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Improving soil fertility through Azolla application in low land rice: A review

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ABSTRACT

The continuous usages of chemical fertilizers have harmful effects on soil organic matter reserves, soil health and environmental safety. The use of Bio-fertilizers like Azolla not only increases the rice productivity but also improves the long term soil fertility. Azolla is a fast growing aquatic pteridophyte which fixes atmospheric Nitrogen by forming a symbiotic association with the Blue-Green Algae, *Anabaena azollae*. Azolla is an efficient Nitrogen fixer. It is grown in lowland rice fields because flooded habitat is suitable for it. Under favorable field condition, it fixes atmospheric nitrogen at a rate exceeding that of the Legume-Rhizobium symbiotic relationship. It increases the rice yield equivalent to that produced by 30-60 kg N/ha. As green manure in water logged soil, it enhances the rapid mineralization of nitrogen. It reduces the NH_3 volatilization losses through its influence on floodwater pH that leads to the conservation of urea-N in the system to improve the efficiency of N fertilizers. It significantly improves the physical and chemical properties of the soil including improvement in soil microbial activities. It helps in addition of Organic Matter and release of cations such as Magnesium, Calcium and Sodium. The total N, available P and exchangeable K in the soil and N-uptake by rice can be improved. Therefore, Azolla application is considered as a good practice for sustaining soil fertility and crop productivity irrespective of some limitations.

INTRODUCTION

Azolla is a fast growing free floating freshwater fern. It is a small pteridophyte which doubles its biomass in 3-5 days and fixes atmospheric nitrogen by forming a symbiotic association with the Blue-Green Algae, *Anabaena azollae* (Bhubaneswari and Kumar 2013). Azolla has characteristic bilobed leaf that consists of a dorsal and ventral lobe. The dorsal lobe is green or purple in colour and has a central cavity which houses the symbiotic *Anabaena azollae*. The ventral lobe is relatively thin and always remains partially submerged in water and provides buoyancy (Raja et al. 2012). The symbiont liberates a substantial amount of biologically fixed nitrogen as ammonia which is absorbed by the host through branched hairs present in the cavity and unbranched hairs transport fixed carbon from host to the Cyanobiont (Peters et al. 1980). *Azolla* species live in areas where there is plenty of water like lakes, streams, swamps and other small water bodies. The most suitable target crop for the application of Azolla is lowland rice because both plants require similar environmental conditions i.e a flooded habitat and they grow together compatibly. The worldwide distribution of Azolla is represented by following six recognizable species: *A. pinnata, A. filiculoides, A. rubra, A. microphylla, A. imbricate* and *A. caroliniana* and all these contain the *Anabaena* association (Giller 2001; Raja et al. 2012).

The application of nitrogenous fertilizers has become a crucial practice to increase per unit yield of any crop since most of the agricultural soils are deficit in Nitrogen. But the continuous usages of such chemical fertilizers has created harmful effects on soil organic matter reserves thereby making further deficiency in Nitrogen (Hossain et al. 2001). Similarly, the nitrogenous fertilizers cause acidification of the soils (Stumpe and Vlek 1991) and significantly reduce the microbial activity in the soil in long run (Sutton et al. 1991). The application of chemical fertilizers has adverse effects on long term soil fertility, soil productivity

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and environmental safety. Therefore, a new strategy should be taken in account to utilize the biological fertilizers that will not only increase the rice productivity, but also improve the long term soil fertility.

Therefore, an intensive reviews on role of Azolla in soil fertility enhancement has been carried out with following objectives; i) To know about the roles of Azolla as biofertilizer for soil nitrogen fertility in low land rice and ii) To know about the effects of Azolla on different soil fertility parameters.

METHODOLOGY

In total 36 research papers from 1969 to 2014 were collected for getting information on the roles of Azolla to enhance the soil fertility. The collected information was arranged systematically under sub headings namely; the efficient biological nitrogen fixer and biofertilizer, as green manure crop, reduction of NH_3 volatilization and increased N use efficiency, soil physical and chemical property enhancement, mineralization and other nutrient availability, soil organic matter content and biological activities. The research papers were collected from journal articles, proceedings, reports, books and online internet sources.

