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Azolla for Socio-Economic Development of Farming Community and Environmental Benefits

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ABSTRACT

Aquatic fern, *Azolla* is an under exploited multi utility resource, offering socio-economic and environmental benefits in different forms (fresh, dry and compost). It could serve as a potential manure or fertilizer and quality feed stuff for efficient nutrient recycling in agriculture, livestock, poultry and aquaculture sectors, consequentially curtailing input cost and enhancing farm output for higher economic returns. Its role as bio-fertilizer in paddy fields is well known. As manure it improves soil health by adding nutrients (N, P and K), carbon and organic matter into the soil. Unlike traditional mulching materials, *Azolla* provide additional moisture to the soil, besides conserving soil moisture and checking weed growth in orchards and vegetable fields. Further, it serves as a low cost protein rich feed resource for animals like cattle, pigs, goat, poultry, ducks and fish for improved health and increased production of milk, eggs and meat. Known for its historic role in cooling down the earth about 50 million years ago by carbon dioxide sequestering, *Azolla* needs to be exploited by the farming community in such a way that it is cultivated and utilised in maximum possible forms without much cost, labour and extra land requirement for socio-economic and environmental benefits.

Key Words: *Azolla*, Carbon Dioxide, Compost, Feed, Manure, Mulching, Orchards.

INTRODUCTION

Owing to continuous increase in environmental pollution and global warming, efforts are being made worldwide to sustain food production targets through suitable technological interventions involving environmental health management and diversification in food production sectors viz; agriculture, animal husbandry, dairy and aquaculture. In this direction, more emphasis is being laid on adoption of organic farming technologies, which can help the farming community economically, besides offering environmental benefits. With increasing concerns towards environmental health and food safety, enhanced public awareness is also demanding organic solutions to pollution and global warming. Further, the farming community needs low cost innovations to cut down input cost without affecting its output. In this context, locally available low cost organic resources are expected to play an important role.

Azolla as a solution

Azolla is one of such organic resources, which can be used in different forms in agriculture, livestock and aquaculture sectors for economic and environmental benefits, without much labour and cost. Although, *Azolla* is well documented as a potential fertilizer and feed resource in agriculture, livestock and aquaculture sector (Hasan and Chakrabarti, 2009; Chander, 2011; Anitha *et al,* 2016; Brouwer *et al,* 2018), but its actual potential has not been realised so far. *Azolla* is an aquatic nitrogen (N_2) fixing fern, which grows very fast and has been used in paddy fields as a potential Bio-fertilizer for more than 1000 years. *Azolla* is a surface floating type of aquatic plant, which doubles its biomass in 2-5 days (Watanabe *et al,* 1989; Hasan and Chakrabarti, 2009) under ideal environmental conditions (temperature 18-26^{0}C and pH 5.5-7.0). An *Azolla* mat spread over 1 hectare (ha) of water surface can fix 1-2.5 kg atmospheric nitrogen daily,

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Table 1: Nutritive composition (%) of *Azolla* (DM basis)

Dry matter	Crude Protein	Ether Extract	Crude Fibre	Total Ash	Reference
5.6	26.7	4.6	11.2	15.1	Becerra *et al,* 1995
NR*	25.78	3.47	15.71	15.76	Basak *et al,* 2002
5-7	19-30	3-6	NR	14-20	Hassan and Chakrabarti, 2009
6.7	20.6	3.8	15.0	15.9	The *Azolla* Foundation http://theazollafoundation.org/
NR	21.5	3.3	16.1	19.2	Feedipedia, 2013
3.78-6.28	21.60-37.78	2.60-4.99	8.44-16.84	17.74-26.23	Kaur *et al,* 2016
4.7	22.48	4.50	14.70	17.34	Anitha *et al,* 2016

