LITERATURE REVIEW

2.1 ALLELOPATHY & IT'S SIGNIFICANCE

Allelo-chemicals on the plant growth are yet to be a widely studied aspect. The need to understand the mechanism of action of these chemicals has become inevitable in order to exploit them in the management of agro systems for better economic yields. Despite of the apprehension that allelopathy acts as a replacement to synthetic agro- chemicals, its application in the aquatic ecosystem with special note to pond or wetlands, needs to undergo extensive refinement in techniques and commercialization both at national and international level. Currently, there are a very few citations exploring the relationship of allelopathic plants in aquatic ecosystem. Most of the works at international level depict the marine ecology and use of terrestrial crops (mostly rice) as releaser (Seal *et al*., 2004). A group of Australian researchers (Ahn JK and Chung, 2000) applied rice as the source of allele-chemical for the eradication of arrowhead (*Sagittaria montevidensis*). Dated back, the same source as aquatic hull extract was studied upon from China and Iran (Seyyednejad *et al*., 2010; Gopal and Goel, 1993). However, rice being one of the staple crops in India; it can never be afforded to be used for treating an aquatic weed.

2.2 AQUATIC ALLELOPATHY- WETLAND MACROPHYTES

At national level, the interactions of water hyacinth at certain cases have been highlighted (Kathiresan *et al*., 2006). Certain books compiling allelopathy in India were also published which do give us some information (Inderjit S and Mukherjee, 2006; Zhang *et al*., 2009). A few more reviews or short communications were also done but the bioactive compounds responsible was yet to be detected for most of them, and the few existing experiments had inconclusive results and based on a limited number of species which further hinders the study of the effects of those plants on fish population. Moreover it would be more beneficial and more sustainable to apply allele-chemicals from plants belonging to native or neighbouring ecosystem then to work on economic plants from terrestrial ecosystem which most articles cite.

The aquatic macrophyte has been well noted for their allelopathic activity of both stimulation and inhibition associated with marked physiological and biochemical changes (Yalew and Andrea, 2012).The phenomenon were specially common in plankton inhibition as a consequence of competition for co-existence. Literature survey also shows the significance of aquatic allelopathy in mitigation of phytoplankton in an eco-friendly and effective procedure (Fariba *et al*., 2013; Meng *et al*., 2008). It was in 1999 when the study of aquatic allelopathy gained momentum. The study reported the rhizosphere zone as highly effective allelopathic centre of a plant with prevailing aerobic condition surrounded by anaerobic condition due to water logging. This principal is proclaimed to be a vital difference between terrestrial and aquatic ecosystem in terms of dispersion of chemicals (Christensen *et al*., 1994; Flessa, 1994; Sorrel & Armstrong, 1994). However it was also studied that the effect of allelochemicals on other plants or organisms in on an immense scale and gets expressed eventually when the target host is under stressed environment or in an acute nutritional efficiency. In this context, the example of soft corals was studied (Reigosa *et al*., 1999; Fleury *et al*., 2000). It is further reported that diterpenoids released due to environmental stress are found in many aquatic macrophytes which are fish toxic in nature.

2.3 ALLELOCHEMICALS AS AQUACULTURE DRUGS

The concern for use of synthetic chemicals in large scle fish farms have been stated by The State of World Fisheries and aquaculture, which showed the fishes as 15% protein intake source to human's consumption. These fish sources are stocked and reared using artificial dyes and antibiotics strictly banned by the European Union and United States

(FAO, Roberts, 2002). As such plants are the only suggested alternatives with prophylactic and therapeutic activity in aquaculture system (Turker and Yildirim, 2015). The use of allelopathy in aquaculture is broadly reported mostly in marine ecosystem. The allelochemicals exudates by a marine animal *Ciona savignyi*, has been reported to prevent ascidians fouling by inhibition of metamorphosis of marine larvae (Cahill *et al*., 2012). A new perception on autotrophs and heterotrophs in aquatic ecosystem was reported with the discovery of polyunsaturated aldehydes (PUAs), oxylipins and epoxyalcohols which are the secondary metabolites of aquatic plants and seem to interference with the food web, thus linking the lowest strata of ecological pyramid with the higher stratsa (Miralto *et al*., 1999; Wendel and Juttner, 1996; Pohnert, 2004 and VanDonk *et al*, 2011). In relation to fresh water fish, the aqueous extract of *Vernonia anygdalina* has been tested as the antifungal agent against saprolegnesis causing fungi saprolegnia sp. In *Clarias gariepinus* (Ilondu *et al*., 2009). The allelopathy of aquatic macrophyte against fish fungal infections is scarce. In 1999, Rai *et al*., showed the effects of essential oil, a non-polar allelochemicals from asteraceae showing antifungal activity against fish disease causing fungus Saprolegnia ferex (Rai *et al*., 1999).

