Abstract: Livestock has a significant role in the world economy. Livestock is the major source of livelihood for about 20.5 million people in India and livestock resources contribute 4.11% of the country's GDP and 25.6% of total agriculture GDP. On the other hand, there is a huge gap between demand and supply of feed and fodder in India, which can be reduced by exploring natural feed resources as supplements. To complete the shortage of feed and optimum production of livestock, it is significant to explore some non-conventional nutritive feed resources. The aquatic fern, *Azolla* has been identified as one of the most efficient substitutes for livestock as it can be easily digested due to its low lignin with high protein content having especially essential amino acid lysine. Its unique nutrient aspects make it an ideal feed for livestock, poultry, goat, fish, and pigs. Nutraceutical aspects of *Azolla* bio-feed technology will be taken up in a big way by the dairy farmers, especially, by those who experience land scarce conditions for fodder production.

Keywords: Agriculture, *Azolla*, Bio-feed technology, Livestock, Supplement.

**INTRODUCTION**
Livestock refers to domestic animals, which are kept for use or profit (Verma, 2017). It plays a significant role in the world economy. Livestock is the major source of livelihood for about 20.5 million people in India. There are vast livestock resources in India that contribute 4.11% of GDP and 25.6% of total agriculture GDP, even so there is a huge gap between demand and supply of feed and fodder in India which can be reduced by exploring natural feed resources as supplements. The natural resources must be fully explored to promote agriculture production that can reduce dependence on chemical input. At present, the conventional feeds are not quite enough to complete the shortage of feed and fodders to make animal production more viable and productive (Chatterjee et al., 2013). There is about 60% deficiency of green fodder in general. In order to complete the shortage of feed and optimum production of livestock, it is utmost significant to explore some non-conventional feed resources without compromising the nutrient quality of feed.
**Azolla** is an aquatic fern that freely floats on the water surface (Agnihotri, 2019). The term Azolla is derived from two Greek words azo means to dry and allyo means to kill which depicts the aqueous habit of the plant. Azolla is heterosporous and leptosporangiate fern from aquatic and semi-aquatic habitats. The normal habitats of Azolla are natural ponds, ditches, canals, and paddy fields and where agricultural runoff water is seasonally covered by a thick mat of Azolla, with other free-floating aquatic plants such as Lemna, Riccia, Pistia, Salvinia, Spirodela, and Ricciocarpus.

Azolla (Fig. 1-6) has been identified as one of the most efficient substitutes for livestock feed as it can be easily digested due to its low lignin content and high protein content. Its unique nutrient aspects make it an ideal feed for livestock, poultry, goat, fish, and pigs (Gouri et al., 2012). Ambade et al. (2010) reported 15-20% increase in yield of cattle milk after feeding Azolla. Azolla is very rich in proteins, vitamins (vitamin B₁₂), and minerals including calcium, potassium, iron, phosphorous, copper, magnesium etc., as mentioned in table 1. Sanginga and Van Hove (1989) reported that amino acids are the constituent that makes Azolla a unique feed supplement. Cohen et al. (2002) reported to have an essential component like 3-Deoxyxanthocyanins which are the only known flavonoids of Azolla and various antioxidants like phyto-constituents such as tannins, phenolic contents and flavonoids from Azolla crude extract.

Azolla has many applications as a bio-fertilizer in agriculture and also has the source of human food, poultry feed, fish feed, and mosquito control. Under ideal conditions, Azolla doubles its biomass very rapidly. Due to its high nutritive value, it is known as a green gold mine and super plant. Besides the nitrogen fixation, its development is also responsible for favorable changes in the aquatic medium like prevention of pH changes, lowering of water temperature, suppression of weeds, and mosquito larva. Azolla is effective in the biological control of mosquitoes due to its growth as a dense layer on the water surface and preventing mosquito larvae from coming up for inhalation. In this article, authors are trying to discuss the azolla bio-feed technology's potential use in future agriculture.