* Not reported

with annual biomass production of 300-600 tones (t), depending on the environmental conditions (temperature, pH and humidity) and nutrient status (nitrates and phosphates) of the water. *Azolla* is a good source of quality protein (15-40% on dry matter basis), which also varies with species, environmental conditions, culture practices and nutrient availability (Feedipedia, 2013; Kaur *et al,* 2015; Kaur *et al,* 2016; Brouwer *et al,* 2018; Slembrouck *et al,* 2018) (Table 1). Lysine and methionine content in most *Azolla* species has been reported to be higher than many conventional plant protein sources (Fiogbe *et al,* 2004) and also contain important minerals like calcium, phosphorus, potassium, iron, zinc and manganese (Kathirvelan *et al,* 2015). Further, besides absorbing atmospheric N_2, it has immense capacity to sequester carbon dioxide (CO_2) from the air (Speelman *et al,* 2009) at a faster rate as compared to other plants and; also holds good percentage (%) of water (94-96%). As per scientific estimates, available historical fossil records reveal that about 50 million years ago, when earth was a much hotter place, *Azolla* mat over the oceans (Brinkhuis *et al,* 2006) helped in cooling down the planet by sequestering about 10 trillion tons of CO_2 in 1 million years and transformed it from a hot ball to what it is today. *Azolla*'s cosmic potential to sequester CO_2 from the atmospheric is due to its rapid growth in water without any need for a soil-based nitrogen source.

The above listed properties make *Azolla* a multiple utility resource, which can be used as potential manure, nutritive feed ingredient and an effective mulching material in different farming systems, including agriculture, livestock, dairy and fisheries, besides alleviating global warming through CO_2 sequestering. Hence, it needs to be integrated with our traditional farming systems in such a way that it could offer all its benefits and help the farmers as a multiple utility resource, without any extra land requirements. *Azolla* culture technology is very simple, requiring two major inputs i.e., organic manure (mostly cow or buffalo dung) and water. Most of the rural households rear dairy animals to fulfil their domestic milk demand, which produces sufficient organic manure within the farm or village. Hence, *Azolla* culture can be adopted without much cost and additional labour requirements (Kaur *et al,* 2015).

Proposed model

To exploit maximum economic benefits from *Azolla*, it is proposed to integrate it with the orchards or groves, where it can serve as manure, mulching material, carbon and organic matter resource to improve soil fertility and consequentially the

farm production, without any additional land requirement. Traditionally, a variety of mulching materials, like paddy/wheat husk, wood saw, plastic sheets, cardboards, animal manure, leaves, sugarcane bagasse, grass etc., are used in the orchards or groves to i) preserve soil moisture and ii) control weed growth, which needs to be arranged from outside the farm. As a mulching material, *Azolla* holds an edge over the above listed material due to following additional benefits:

1. *Azolla* can be cultured within the orchards itself, without extra land requirement – No transport or procurement hassles.
2. Besides nutrients, *Azolla* also provides moisture to the plants – Dual benefit.
3. *Azolla* can be cultured easily throughout the year with simple technological interventions – Regular supply.
4. It decomposes fast and adds good amount of nitrogen, phosphorous, carbon and organic matter to the soil-Soil health restoration.
5. It will provide cooling effect through absorption of CO_2 from the surrounding environment – Environmental benefits.
6. Surplus *Azolla* can be sold out to other farmers (agriculture, livestock, poultry and aquaculture) for additional income –Enhanced income per unit land holding.

Azolla culture

For *Azolla* culture in the orchards, earthen pits can be dug out in available land between the trees or portable *Azolla* beds can be installed between the trees (Fig. 1 and 2). *Azolla* culture in earthen pits involves following steps:

1. Dig 1- 1 ½ feet pits of 5 x 2 m (10 m^2) to 8 x 2 m (16 m^2) size.
2. Fix polythene/tarpaulin sheet in the pit.
3. Spread 2" (inch) soil layer at bottom of the pit.
4. Add cow dung (@ 1kg/m^2) and DAP (@ 3-4g/m^2) slurry in the pit over the soil layer.
5. Add 20-25 cm water and leave for 24 hours.

