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Rice cum Fish Culture (*Rizi – Pisciculture*) Based Farming Systems – A Way Forward for Organic Rice Production to Enhance Soil and Crop Productivity, Profitability, and Nutritional Security of the Marginal Farmers

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Introduction

Tamil Nadu is one of the most important states for rice production in India because of its favourable soil and climatic conditions. Rice in Tamil Nadu is mainly grown in the Cauvery Delta Zone (CDZ), which lies in the eastern part of the state. The CDZ has a total land area of 1.45 million ha, which is equivalent to 11% of the state area. Rice dominates in the cropping systems of Cauvery Delta Zone. It is understandable that with North East monsoon rains pouring at high intensity for short spells coupled with flat slopes and heavy soil, rice is the only ideal crop. Though rice is cultivated predominantly in Cauvery Delta Zone, due to increase in the cost of inputs especially chemical fertilizers, the net return per hectare in rice hardly exceeds Rs. 25,000. It is evident that intensification of mono-culture of rice production system leads to anthropogenic alterations that negatively impact the soil physico-chemical and biochemical indicators resulting in loss of biodiversity and degradation of natural resource base, making farming unsustainable in the long run (Nayak *et al.,* , 2020). The farming constraints in rice growing areas are poor rainfall distribution linked to monsoon based monocropping of rice, dismal economic returns from rice, inadequate or absence of diversification of farm components and exclusive dependence on agrochemical inputs (Kathiresan *et al.,* , 2020). Under such a circumstance, any approaches that would reverse soil degradation, conserve natural resources, improve the soil fertility is need of the hour to stabilize the farm revenue.

Integrated farming systems (IFS) is normally viewed as a sustainable alternative for enhancing livelihood security of small and marginal farmers. However, the successful adoption of IFS is facing challenges of declining land holding size. In the low-lying areas, integration of different enterprises needs proper system, development and validation. The small and marginal farmers may not prefer to invest more for the implementation of IFS. Another major hurdles in adopting IFS are marketing of low volume farm products like egg, chicken, flowers, vegetables and fruits under small farmers' holdings. In CDZ, the farm families never stay in the field where the system will be developed. Hence feeding the animals, birds would be very difficult. Due to the above said reasons, the security of the different components also remains a big challenge. Hence an alternate farming system which integrates an enterprise in the rice field would promote higher farm productivity with minimal risk needs to be evaluated. The rice-fish system was observed to be a profitable technology and that adoption increased household income, labour absorption and better liquidity (Purba *et al.,* , 1998). Main beneficial effects of rice-fish culture were related to environmental sustainability, system biodiversity, farm diversification and household nutrition (Rothius *et al.,* , 1998). Integration of fish in rice fields increased dietary standards in terms of animal protein requirement of the poor rural households (Guttman, 1999). Use of organic manures along with organic pest control in rice was demonstrated as a sustainable approach in rice farming with enhanced crop productivity, improved soil fertility status, increased economic return and reduced agrochemical input (Jayakanth *et al.,* , 2000).

Fertilization of Rice Fields

Increase in the cropping intensity, and higher rates of organic matter decomposition under the existing hot and humid climate, lesser application of organic manure and negligible dependence on green manure practice etc. has led to decline in the crop productivity due to depletion of soil nutrients. Nitrogen (N) is the main limiting nutrient element in paddy fields (Zhu *et al.,* 2018). Thus, a large amount of N fertilizer is needed to meet the demand for rice production (Wang *et al.,* 2017). Excessive applications of chemical N fertilizer increase farmers' input costs, bring about low N use efficiency (Liu *et al.,* 2018), and bring about many environmental problems (He *et al.,* 2018). The use of green manures (GMs) cultivated in agroecosystems is an alternative approach that can be used to solve the problem of excessive N fertilizer application (Zhang *et al.,* 2016) and to improve rice production

Green manuring

Green manuring with nitrogen fixing legume crop can provide a substantial portion of N requirement for rice and also add organic matter (OM) to maintain soil fertility which is essential for sustainable agriculture. Green manuring crops not only transfer nutrients to soil but also can lead to deep root system for nutrient uptake from deeper soil causing absorption of less available nutrients, thereby increasing concentration of plant nutrients in the surface soil (Noordwijk *et al.,* 2015), and reducing the use of fertilizer (especially N). Hence GM can prevent the environmental risks related to $NO3^-$ leaching. Well nodulated Sesbania plants can derive up to 90% N from fixation (Pareek *et al.,* 1990) and consequently contribute N in rice cultivation. Hence a viable option is to grow the GM crop and apply it to the soil to reduce the application of synthetic N fertilizer and to improve subsequent crop productivity.

Azolla

Azolla is a free-floating aquatic fern, and naturally available mostly on moist soil, ditches and marshy ponds and widely distributed in tropical India. Nitrogen fixing capabilities of Azolla through the symbiotic cyanobionts (around 1100 kg N/ha /year to the plants) are making plant unique and considered as one of the best bio-fertilizer, feed for livestock and biofuel. Azolla in the rice fields provides substantial amount of nitrogen for rice growth and reduces weed infestations.