**DISTRIBUTION OF AZOLLA**

There are at least eight species of Azolla worldwide namely Azolla caroliniana, Azolla microphylla, Azolla circinata, Azolla japonica, Azolla nilotica, Azolla mexicana, Azolla pinnata, and Azolla rubra. But Azolla pinnata is the most commonly found in India. Azolla belongs to genus Azolla, division Pteridophyta, family Azollaceae and order Salviniales (Nordiah et al., 2012). Azolla is divided into two subgenera (Euazolla, Rhizosperma) and six species (Raja et al., 2012). The subgenus Euazolla has three megaspore-floats (with septate glochidia) and four species (caroliniana, filiculoides, microphylla, and mexicana). The subgenus Rhizosperma has nine megaspore-floats and two species, i.e. Azolla nilotica (without glochidia) and Azolla pinnata (with glochidia). Azolla species have sporocarp, involved in the production of spores for reproduction and glochidia has a barbed hair-like appearance that helps in the anchoring of microspore massulae (Schirrmeister et al., 2015; van der Burgh et al., 2013). Azolla caroliniana is distributed from Central to South America and the Eastern part of Andes to Western Europe as well as in the Nile Delta, Egypt (Nierop et al., 2011). The filiculoides species is cultivated in South Africa, Western America, Western Europe, Australia, and Asia (van Kempen et al., 2016). Azolla mexicana has shown a little expansion from its indigenous area while A. microphylla is mainly confined to the Galapagos Islands (Pereira, 2017). Similarly, an African native species, i.e. Azolla nilotica is distributed in South Africa, Eastern Africa, Egypt and (Sadeghi et al., 2013). Azolla pinnata (including its three sub-species) is distributed in tropical Africa, and Australasia Southeast Asia (Carrapico et al., 2000; Brouwer et al., 2018).
Fig. 1: Sporocarp of *Azolla*.

Fig. 2: Fronds under microscope.

Fig. 3: Dividing spores.

Fig. 4: Sporophyll of *Azolla*.

Fig. 5: Green *Azolla*.

Fig. 6: Dried *Azolla*.
Table 1: Nutrient profile of Azolla

| S. No. | Nutrient Profile | References |
|--------|-----------------|------------|
| 1.     | Potential source of protein (25- 35%) | Lumpkin, 1984 |
| 2.     | Almost all essential amino acids (7-10%) especially lysine | Sanginga and Van Hove, 1989 |
| 3.     | Essential minerals such as Iron, Calcium, Phosphorous, Magnesium, Manganese, Potassium, and Copper (10- 15%), Vitamins like A and B₁₂ | Bacerra et al., 1995; Veys et al., 1999 |
| 4.     | Carotenoids, Chlorophyll ‘a’ and ‘b’, Bio-polymers, Probiotics, and Growth promoting intermediates | Tamany et al., 1992; Pillai et al., 2005; Lakshmi and Sailaja, 2012; Mathur et al., 2013; Parashuramulu et al., 2013; Cherryl et al., 2014; Katoch et al., 2021 |

USES AND IMPORTANCE OF AZOLLA

1. Importance of Azolla in fish pond: Azolla can be used in fish pond either directly or indirectly due to its nutrient composition (dry weight) as shown in table 1. It can be used as food in azolla-macrophytophagous fish pond culture. It has been reported that azolla increase the production of fish faeces which act as organic fertilizer in pond. Azolla is used as a supplement to natural feed that can reduce the high dependency on fish meal and fish oil. The fish species like rohu, catla, grass carp and tilapia have been reported to convert raw protein from Azolla into the best edible protein, thus reduces the cost of production of feeds.

2. Significance of Azolla meal: Among published papers reviewed, it was found that in Tilapia species (Oreochromis niloticus, Tilapia zillii, Tilapia mossambica,) and in the Family of Cyprinidae (Labeo rohita, Catla catla, Labeo calbasu, Labeo fimbriatus, Barbonymus gonionotus Ctenopharyngodon idella), Azolla was incorporated in their diets. The azolla an aquatic fern has been successfully used in tilapia and carp culture as a source of protein. Authors have been studied the effect on growth, performance and survivability of tilapia fingerlings by using azolla as a component in feed. Most of the literature reviewed reported the increase in performance of fries at the increased dietary content of azolla. According to Sithara and Kamalaveni (2008), biochemical parameters like protein, carbohydrates and lipids contents in liver and muscles were increased when fish fed a diet containing wheat bran, rice bran and azolla in ratio of 25:25:50 for duration of 90 days. The information of effect of azolla as a feed ingredient is summarized in table 2.