DISCUSSION

The efficient biological nitrogen fixer and biofertilizer

Azolla is considered as a natural nitrogen (N) factory because it can fix atmospheric nitrogen (N_2) with the help of *Azolla anabaena*. The ability of nitrogen fixation is due to the presence of the symbiotic cyano-bacterium *Anabaena* that occurs in the dorsal leaf cavities of the fronds (Peters and Meeks 1989). The symbiont is able to meet the entire nitrogen requirement of the association. The nitrogen fixing capacity of Azolla has been estimated to be 1.1 kg N/ha/day and this fixed nitrogen is sufficient to meet the entire nitrogen requirement of rice crop within a few weeks (Lumpkin and Plucknett 1980). Similarly, under favorable field condition, this association can fix atmospheric nitrogen at a rate exceeding that of the legume-Rhizobium symbiotic relationship (Lumpkin and Plueknett 1985). Azolla is of great agronomic value for rice crop where it is used as dual crop with rice and contributes 40-60 kg N/ha per rice crop (Kannaiyan 1982). *Azolla* species have been successfully exploited as an efficient biofertilizer for rice paddy fields because of the nitrogen fixing potential. The characteristics of Azolla as biofertilizer for rice include; requirement of shallow freshwater habitat, rapid growth, high nitrogen fixing capacity, quick deposition and growth along with rice without competing for light and space (Vlek et al. 1995). *A. pinnata* fixes 75 mg N/g dry weight/day and produces a biomass of 347 ton fresh weight ha^{-1} in a year. This biomass contains 868 kg N which is equivalent to 1900 Kg urea (Yadav et al. 2014). Thus, Azolla forms an economical and ecofriendly biofertilizer which provides unseen benefits in terms of carbon and nitrogen enrichment of soil and overall improvement in soil/crop management practices and fertility status (Kaushik and Prasanna 1989).

As green manure crop

Utilization of Azolla as a green manure in rice fields has been extensively studied. Azolla is an excellent source of nitrogen fertilizer for rice which can reduce or even eliminate the use of chemical fertilizers. Watanabe et al. (1989) found that the use of Azolla can replace 30–60 kg of mineral N fertilizer depending on frequency and time of incorporation. Incubation of Azolla as green manure in water logged soil resulted in rapid mineralization of Nitrogen with release of 60-80% of the nitrogen within two weeks (Ito and Watanabe 1985). According to Gopalaswamy and Kannaiyan (2000) Azolla incubation significantly improved the microbial population including cellulolytic, phosphate solubilizing and urea hydrolyzing bacteria. A study showed that the response of Azolla as green manure was better in dry season than in wet season and short duration rice varieties responded better than the late duration varieties (Singh 1989).

Reduction of NH_3 volatilization and increased N use efficiency

Sisworo et al. (1995) described Azolla grown in standing rice crop buffered soil nitrogen availability, absorbing available excess N in early rice growth stage and releases N at later stage which is helpful to increase N use efficiency. From the research evidences it was found that Azolla used as a cover on the floodwater surface of rice can indeed control the volatilisation losses through its influence on floodwater pH (Kern et al. 2007), the most important factor influencing NH_3 volatilization. A full Azolla cover on the floodwater surface at the time of the first urea application effectively prevented the rapid increase in floodwater pH associated with urea hydrolysis (Reddy et al. 1990) and the algal photosynthetic activities. Ammonia volatilization and the gaseous emission of NH_3 to the atmosphere are reportedly the major cause of low N fertilizer efficiency and important mechanisms for N losses in lowland rice fields. And such gaseous losses are responsible for substantial economic loss to farmers and create negative impacts on the atmosphere and water quality. Therefore, use of Azolla to improve the N fertilizer efficiency has created a more concern (De Macale and Vlek 2004). Also, the Azolla cover reduces the floodwater temperature significantly compared to the Azolla free plots. Flood water temperature affects the relative proportion of NH_3 volatilization present at a given pH (De Macale and Vlek 2004). Rice crop is a poor competitor for available Nitrogen early in the growing season. As a result Azolla effectively competes with young rice plants for applied N, taking nearly twice the urea-N than the rice plants. This leads to the conservation of urea-N in the system, yielding a complete N recovery in the system early in the growing season (Hatt and Weber 2008). Many researches have shown that Azolla incorporation helps to improve the efficiency of N fertilizers for lowland rice. The N use efficiency with Azolla application was found to be increased from 32% when Azolla was applied alone and to 43-53% when it was applied in combination with 100 kg N/ha. This showed an interaction between them which resulted in a more efficient use of N from both sources (Kumarasinghe and Eskew 1993).