The common medicinal plants having aroma nad growing in and around water bodies are studied for the efficacy are studied against fish disease causing micro-organisms *Azadirachta indica*, *Curcuma longa*, *Phyllanthus niruri* have been studied as herbal formulations of aquaculture drugs against water borne pathogens (Sivakumar *et al*., 2013). The use of plants both terrestrial and aquatic, as fish curatives against pathogens was also vividly studies (Abutbul *et al*., 2005).

2.4 ANTIOXIDANTS IN AQUACULTURE

The reactive oxygen species (ROS) causes cell damage and challenges the innate immune system of an organism. The drugs obtained from only plant sources showed high antioxidant content with potent free radical scavenging property. Phenols, flavonoids, folic acid etc are the prime radical scavengers in macrophytes (Ghasemzadeh and Ghasemzadeh, 2011; Syahidah *et al*., 2015).

The carotenoids are an essential requirement for fish growth, skin and muscles. They also play an important role in liver functions and fertilization. But this organic pigment is not produced as an fish metabolite and needs to be outsourced by the fish. The carotenoids are naturally produced by plants with colourful flowers usually yellow to red (Tacon, 1981).

Flavonoids are the allelochemicals with polyphenol group and form an important part of most of the plant produced bioactive fractions. They are also an integral part of antimicrobials and disinfectants. Hence they form a defence mechanism in any organism. The polar extracts of the plants from aerial parts usually have higher content of flavonoids. The ethyl acetate fraction is noteworthy in this regard. Rigorous fish rearing as a commercial avenue has exposed the fish population to environmental stress and has imbalanced the normal physiology and the homeostasis (Syahidah *et al*., 2015).In order to overcome this threat, plants as a natural source of antioxidants not only boost the immune system but also nullifies the bioaccumulation of harmful chemicals (Yanisblieva *et al*, 2006).

The use of antioxidative immune-stimulants in fish feed has been practised for years and the substituent of known plant extracts in this mixture can be a healthy aspect of aquaculture as these plant additives have been already considered safe for human consumption. The immune-stimulant activity of *Coriandrum sativa* aginst *Aeromonas* *hydrophila* in *Catla catla* ahve been reported (Innocent, 2011;Reverter *et al*., 2014) and root exudates of *Ruta graveoleus* against *Saprolegnia sp*. Has also been studied in this regard (Karouei *et al*., 2012)

2.5 PLANTS IN FISH FEED FORMULATION

The fish intake is considered as an important protein source in the dietary chart. The increasing organic contamination and ecological degradation had induced fish farmers to depend on synthetic chemicals for high yield and low cost (Omoregie, 2001). Literature studies suggest articles on use of plants as ingredients of fish feed which intends not only to achieve economic feasibility but also ecological compatibility (Omoregie and Ogbemudia, 1993).

The plant products are added to the fish feed for their growth and high protein production which are named 'Phytobiotics' (Cristea *et al*, 2012) which imparts the products with additional properties of antioxidants, anti-carcinogenic, insecticidal, enhancement of digestive physiology etc (Denev, 2008). In such case, a single plant or even a combination of plant products in defined proportion is tested to achieve a holistic non specific immune booster and defender against pathogens in water (Yin *et al*., 2006). A tabulated form of fish species and the plants used in this process is published in journal of Entomology and Zoology studies (Kaur and Shah, 2017).

