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Azolla in Sustainable Agriculture

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Abstract:

Azolla is a free-floating hydrophyte fern grown in temperate and tropical regions. The symbiotic relationship between Azolla and Anabaena is remarkable owing to its exceptional productivity and capacity for efficient nitrogen fixation. In recent decades, numerous studies have been done to investigate this correlation; nevertheless, there has been a lack of adequate synthesis and coordination in these endeavors. This work aims to comprehensively examine and integrate previous and contemporary studies on the biology and application of Azolla. The objective is to foster enhanced future joint investigations on this valuable resource, commonly referred to as the "green gold mine." This paper provides an overview of the taxonomy, distribution, morphology, physiology, and reproduction of the plant genus Azolla, along with recent advancements in its diverse applications.

The utilization of Azolla as a biofertilizer in agricultural practices holds significant promise for addressing environmental conservation concerns and the imperative of utilizing renewable and sustainable resources. By serving as a natural nitrogen source, Azolla has the potential to contribute greatly to the future well-being of our planet. In addition to its environmental suitability, the utilization of Azolla holds significant economic potential for numerous farmers throughout various regions worldwide who lack the financial means to procure chemical fertilizers. By incorporating Azolla into their agricultural practices, these farmers can potentially improve their economic standing by improving crop yields and reducing expenses. The suitability of Azolla for application on rice stems from the favorable conditions provided by rice paddy fields.

In addition to its application as a biofertilizer across several crop types, Azolla possesses potential uses as an animal feed, a human food source, a medicinal agent, and a water purification agent. Additionally, this technology can be employed for the generation of

hydrogen fuel, the synthesis of biogas, the management of weed growth, the regulation of mosquito populations, and the mitigation of ammonia volatilization that occurs with the application of chemical nitrogen fertilizer.

Keywords: Azolla, anabaena, nitrogen fixation, symbiosis, sustainable bio-energy source

Introduction:

Sustainable development pertains to a paradigm of human development wherein the utilization of resources is directed towards fulfilling human needs while concurrently safeguarding the environment, ensuring the fulfillment of these needs for both current and forthcoming generations. Azolla is classified as a hyperaccumulator plant due to its ability to uptake heavy metals at a rate 50-500 times higher than typical plants. This characteristic has played a crucial role in advancing the phytoextraction technology. The aquatic fern in question serves as a fundamental component of green manure and decomposed organic matter. Azolla possesses diverse attributes that contribute to the enhancement of crop output while simultaneously mitigating environmental degradation.

Azolla is a taxonomic genus including seven distinct species of aquatic ferns belonging to the family Salviniaceae. These ferns possess a compact, branched floating stem structure that supports roots that dangle beneath the water's surface. It is observed to be suspended on the surface of the aqueous medium. The plant thrives in stagnant and low-velocity aquatic environments due to the disruptive effects of rapid currents and waves. Under optimum conditions, the majority of strains may achieve a doubling of biomass within a week, with a maximum growth rate resulting in a doubling time of 1.9 days. The leaves exhibit an alternate arrangement, with each leaf containing green chlorophyll and a somewhat bigger, thin, colorless floating vertical lobe. Azolla possesses the ability to perform atmospheric nitrogen fixation, exhibits a notable level of productivity, contains a substantial amount of protein, and exerts a suppressive effect on both aquatic weeds and NH_3 volatilization.

Azolla has played a significant role in the field of agriculture throughout history. Throughout the course of history, the plant in question has garnered acknowledgment for its utility in the regions of Southern China and Northern Vietnam. Specifically, it has been employed as a biofertilizer and green manure for the cultivation of rice, owing to its notable capacity for nitrogen fixation. In the 18th century, Azolla was documented as a potential chicken feed in Peru. The promotion of Azolla manufacture in China and Vietnam during the

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early 1960s led to significant growth and extension of this industry in both nations. During the 1970s, there was a surge in global interest due to the oil crisis and the escalating costs of nitrogen fertilizers, which heavily rely on fossil fuels. Azolla emerged as a promising alternative to address this issue, as it was hypothesized to enhance rice cultivation in numerous tropical nations. Nevertheless, the fervor around Azolla waned during the 1980s, subsequently giving way to a phase characterized by skepticism. The decline in azolla production in China and Vietnam can potentially be attributed to the growing utilization of land for food production. Additionally, global Azolla development has not met initial expectations due to significant limitations, including limited water availability, challenges in maintenance and handling, substantial labor demands, and a lack of comprehensive understanding regarding the specific requirements of each azolla species. The attempt to introduce azolla as a cattle feed in the Philippines was unsuccessful. It is important to acknowledge that azolla is frequently seen as a pernicious weed by farmers, indicating that the perception of azolla is not universally favorable.