Soil physical and chemical property enhancement

Azolla application in rice fields sustains the soil fertility index. Van Hove (1989) found that Azolla improves soil structure. It has been found that Azolla significantly improved the physical and chemical properties of the soil especially Nitrogen, Organic Matter and release of other cations such as Magnesium, Calcium and Sodium (Bhuvaneshwari and Kumar 2013). Kotpal and Bali (2003) stated that after its decomposition, humus is formed which increases the water holding capacity of the soil and promotes aeration and drainage. Similarly, Azolla use is also an affordable practice and does not cause eutrophication and perturbation of soil (Scheir 1999). The value for soil N, soil OM, bulk density and porosity of the soil were found to be increased simultaneously for Azolla treatments; 0, 20, 40, 60 and 80 g/kg soil in all incubation times; 2^{nd}, 4^{th}, 6^{th} and 8^{th} week (Awodun 2008). Similarly, total N, available P, exchangeable K and N-uptake found to be increased simultaneously for *A. pinnata* treatments; 0, 2.5, 5.0, 7.5 and 10 t/ha (Rivaie and Isnaini 2013).

Mineralization and other nutrient availability

Azolla has low C:N ratio, therefore it is mineralized more faster than other species (Wang et al. 1987) and supply nitrogen to the crop plant. It also contributes to the supply of Phosphorus, Potassium, Sulfur, Zinc, Iron and Molybdenum in sufficient amounts in addition to other micronutrients besides addition of Nitrogen. Similarly, the soil biological health due to application of Azolla has resulted in improving mineralization and consequent increase in the soil microbial status (Yadav et al. 2014). The soil fertility is also influenced by the humic substances formed during the decomposition of Azolla (Bhardwaj and Gaur 1970). Similarly, its application as a green manure on agricultural lands can increase the availability of nutrients and improve soil physical properties, especially the soil porosity (Singh and Singh 1990; Choudhary and Kennedy 2004).

Soil organic matter content and biological activities

Soil fertility is influenced by the humic substances formed during the decomposition of Azolla (Bhardwaj and Gaur 1970). Application of Azolla enhances the soil nutrients availability by their biological activity in particular and helps build up the micro flora. The decomposed organic matter from Azolla biomass plays an active role in the development of microbial population irrespective of the time taken for mineralization. Its continuous application increased the organic nitrogen content of the soil significantly (Yadav et al. 2014). Similarly, Kannaiyan and Subramani (1992) stated that there were increased cellulolytic and urea hydrolyzing activities in addition to significant increase in the population of heterotrophic bacteria due to Azolla application. Azolla incorporation also increased the soil urease and phosphatase activity (Thanikachalam et al. 1984). Therefore, besides sustaining rice yields, it also enhances the soil biological health and optimize use of organic, inorganic and biological inputs in an integrated manner taking into consideration the ecological and soil conditions to sustain crop productivity (Yadav et al. 2014).

CONCLUSION

There is an increasing concern about sustaining soil fertility and environmental health. Application of biofertilitzer like Azolla could help effectively developing countries to improve a more sustainable agriculture, without the risk of problems associated with the adverse effects of chemical fertilizers on long term soil fertility, soil productivity and environmental issues. Application of Azolla has been found to improve the physical and chemical properties of the soil and microbial population of the soil. These improvements were significant for soil Nitrogen, Organic matter and other cations (Mg, Ca and Na) which directly help for improving the soil fertility.

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