3. Use of Azolla in poultry: The poultry industry is one of the most profitable business sector in India that provides nutritious eggs and meats for human within the shortest possible time. In poultry, feed is quite expensive input and about 70% of production cost is for feed alone. As feed related improvement in the performance has a profound effect on profitably, the poultry nutritionists have used azolla as alternative cost effective, non-conventional feed ingredients (Fig. 7). Azolla feeding in poultry (20-30g/bird/day) reduce consumption of concentrate feed by 13% and can increase egg weight by 6.62% Total protein content, carotene, albumin, globulin, has been reported to increase 12.9%, 8.64%, 3.4%, 9.5% respectively in edible portion of egg. Subudhi and Singh (1978) concluded that green Azolla could replace commercial feed by 20% in the diet of young chickens. They reported that to replace this much (20%) commercial feed about 9 kg of fresh Azolla would require each day for 100 chickens. The nutrient digestibility is high in case of fresh azolla due to its low lignin content. The information about effect of Azolla as a feed in poultry is summarized in table 3.
Table 2: Information about effect of Azolla as a feed on different fish species.

| Common name | Scientific name | Percentage of Azolla | Results | References |
|-------------|-----------------|----------------------|---------|------------|
| Nile tilapia | Oreochromis niloticus | 42% | Improvement on growth performance, feed utilization and survival rate on Nile tilapia | Santiago et al., 1988 |
| Mozambique tilapia | Tilapia mossambica | 50% | Protein, carbohydrate and lipid contents in liver and muscles were increased | Sithara and Kamalaveni, 2008 |
| Red breast Tilapia | Tilapia rendalli | 40% | Highest performance | Micha et al., 1988 |
| Rohu | Labeo rohita | 40% | Higher weight gain and good utilization | Das et al., 2004 |
| Orange fin labeo | Labeo calbasu | 30% | High growth without any adverse effect | Gangadhar et al., 2017 |
| Catla | (Catla catla) | 20% | Performance was high | Umalatha et al., 2018 |
| Fringed lipped peninsula carp | Labeo fimbriatus | 40% | Production was more | Gangadhar et al., 2015 |
| Grass carp | Ctenopharyngodon idella | 30% | Improved growth | Ayyappan and Ali, 2007 |
| Thai Silver | Barbonymus gonionotus | 25% | General growth and barb production performance of fish was higher | Das et al., 2004 |

Table 3: Information about effect of Azolla as a feed on different poultry species.

| Organism | % of Azolla | Result | References |
|----------|-------------|--------|------------|
| Broiler Chickens | 5-15% | Improves FCR, energy efficiency and performance | Lejeune et al., 1999; Dhumal et al., 2009; Namra et al., 2010 |
| Layer Chickens | 5%-10% | Reported good egg mass output and FCR | Kannaiyan and Kumar, 2005; Lakshmanan et al., 2017 |
| Quails | 15% | Enhanced the growth and FCR without affecting feed consumption and Carcass traits. | Rathod et al., 2013; Varadharajan et al., 2019 |
| Ducks | 20-40% | No toxic effect of Azolla cristata supplementation | Safriyani et al., 2020 |

4. Use of Azolla in pig culture: Azolla can be incorporated in pig diet 1.2 kg/pig/day during growing phase (30-60kg) and 3.25kg during finishing phase (60-90kg) as soya bean substitute without affecting normal growth rate (Becerra et al., 1990).

5. Azolla as a feed for Mallards: Azolla as a feed for Muscovy (meat production) and Mallard (egg production) ducks has also been a common practice in Vietnam (Katole et al., 2017). Becerra et al. (1995) conducted trials to determine the effect of feeding Azolla microphylla as partial replacement of the protein in boiled soya bean in diets based on sugar cane juice for meat ducks. Fresh Azolla was offered three, four or five times per day, at a rate of 1 kg fresh weight per pen at each feeding and the times increased with the age of the birds to minimize losses. The rations were fed from the age of one month to 70 days old.

6. Effect of Azolla on Cattle and milk production: Fodder is primary requirement for cattle. Even the animals are fed with various commercial feeds till fresh green grass is available as green fodder that...
can greatly reduce the expenditure on commercial feeds (Chethan et al., 2021). The success of dairy farmers depends mainly on increasing milk production without increase in feeding cost. Thus, growing azolla is a good option to reduce the cost. *Azolla* is a highly productive plant. *Azolla* can double its biomass within 3-10 days, depending on climatic conditions, and yield can reach up to 8–10-ton fresh matter/ha in Asian rice fields. In India, yields of 37.8-ton fresh weight/ha (2.78 t DM/ha) have been reported for *Azolla pinnata*. *Azolla* inclusion in cattle 2kg/per/day feed increase milk production up to 30%, improve milk quality and animal health.

**CONCLUSION**

*Azolla* can be used as a novel feed supplement or substitute for pig, cattle, fish, and poultry, apart from its utility as a bio-fertilizer for wetland paddy. *Azolla* bio-feed technology will be taken up in a big way by the dairy farmers, especially, by those who experience land scarce conditions for fodder production.

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