and fruiting
- Increase plant establishment and survival at seedling or transplanting
- Produce more vigorous and healthy plants
- Improve drought tolerance, allowing watering reduction
- Optimize fertilizers use, especially nitrogen
- Increase tolerance to soil salinity
- Contribute to maintain soil quality and nutrient cycling

Azolla as Biofertilizer in Rice Cultivation

Azolla is used as a biofertilizer and produces around 300 tonnes of green bio-hectare per year under normal subtropical climate which is comparable to 800 kg of nitrogen (1800 kgs of urea). The important factor in using Azolla as a biofertilizer for rice crop is its quick decomposition in soil and efficient availability of its nitrogen to rice plant. The quick multiplication rate and rapid decomposing capacity of Azolla has become paramount important factor to use as green manure cum biofertilizer in rice field. The benefits of Azolla application in the rice field are the following: Basal application of green manure @ 10-12 tones/hectare increases soil nitrogen by 50-60 kg/ha and reduces 30-35 kg of nitrogenous fertilizer requirement of rice crop. Release of green Azolla twice as dual cropping in rice crop @ 500 kg/ha enriches soil nitrogen by 50 kg/ha and reduces nitrogen requirement by 20-30 kg/ha. Use of Azolla increases rice yield by 20 to 30%.

In summary the characteristics that make Azolla suitable as a biofertilizer in rice are as follows:

1. Azolla fixes nitrogen at substantial rates.
2. Azolla has rapid growth.
3. Since Azolla floats at the water surface, it cannot complete with rice for light and space.
4. In most climates, Azolla grows best under a partial shade of vegetation which a rice canopy, in its early and intermediate stages of growth can easily provide.
5. When rice approaches maturity, due to low light intensities under the canopy and depletion of nutrients, Azolla begins to die and decompose, thus releasing nutrients into the medium.
6. Azolla decomposes rapidly and therefore the nitrogen it has fixed and the phosphorus and other nutrients it may have observed from the water, perhaps in competition with the rice are rapidly released back in to the medium and made available for uptake by rice during grain development.
7. Azolla has great ability than rice to accumulate potassium in its tissues in low potassium environment; thus, after decomposition, it makes this nutrient available to rice.
8. A thick Azolla mat in a rice field has the side benefit of suppressing weeds.

Azolla as Green Manure

Azolla can also been used as green manure in the cultivation of water bamboo, arrowhead, taro, Wheat and rice [13, 14, 15]. Incubation of Azolla as green manure in water logged soil resulted in rapid mineralization with a release of 60-80% of the nitrogen within two weeks ([16]. Sharma and co-workers [17] also recorded the highest yields of wheat with application of 20 tonnes of Azolla and 60 kg nitrogen.

Azolla: Beneficial Effects on Crops

Azolla is beneficial to wheat when applied in a rotating rice-wheat cropping system [18]. Mahapatra and Sharma [19] found that application of Azolla with Sesbania had beneficial residual effect on subsequent wheat crops, raising grain yield by 56-69 % over control. Ram et al [20] found that incorporation of 6,12,18 and 24 tha-1 of fresh Azolla into the soil significantly increased water holding capacity, organic carbon, ammonium nitrogen, nitrate-nitrogen and its available phosphorus, potassium, calcium and magnesium, while it decreased pH and bulk density, such incorporation significantly raised the yield of mung beans.

Azolla: Beneficial Effects on Physio-chemical Properties of Soil

Azolla is used to increase soil fertility. Singh and Singh [21] found that Azolla application improves soil fertility by increasing total nitrogen, organic carbon and available phosphorus in soil these findings were supported by [22, 23]. Van Hove [13] found that Azolla improves soil structure.

Azolla in Reclamation of Saline Soils

Although, Azolla is relatively sensitive to salt, cultivation in saline environment for a period of two consecutive years decreased salt content from 0.35-0.15 and desalinate rate (71.4%) was 1.8 times faster than through water leaching and 2.1 times faster than Sesbania and also reduced the electrical expanse.
conductivity, pH of acidic soil and increased calcium content of soil [24].

