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Potentials and Possibilities of Duckweed Aquaculturein Rural India-An Overview

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Abstract—*Duckweeds are tiny, free floating, aquatic green plants commonly found in lentic or slowly moving water bodies, belonging to the family Lemnaceae. They significantly improve the quality of waste water through virtual natural treatment with respect to Biological Oxygen Demand (BOD), total nitrogen, total phosphorus, total suspended salts, electrical conductivity and total dissolved solutes. Duckweeds can be readily used as a feed for fishes, poultry, pigs and ruminants because of their amino acid profile. Further, duckweeds can be readily harvested and their biomass can be used for bio fuel and bio plastic production. The present paper emphasises on the different aspects of duckweed aquaculture.*

Keywords*: Lemnaceae, BOD, TSS, eutrophication , bio fuel*

1. INTRODUCTION

For more than twenty five years, duckweed aquaculture have been a potential technology to combine both waste water management and feed production in developing and industrialized countries. Duckweeds are tiny, free floating plants that belong to the family Lemnaceae. Morphologically the plantare with tiny leaves only a few millimetres wide, having unique growth characteristics. The Lemnaceae family includes five genera and fourty known species. Five common genera include *Lemna* ,*Spirodela*,*Landoltia*, *Wolffia* and *Wolfiella*.[14]These aquatic macrophytes include the smallest flowering plants. The Lemna species has been reported to be 6-8 mm in length and are made up of green vascular fronds that resemble fusion of leaves and stem. Plants of duckweeds propagate through vegetative propagation and their biomass doubles' in almost 48 hours under controlled and axenic culture [14]. A steady supply of nutrients and trace elements are needed for its optimum vegetative growth.Generally, nutrients from various agricultural land, sewage system faecal matter of animals causes eutrophication of rural water bodies, thus promoting the growth of duckweeds. A complete covering of the duckweedsin the water body block sunlight, decreasing the rate of photosynthesis and subsequently oxygen causing hypoxia. This in turn has a positive impact on duckweed growth ensuring a positive feedback loop.[1]

Duckweeds are capable of accumulating nutrients and minerals from the waste water. They have a comparatively high productivity and nutritional value and thus should be harvested from the pond regularly. They also have a high protein content and is used a feed supplement for fishes and poultry birds. They also can be used for production of bioethanol as a source of bio fuel.15]. Today, thanks to its rapid growth, short life span, simple axenic culture on liquid medium and high content of protein, plants of Lemnaceaeare of great interest as an ideal and efficient plant expression system for production of foreign target proteins.[2]

The following aspects of Duckweed aquaculture are discussed below-

1. **Wastewatermanagement**- Duckweeds has been used for treatment of dilute and raw sewage arising from the industry as well as domestic sewage. Since Lemnaceae shows a very high capacity of accumulating heavy metals and organic xenobiotics in their tissues , it makes them potentially suitable for removal of these compounds from the industrial wastes. Duckweed water treatment system can be designed and operated as as a plug flow and a batch A plug flow system is more suitable for treatment of larger amount of waste water originating in urban areas [2]. The plug flow system ensures an improved and more continuous distribution of the nutrients system. A batch system is applicable at the village level, where the pond act as batch reactors [2].

The batch culture technique is based on and designed on conventional stabilisation ponds or may be type of aquatic bodies with addition of a floating grid system made up of bamboo. A narrow pond channel is more suitable than a wider one. However, primary treatment of raw waste water is essential for initial separation of some of the settleable fractions of pathogens , solids and floating materials. Adequate pre-treatment is also important to release organically bound N_2 and phosphorous through microbial hydrolysis. This is because availability of ammonium (NH_4^+) and phosphates (PO_4^-)is a limiting step for treatment of waste water with high

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BOD load, such as from sugar, rubber and food processing industries [15]. For village purpose, latrines of pour flush types can be used for nutrient supply to duckweed ponds.[3] Simultaneously which will be usefull for recycling of faecal matter in the light of biodegradable recycling and can desist faecal borne diseases to the human beings, particularly in rural areas where sanitation system is still not up to the mark of satisfaction. In this case, a submerged bamboo case is made that acts as a pre-treatment stage for anaerobic digestion.

Table 1: Range of nutrient concentration in water for optimum growth of Duckweeds (Landolt 1996)

Chemical elements are expressed in mg/l and conductivity in µs/cm

Parameters	Absolute range
pH	3.5-10.4
N	0.003-43
K	0.5-1.0
Ca	0.1-0.365
Mg	0.1-0.230
P	0.001-54
Conductivity	10-10900

Benefits of duckweed cultivation in waste water management

- **TSS removal**-T.S.S are removed mainly by sedimentation and biodegradation of organic particles in the pre-treatment in a duckweed pond. A minor fraction is absorbed by the roots of duckweeds, where organic particles undergo aerobic biodegradation by micro organisms and a part of the degraded product is assimilated by the plants. Since enormous algal mat contribute significantly to the T.S.S concentration, duckweed mat prevents penetration of sunlight and subsequent growth of algae.[4]
- **BOD removal** – It is generally said that BOD is substantially removed by both aerobic and anaerobic micro organisms associated with the plant surfaces.[5]
- **Nitrogen removal**- The nitrogen balance in a duckweed pond is maintained by the plant uptake ,denitrification, volatisation of ammonia, microbial uptake and sedimentation. Results suggests that approx 50% of the total nitrogen load is assimilated by duckweed while the remaining nitrogen is removed by microbial degradation through natural process.[6]
- **Phosphorous removal**- In aDuckweed treatment system, phosphorous is normally removed from the system by the following mechanisms like plant uptake, adsorption to clay particles and organic matter, chemical precipitation with Ca^{2+}, Fe^{3+} , Al^{3+} and microbial uptake.[6-7]
- **Removal of Heavy metals and Organic Compounds**-Duckweeds can be used for efficient removal of metals from waste water. This is because Lemnaceae can tolerate and accumulate high concentration of heavy metals and organic compounds with accumulation factors ranging between multiples of 10^2 to 10^5.[7]