Note: Normally to protect the *Azolla* stock from extreme heat during summers and extreme cold during winters, the pits are covered with 50% sun shade net (Abduh *et al,* 2017). However, it is not required in orchards as the trees protect the pits from extreme temperatures.

6. Add *Azolla* inoculums in the pits to cover about 50% of water surface so as to prevent algae formation in the pits.
7. *Azolla* will grow and cover the entire water surface within 3-4 days.
8. Once complete *Azolla* mat is formed in the pit, start harvesting ¼ (25%) of the stock daily.
9. Keep adding cow dung (@ 1kg/m^2) slurry in the pit after every 7-10 days. In case *Azolla* growth slows down, add DAP solution @3-5 g/m^2.
10. Maintain water level in the pit and replace 20- 25% water with fresh water after every 4 weeks. Pit water can be used as liquid manure for orchard trees.
11. Renew *Azolla* pits (steps 3-6) after every 5-6 months, after complete drainage and cleaning. Use drained sludge as manure.

Azolla culture in portable beds (Fig. 1) is also carried out as in case of earthen pits from step 3 to 11 and these beds can be shifted within the farm whenever required.

Utilization of *Azolla* in orchards

Growing *Azolla* mats in the pits will continuously absorb N_2 and CO_2 from the air, while harvested *Azolla* biomass can be utilized in the orchard as manure, mulching material and soil tonic in following two forms:

Fresh *Azolla*

Freshly harvested *Azolla* can be used as mulching layer around the fruit trees, which will provide moisture, prevent soil moisture evaporation and serve as a potential bio-fertilizer by providing nutrients (N, P & K) and organic carbon to the soil on decomposition. It is very easy to harvest *Azolla*

Fig. 1: *Azolla* culture in Kinnow orchard of fish integrated unit at College of Fisheries, Punjab

Fig. 2: *Azolla* beds in an integrated orchard farm in Philippines for feeding fish and chickens

Picture Source: Article in Philippines magazine "*Monthly Agriculture*" by Patricia Bianca S. Taculao (https://www.agriculture.com.ph/2020/05/22/partners-setup-an-azolla-farm-to provide-feed-for-their-livestock/)

from the pit or bed with the help of a scoop net or sieve and transfer it directly around the trees (Fig. 3).

Azolla compost

Surplus *Azolla* harvest can be filled in earthen pits and left for 4-5 weeks to decompose naturally

Fig. 3: Harvesting and utilization of *Azolla* for mulching and manuring in orchards

Table 2: Nutritive value of *Azolla* Compost (Ansal *et al,* 2016)

S. No.	Nutrient	Percentage (%)
1	Nitrogen	2.5 - 3.0
2	Phosphorus	0.4 - 0.6
3	Potassium	1.0 - 1.25
4	Carbon	28 - 30
5	Carbon : Nitrogen Ratio (C:N ratio)	10 - 12

Fig.4: *Azolla* **compost**

into high quality compost (Table-2), which needs to be simply reshuffled occasionally with the help of a raker to aerate the decomposing *Azolla* to accelerate its decomposition process. Once the compost is ready, it is dried and stored (Fig. 4) to manure the trees, whenever *Azolla* harvest declines due to environmental extremities.

Additional benefits

After meeting the farm needs, surplus stock of fresh *Azolla* and *Azolla* compost can be utilized for additional income, as given below.