Plants such as garlic, onion, marjoram, caraway etc are reported to promote the body weight and promote protein digestibility in aquatic animals (Sivaram *et al*, 2004; Shalaby, 2004). A bioactive compound "Allicin" present in garlic is eported to increase the feed intake intake in fish (Lee and Gao, 2012). It was studies that the increase in fish growth was also enhanced by the extract of the plant *Phyllanthus emblica* (Sivagurunathan and Innocent, 2012). In the economic point of view, according to Rumsey, the addition of plant protein in fish feed can reduce the cost of feed (Rumsey, 1993). Moreover the nutritional value of the feed was authenticated by El-Sayed (El-Sayed, 1999). In another interesting study, the use of turmeric powder was used to protect the feed from damage and increase the self life from sunlight or other biotic factors (Shrinivasan and Satya Barayanan, 1987).

2.6 PLANTS AS ANTI-ALGAL AGENTS

As for algal bloom control, very scanty works have been done in India with special note to *Microcystis aeruginosa*, yet no remedy is attained. International works on application of allelopathy against Microcystis cites use of Potamogeton spp (Chen *et al*., 2004); Giant reeds; and mandarin skin and banana peel (Oberholster, 2011). The allele-compounds will be further screened for removal of algal bloom especially blooms caused by *M. aeruginosa*. They are the most common toxic bloom in eutrophic freshwater (Carmichael, 1992). They form persistent microcystin toxins (Turner *et al*., 1990) which can be rendered as hepatotoxic agent (Bell and Codd, 1994; Falconer, 1996; Anderson *et al*., 1993) and are associated with steep decline in fish population (Bury *et al*., 1996) and aquatic invertebrates. These natural products are effective and often quickly biodegradable and hence present no threat of toxic residue.

There are literatures of antialgal activity against *M. aeruginosa* from various other plant secondary metabolites (Liyan *et al*., 2005) which have shown sustained results (Patterson *et al*., 1994; Carmichael, 1992; Kuete & Efferth, 2010). These secondary metabolites or allelochemicals (Hong *et al*., 2010; hUallacháin & Fenton, 2010) are exudates from plant roots or leaves (Ding *et al*., 2008) which disable their proliferation ability and further helps reduce release of microcystin (Nakai *et al*., 2012) without interfering into the ecological ambience.

2.7 AQUATIC MACROPYTES IN THE PRESENT STUDY

The *Vallisneria spiralis* is mainly reported against algal bloom control caused by *Microcystis aeruginosa* (Cyanophyceae) (Wang *et al*., 2006). The earliest reports of the presence of polyphenols in *V. spiralis* dates back to 1981 as reported and published in bulletein (Stom and Roth, 1981). The total amount of phenols was quantified by Gas chromatography and Polarography (Suslov, 1978).

The use of *Ipomoea aquatica* has been mostly reported among the piscicidal chemicals available in nature (Harada, 1989). However there are ample literatures narrating the use of this vegetable as therapeutic efficiency with remarkable contents of succinate, citrate, carnitine etc (Ssajak *et al*., 2017). There are also reports of the use of *I. aquatica* as an allelopathic tool against mitigation of algal growth. The advantages cited were quick degradation and easy availability (Zhang *et al*., 2007).

The initial allelopathic activity of *C. rotundus* have been tested against seedling germination of various agricultural crops and have been found to possess antagonistic activity (Singh, 1968; Meissner *et al*., 1980). During the 19th century, the use of Cyperus tubers were reported as supplementary in fish feed but was under scientific trail. It was reported in *Cirrhinus mrigala* (Rambabu *et al*., 2004). In this preview, it was seen that fishes shown enhanced growth to plant based formulated feed (Johnsen and Adams, 1986) improving palability in reduced cost.

The phytochemical analysis of banana leaves reveals the presence of saponnins, alkaloids, flavonoids, terpenoids etc which are a major contain of commercially available antibiotics against fish diseases (Bisht *et al*., 2016). A feed trial of banana leaf based formulated feed was done on overall impact on *Ctenopharyngodon idella* while infected with *Aeromonas hydrophila*. The change in feed conversion ratio (FCR) was noted however no prophylactic activity was detected (Mayrhofer *et al*., 2017). There are reports of the pharmaceutical activity of banana leaves to combat the mortality rate of *Clarias gariepinus* larva (Walakira *et al*., 2014).