Nevertheless, it is important to acknowledge that azolla possesses numerous indisputable agronomic characteristics. These include its ability to effectively convert atmospheric nitrogen into a usable form, its remarkable productivity under suitable conditions, its substantial protein content, its herbicidal properties, and its capability to reduce the volatilization of N-fertilizers. Due to these factors, azolla regained prominence in the late 1990s, particularly as a constituent of integrated agricultural practices such as rice-fish-azolla, rice-duck-azolla, rice-duck-fish-azolla, or pig-fish-azolla systems. The adoption of azolla by cattle farmers continues to encounter significant obstacles. In the context of India, despite the efforts made by non-governmental organizations, cooperatives, and government agencies, the adoption of some practices has been characterized by a sluggish and irregular pace. This may be attributed to several challenges such as suboptimal crop yields, issues related to pest control, challenges in processing and storing agricultural produce, as well as the labor-intensive nature of these practices.

Azolla

Azolla sp. is a little aquatic fern that exhibits a free-floating lifestyle within freshwater habitats, predominantly found in tropical and sub-tropical regions of Asia, Africa, and America. The term "Azolla" originates from the Greek words "azo" (to dry) and "allyo" (to kill), indicating that the plant perishes when it becomes dry. The establishment of the Genus

Azolla can be attributed to Lamarck in 1783, who classified it within the family Salviniaceae under the order Salviniales. Azolla is taxonomically classified within the monotypic family Azollaceae, and it comprises a total of seven living species. Azolla can be classified into two subgenera, namely Euazolla and Rhizosperma. Currently, the family Salviniaceaeceae consists of seven living species, namely Azolla caroliniana Willd., Azolla cristata Kaulf., Azolla filiculoides Lam., Azolla imbricata (Roxb. ex Griff.) Nakai, Azolla mexicana C. Presl, Azolla microphylla Kaulf., and Azolla pinnata R. Br. The Sub-Genus Euazolla is distinguished by the existence of three megasporocarp floats, whereas the Sub-Genus Rhizosperma comprises nine megaspore floats. Trichomes play a significant role in the taxonomic identification of organisms at the species level.

Distribution

Azolla is naturally found in freshwater habitats such as ditches, ponds, lakes, and slow-moving rivers in warm temperate and tropical climates. The lack of presence in areas characterized by extended periods of frigid temperatures or arid conditions.

Habit and Morphology

The Azolla plants exhibit a delicate morphology, characterized by their diminutive size and triangular or polygonal shape. The organism exhibits a free-floating and aquatic nature, however, it is capable of thriving in damp soils as long as the soil retains sufficient moisture. The plant's sporophytic structure consists of a horizontal rhizome, ranging in diameter from 0.5 to 7 cm, which gives rise to branches characterized by tightly packed and overlapping

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leaves. A leaf is composed of a comparatively thick dorsal lobe and a relatively narrow ventral lobe. The symbiotic Blue Green Alga is exclusively localized within the dorsal lobe.

Azolla as Green manure

Azolla was predominantly cultivated as a green manure for rice cultivation. However, it is also cultivated in conjunction with water bamboo (Zizanica aquatica), arrowhead (Sagittaria sagittifolia), and taro (Colocasia esculenta). The utilization of Azolla green manure resulted in a notable improvement in various growth parameters of rice plants, including the number of shoots, length of the longest leaf, fresh weight, and dry weight. The growth of Azolla resulted in an elevation of soil nitrogen levels comparable to those observed in a soybean crop. The utilization of Azolla as a form of green manure involves the direct collection of this aquatic plant from ponds or ditches. As previously said, this plant species has the potential to be cultivated in nurseries and afterward transplanted into field settings. A dense layer of Azolla will develop during a period of approximately 2-3 weeks following its application, and subsequently, it can be integrated into the soil. Furthermore, it is worth noting that rice can be transplanted in the field at a later stage. Split dosages of single super phosphate (25-50 kg ha–1) are applied. Upon analyzing the soil's phosphorus status, it is possible to decrease the dosage of phosphorus accordingly. Instead of single super phosphate, cattle dung or slurry can serve as viable alternatives. When faced with a pest infestation or attack, it is necessary to implement pest management methods. The application of Azolla by this method has been found to contribute approximately 20-40 kg N ha–1 (Yadav et al., 2014). The incorporation of fresh Azolla into the soil resulted in notable enhancements in many soil properties, including water-holding capacity, organic carbon content, ammonium nitrogen, nitrate nitrogen, and accessible phosphorus, potassium, calcium, and magnesium. Conversely, this incorporation led to a drop in soil pH and bulk density. These changes in soil characteristics had a major positive impact on the production of mung beans.

Azolla production technology is simple and not very expensive and at the same time, it is very efficient in terms of biomass accumulation and nitrogen fixation. The rice growing season is also conducive to the growth of Azolla plants.