1. **Nutritive value of Duckweeds**- The amino acid profile of duckweed compares favourably with FAO reference and resembles more closely with animal protein (except methionine and tryptophan that are found in trace). Other important compounds like minerals and vitamins are also found in Duckweeds. Duckweeds contain about 40 different minerals including vitamins A,B_1,B_2, B_6, C, E, and PP. Especially the contents of Vitamin E (20-40ppm) and PP factor (40-60ppm) are remarkably high along with fairly high concentration of Xanthophyll and Carotene. The low fibre content of duckweeds and high nutritive value makes it a quality food for animals including humans. [7]
2. **Duckweed as fish feed**- Duckweed can be fed fresh or in a combination with other feed components to a fish polyculture of Indian and Chinese carp species like Grass carp(*Ctenopharyngodonidella*), silver barb *(Puntinus*gonionotus*)* and tilapias (*Oreochromis sp*.). The smaller duckweed species like *Wolffiasp, Wolfiella sp. and Lemna sp.* are reported to serve as feed for fry and fingerlings.[8]
3. **Duckweed as poultry feed**- Chickens are preferably fed on dried duckweeds where an increase of 10-30% in dry weight takes place. Ducks readily fed directly on fresh duckweeds from the pond surface showed an overall 15-25% increase in their dry weight.[9-10]
4. **Duckweed as Ruminant Food**-Russoff et al (1985-86) suggested that a maximum of 75% of the total food of cattle can compromise of duckweed without affecting the taste of milk. The weight gain of calves fed with 67% of duckweeds and remaining 33% with silage of corn showed a daily weight gain of 0.95 kg compared to 0.5% kg weight gain when fed on a concentrate of corn silage diet.[11-12]
5. **Duckweed as Agriculture fertilizer**-Use of Lemnaceae as a fertilizer and soil improver on fields and gardens was first reported in countries like Angola, China and Mexico. According to Lot etal (1979) application of duckweeds contribute significantly to a superior soil texture, including an improved water and cation exchange and resulted in annual harvest of four crops annually.*Lemnaaoukikusa*and*Lemnaminor* host a plant growth promoting soil bacteria *Cinetobactercalcoaceticus.* This bacteria promotes the growth of the duckweeds and also of other plants,[17] may be a possible question of symbionts.
6. **Production of Bio Fuel**-Researches have demonstrated can be regarded as a potential feedstock for bio ethanol production, because of its high starch accumulation which is about 5%-6% of their dry weight. Starch accumulation

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is affected by many factors like temperature, nutrient deprivation and light duration. *Lemnaaequinoctiales* strain 6000 has been successfully used for bio etanol production due to low cellulose and lignin content by two step enzymatic breakdown.[6]

7. **Production of Bio plastics**- Zeller, Hunt and Sharma suggested that duckweed can be used that duckweed can be used as bio plastics. Duckweed bioplastic can be comparable with other bioplastic materials and with high protein content duckweeds can be a significant source of bioplastics in the near future.[6-16]

2. IMPORTANT PARAMETERS FOR BATCH CULTURE TECHNIQUE OF DUCKWEEDS

1. **Water Depth** - The critical factor in respect to water depth ensures vertical mixing in the pond, so that waste water comes in direct contact with the duckweed fronds for nutrient uptake and BOD degradation. Reported pond depth ranges from 0.3 to 2.7 metres to a maximum upto 5 meters.[2]

2. **Wind protection**- Since duckweeds are susceptible to wind drifts and water current, they must be floating grids made of bamboo dividing the ponds into cells or compartments. Floating bamboo poles into small rectangular areas of 2-5 by 4-8 m are most commonly used.[2]

3. **Labour requirements**- Duckweed shows a maximum growth in a narrow range of optimum environmental conditions. Maintainence of these optimum conditions requires regular, experienced and skilled labours.[2]

4. **Harvesting of Duckweeds**- The quantity and frequency of duckweed harvesting plays major role in the treatment efficiency and nutritional value of the plants. Regular harvesting ensures removal of accumulated nutrients and toxins in the water. Because younger plants show a better nutrient profile and higher growth rate, regular harvesting is important. [2]

5. **Relief for heat stress**- Duckweeds growth rapidly decreases at the temperature above 31^0C to 35 ^{0}C as the plant exhibits severe heat stress. This can be prevented by planting tress like papaya, banana, bamboo that can protect the duckweeds from heat stress which can add to the additional net income.[1-3]

3. CONCLUSION

For more than 40 years, duckweed aquaculture has been used as potential technology for waste water treatment and feed production. The rapidly growing free floating aquatic plants of botanical names Lemnaceae are capable of accumulating nutrients and minerals from waste water. Their high productivity and high nutritional value provide excellent feed supplement for animals such as fish, pigs, cattle and poultry birds. Duckweed aquaculture to create a financial incentive and income to the rural inhabitants of our coutry. Thus the full potential of duckweed lies in its combined use in waste water management, feed production and income generation.

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