Fresh *Azolla*

Orchard farmers also into livestock, poultry or fish farming, can use surplus fresh *Azolla* for feeding their animals (cows, buffalo, pig, goat, sheep, rabbits etc), birds (chicken, ducks etc) and fish (Datta, 2011; Feedipedia, 2013; Mathur *et al,* 2013; Anitha *et al,* 2016). It will not only save input cost, but also enhance milk, egg and meat production with significant increase in farmer's income (Table 3). Further, multiple utility of *Azolla* has attracted the attention of agricultural and livestock farmers in the recent past and they are looking forward to adopt it as a potential manure and feed resource. Hence, *Azolla* inoculums can also be sold to such aspiring farmers at a higher price. Most recently, *Azolla* is also gaining popularity among urban hobbyist maintaining terrace gardens, where it is used as decorative filler base with other flowering aquatic plants like lotus, lilies, *Pistia* and *Eichhornia*. A suitable market for such hobbyist can also be explored through developing working linkages with hi-tech popular plant nurseries in nearby cities. Computer savvy farmers or entrepreneurs can tap this area through on-line marketing, at a much higher price.

Table 3: Daily fresh *Azolla* feeding regime for different animals

S.No.	Animal	Daily ration	Reference
1	Cattle, Buffalo	1.5 -2.0 kg/cattle	Kololgi *et al,*2009; Chander, 2011
2	Pig	1.5 -2.0 kg/pig	Chander, 2011
3	Chicken	10-100g/bird	Lakshmanan *et al,* 2017; Sinha *et al,* 2018
4	Duck	200g/bird	Sujatha *et al*, 2012; Swain *et al,* 2018
5	Sheep/Goat	300-500g/animal	Chander, 2011
6	Rabbit	100g/rabbit	Chander, 2011
7	Fish*	5-10% of fish BW	Kaur and Dhawan, 1997;FAO 2009

*Grass carp and Common carp in carp poly-culture system. However, under monoculture conditions grass carp is fed *Azolla* at higher rates ranging from 30-100% of fish BW (Rahman *et al,* 1992, Asadujjaman and Hossain, 2016), especially by small and marginal farmers.

Azolla compost

Like vermicompost, surplus *Azolla* compost can also be sold in an attractive packet,with a higher price tag, to urban hobbyists for their home/kitchen gardens. *Azolla* compost also serves as potential manure for aquaculture. *Azolla* compost application @ 20,000 kg/ha/yr was found to enhance fish production (common carp, *Cyprinus* carpio) by 5.31% as compared to traditional manuring with cow dung at the same rate, while combination of *Azolla* compost with cow dung in the ratio of 1:1 and 1:3 enhanced the fish growth by 14.61 and 25.80 per cent, respectively (Ansal *et al,* 2016).

Dry *Azolla*

In addition to above listed forms, *Azolla* can also be dried and stored as a promising feed ingredient for fish feed formulation, which has been found to enhance fish biomass production by 28.2% in a carp poly culture system (*Catla catla*, *Labeo rohita* and *Cirrhinus mrigala*) and farmers net profit by 38.64%, when included in the grow out feed @ 10% (Dhawan *et al,* 2010). However, Gangadhar *et al* (2015) reported that dried *Azolla* can be incorporated in *Labeo fimbriatus* feed up to 40% for rearing fry to fingerling, without compromising fish growth and recorded 24.48% saving on feed cost. Sundried *Azolla* can be incorporated in pig feed up to 30% without any significant adverse effect on growth (Mahadevappa *et al,* 2012). For the said purpose, surplus *Azolla* can be dried during hot dry months (April to June) in northern India and stored in moisture proof bags at a dry place. Multiple utility options of *Azolla* offer a complete organic package for the farming community to reap maximum economic returns from their farm assets. World famous soil scientist from India, Dr. Rattan Lal, who has been facilitated with the prestigious "World Food Prize" during the year 2020 and provided leadership to many soil health restoration projects across the world, including Asia, has always advocated to protect soil health through water conservation and recycling of extracted nutrients, carbon and organic matter back into the soil. His research also revealed that restoration of degraded lands by addition of carbon and organic matter not only improved soil health, but also helped in sequestering CO_2 from the air. *Azolla* is a wonderful resource of nutrients, moisture, carbon and organic matter with stupendous CO_2 sequestering ability; hence, need to be exploited by the farming community to the fullest for economic as well as environmental benefits for overall sustainability of the ecosystem.

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