Phosphorus, Potassium and Zinc solubilising bacteria

Zinc deficiency in plants leads to retarded shoot growth, chlorosis, reduced leaf size (Alloway, 2004), susceptibility to heat, light and fungal infections, as well as affects grain yield, pollen formation, root development, water uptake and transport. However due to continuous application of Zinc sulphate @ 25 kg/ in the Cauvery delta Zone leads to increase in the total Zinc content. But the available zinc level is very low. Plants can uptake zinc as divalent cation but only a very minor portion of total zinc is present in soil solution as soluble form. Rest of the zinc is in the form of insoluble complexes and minerals. Due to unavailability of zinc in soil, zinc deficiency occurs which is one of the most widespread micronutrient deficiencies. Plant growth promoting rhizobacteria (PGPR) are soil borne bacteria that colonize the rhizosphere, multiply and compete with other bacteria to promote plant growth (Kloepper and Okon, 1994). Various PGPR have found to be effective zinc solubilizers. These bacteria improve the plant growth and development by colonizing the rhizosphere and by solubilizing complex zinc compounds into simpler ones, thus making zinc available to the plants. Hence Zinc solubilizing bacteria can be used to alleviate Zn deficiency in rice cultivation. Similarly, potassium solubilizing bacteria (KSB) can solubilize K-bearing minerals and convert the insoluble K to soluble forms of K available to plant uptake. The KSB are effective in releasing K from inorganic and insoluble pools of total soil K through solubilization (Saha *et al.,* , 2016). Phosphorus-solubilizing bacteria are commonly used plant probiotics that promote plant development by converting insoluble P into soluble P that is easily absorbed and used by roots (Hamid *et al.,* , 2021). Hence PGPR lant growth-promoting rhizobacteria (PGPR) which enhances biological nitrogen fixation (BNF), synthesis of plant hormones, soil nutrient solubilization (as phosphorus [P] and potassium [K] can be used in rice cultivation to avoid chemical fertilizers.

Rice-Fish- Duck-Azolla culture

Rice-fish culture is an innovative farming system in which rice is the primary crop and fish fingerlings are used as a secondary source of income. Farmers' poverty is reduced as a result of rice-fish farming, which improves yield, creates jobs, and increases nutritional consumption, resulting in food security. Farmers who are youthful, have a larger farm size, and stronger infrastructure is able to make higher money, according to the farm-specific characteristics used to explain income. Among the various farming system options in rice ecologies, rice-fish farming having a great potential in eastern India considering its ecology, available resources, food habits, socioeconomic and livelihood conditions of small and marginal farmers (Nayak *et al.,* , 2020). The benefits of Rice-Fish farming are as follows.

1. Increase in organic fertilization by fish excreta and remains of artificial feed.
2. Better tillering of the rice seedlings due to the activity of the fish and duck
3. Reduction in the number of harmful insects, such as paddy stem borers, whose larvae are eaten by fish.
4. Reduction in rat population due to increase in the water level.

5. Increased mineralization of the organic matter and increased aeration of the soil resulting from the puddling of mud by benthic feeders.
6. Control of algae and weeds (by phytophagons fish) which compete with rice for light and nutrients.
7. Reduces the amount of farm input required.
8. Diverse sources of income
9. Provides farmers with a well-balanced, nutritious diet.

In this method of farming technology, ducks and fish in rice field creates symbiotic relationship between rice-fish-duck yielding maximum mutual benefits to all the entities. Ducks and fishes control the harmful insects and weeds, dropping utilized as organic manure and mobilization of nutrients, activities (continuous movement, scooping and churning of soil) aerate the rice ecologies which increases the availability of nutrients (like nitrogen, phosphorous and potash) to the rice crops, enhances biodiversity and reduces the global warming potentials. RFD-IFS technology reduced the cost of cultivation, increases. Fish grown in the paddy fields, will be ideal use of land and would also be an easy source of cheap and fresh animal proteins. Thus, fish culture can greatly contribute to the socio-economic welfare of rural populations of especially developing countries. An added advantage also is that unlike sea fish or other animal proteins, the fish from the local paddy fields would cause no transport problem and would be most fresh and healthy.

The integration of duck, fish and azolla in the rice field creates symbiotic relationship. Rice-fish, duck and azolla provides mutual benefits to all the entities. The ducks and fish bioturbation (rapid movement) and presence of azolla in the rice ecosystem enhances the concentration of dissolve oxygen in water, resulting aerobic conditions, which decreased methanogens bacterial activity and subsequently decreases the GHG emissions. Azolla used as one the feed components for animals reared (fish, duck) in the systems. The integrated system enhances biological diversity leading to augmentation of nutrient mineralization through faster decomposition of organic matters, thereby enhances the release and availability of nutrients to supports better growth and productions. The RFAD-IFS utilizes the maximum ecological niches, increases soil and water nutrient levels and fertility, provides healthy ecosystem services and reduces the GHG emissions, hence, increases the farm productivity and sustainability

Conclusion

Integrating Rice-Fish-Azolla-Duck would not only increase the farm productivity and profitability and also increase the soil fertility which could be a way forward in organic production of rice.

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