**Azolla in Bioremediation**

It was found that *A. pinnata* and *Lamna minor* removed the heavy metals iron and copper from polluted water [25]. The pollutants at low concentration could be treated by passing it through ponds and can be reused for Agriculture purpose. Recently Anju Arora [26] found that tolerance and phytoaccumulation of chromium by three *Azolla* species and also results found by Cohen-Shoel [27] shows biofiltration of toxic elements by *Azolla* biomass. *Azolla* exhibits a remarkable ability to concentrate metals Cu, Cd, Cr, Ni, Pb and nutrients directly from pollutants or sewage water.

**Azolla as Mosquito Repellent**

*Azolla* can also be used in the control of mosquitoes, for a thick *Azolla* mat on the water surface can prevent breeding and adult emergence. In a survey of pools, ponds, wells, rice fields and drains [28] found that breeding by *Anopheles* spp. was almost completely suppressed in water bodies that were completely covered with *Azolla*. Rajendran and Reuben [29] showed that *A. pinnata* greatly reduced both oviposition and adult emergence of *Culex quinquefasciatus say* and *Anopheles culicifacies Giles*, but not larval survival. Egg hatchability was partially reduced.

**Azolla in Weed Control**

It was also seen that *Azolla* controls the weed growth. Our findings were supported by [30] and found that an *Azolla* cover significantly reduced the total amount of weeds; particularly the predominant weed *Monochoria vaginalis*, through grasses and hedges could not always be controlled.

**Azolla in Production of Biogas**

Anaerobic fermentation of *Azolla* (or a mixture of *Azolla* and rice straw) results in the production of methane gas which can be utilized as fuel and remaining effluent can be used as a fertilizer because it contains all the nutrients originally incorporated in plant tissues except for a small percentage of nitrogen lost as ammonia [13]. Das [31] mixed cow dung and *Azolla* residues and found that best ratio was 1:0.4, which gave a gas production 1.4 times that of cow dung alone.

**Azolla and Bioenergy**

A non-polluting, high energy fuel when *Azolla-Anabaena* is grown in a nitrogen-free atmosphere and or a water medium containing nitrate, the nitrogenise in the symbionts, instead of fixing nitrogen evolves hydrogen, using water as the source[32, 33]. Hall [34] shows that rate of hydrogen production can be increased by exposure to a micro aerobic environment, a partial vacuum or argon-enriched or carbon dioxide enriched atmosphere or by immobilization of cells of *Anabaena-Azollae* isolated from the fern.

**Azolla as Human food**

A few researchers have experimented with the preparation of *Azolla* in soups or “Azolla meatballs as food for man. However such recipes are as yet unpublished [13]. Li Shi-Zhen published a book in china in the 16th century that described the medicinal properties of *Azolla* [35]. In Tanzania, *Azolla* has been reported to be used effectively as traditional cough medicine [36]. *Azolla* is also used as a salad in western countries due to high quantity of protein.

**Azolla as a Component of Space Diet**

Recent research by Katayama [37] in collaboration with Space Agriculture Task Force suggested *Azolla* as a component of the space diet during habitation on Mars and found that *Azolla* was found to meet human nutritional requirements on Mars.

**Azolla as Nutritional Supplement for Livestock**

*Azolla* is used as food supplement for variety of animals including pigs, rabbits, chickens, ducks and fish [13]. Seultrpo [38] reported that *Azolla* is harvested in large quantities and utilised as fodder for cattle and pigs. It was also found that broilers feed with *Azolla* resulted in growth and body weight values similar to those resulting from the use of maize-soya bean meal. Das [31] found that digested *Azolla* slurry remaining after biogas production was suitable as fish pond fertilizer, in the study lactating cows [39] found that *Azolla* could be used as feed ingredient with milk yields and fat percentage being maintained at the same levels as with conventional feeds.

**Conclusion**

The mankind is threatened by drastic global environmental changes triggered by his own activities, we need to investigate and develop alternative strategies for conducting our affairs. The application of *Azolla* as biofertilizer and all other important uses play a significant role in maintaining or improving the state of global environment. There is a definite need to exploit the potential of the Aquatic Pteridophyte in a more efficient manner in the future, through biotechnological interventions. Therefore a combination of approaches involving basic and applied research should be taken towards making *Azolla* more resistant to environmental fluctuation and also less labour-intensive, so that its actual utilization is diversified and enhanced in Agriculture, industry and environmental management. In a review on *Azolla Wagner* [36] calls *Azolla* “a green gold mine” this fact can be ignored with regard to substituting it for inorganic fertilizer and other important uses mentioned above to conserve the environment as well as to maintain the sustainable agriculture.

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