Azolla - Soil nutrient availability

Azolla exhibits a remarkable ability to accumulate potassium (K) inside its tissues when subjected to conditions of limited potassium availability. Moreover, it demonstrates rapid

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breakdown, resulting in the liberation of vital nutrients such as nitrogen (N), phosphorous (P), and potassium (K) into the adjacent agricultural area following the drainage of water from the field. As stated by Bhusal and Thakur (2021), the aforementioned component exhibits the capacity to augment the solubility of Zinc (Zn), Iron (Fe), and Magnesium (Mg), hence enabling their absorption by the rice plant. Moreover, it facilitates the release of phytohormones and essential nutrients, hence enhancing the rate of agricultural productivity. The regular application of this approach has resulted in an increased availability of nutrients in the soil. In a general context, the application of Azolla improves the availability of soil nutrients through biological mechanisms, hence promoting the colonization of microorganisms that aid in mineralization. Following decomposition, Azolla released phosphorous (P) that subsequently became available in the soil. The Azolla plant exemplifies the positive results associated with the implementation of integrated soil nutrient management systems, a crucial element that is presently lacking in many Asian nations.

Biological nitrogen fixation

The utilization of Azolla in rice paddy fields has been found to have a beneficial impact on the soil fertility index. The capacity to perform nitrogen fixation is attributed to the existence of the symbiotic cyanobacterium Anabaena, which is found within the dorsal leaf chambers of the fronds. The symbiotic organism is capable of fulfilling the entirety of the nitrogen needs inside the mutualistic relationship. The Calvin cycle is functional in both the chloroplasts of plants and the principal outcome of the photosynthetic process is the synthesis of sucrose. There is a significant correlation between nitrogen fixation and photosynthesis, whereby

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photosynthesis serves as the primary source of ATP and NADPH. The nitrogen-fixing ability of Azolla in agricultural settings has been quantified to be approximately 1.1 kg N ha–1 day–1. This amount of fixed nitrogen is deemed adequate to fulfill the complete nitrogen needs of the rice crop within a short period.

Effect of Azolla on weeds

According to Sureshkumar et al. (2016), the presence of weeds can result in a decrease in rice output, with reductions ranging from 15% to 20% and potentially reaching up to 50%. The presence of Azolla on the water surface leads to a reduction in the amount of light that reaches the soil surface, which subsequently decreases the germination rate of weeds by around 70%. Therefore, the proliferation of Azolla in flooded rice fields has the effect of diminishing the presence of aquatic weeds such as Echinochloa crus-galli, Cyperus sp., Paspalum sp., among others. Consequently, this phenomenon contributes to the enhancement of crop development and production.

Other uses

Azolla is utilized as a source of fish feed and as a means of weed management. Additionally, it serves as an effective method for mosquito control and is cultivated as a fodder crop. Azolla was utilized as a feed source for various livestock species, including pigs, ducks, chickens, cattle, and fish. The utilization of Azolla for water purification and its incorporation as a constituent in soap manufacturing has been observed among certain African tribes. In New Zealand, the practice of chewing was employed as a means to alleviate symptoms of sore throat. Azolla is utilized in the formulation of cough medicine. Azolla is utilized as a constituent of the Space Diet and is also employed in the generation of biogas.

Conclusion:

Effective soil health management is a crucial aspect of achieving sustainable intensification in agriculture. It has been observed that Azolla, a type of aquatic fern, can significantly impact the overall composition and activity of nitrogen-fixing bacteria within the soil and microbial community. The enhancement of soil enzymes will lead to an improvement in the soil fertility index. Consequently, the utilization of highly effective strains of Azolla is imperative to sustain soil fertility. The rapid rates of growth exhibited by Azolla contribute to the mitigation of environmental concerns, rendering it a cost-efficient approach to the development of wetland ecosystems. Before employing Azolla as a farming technique, it is imperative to evaluate the economic aspects associated with its utilization. This is mostly due to the labor-intensive nature of the technology, making it more viable in regions where agricultural labor costs are somewhat inexpensive. In addition to its applications as a biofertilizer and cattle feed, Azolla, a very valuable natural resource, is also employed in the fields of medicine, water purification, human nutrition, and biogas production. The Azolla-Anabaena system demonstrates significant potential as a biofertilizer for rice cultivation, while also exhibiting several additional applications. To enhance its efficacy within the agricultural and related sectors, a concentrated effort is necessary. Therefore, it is imperative to prioritize the resolution of specific pivotal concerns about Azolla to optimize its exploitation and enhance its utilization. The promotion of Azolla as a viable bioinoculant for sustainable crop production and development necessitates collaborative efforts from policymakers, scientists and farmers.