CHAPTER -2
REVIEW OF LITERATURE
2. REVIEW OF LITERATURE

To retrospect the works already done in the field of allelopathy and Blue Green Algal technology for sustainable Rice production by different workers for enabling us to understand the research problem properly, the review of literature is cited here with. This would help us to frame a sound background for present study.

Paddy (*Oryza sativa*) is monocot plant, of the grass family (Poaceae). As a cereal grain, it is the most popular cereal worldwide, serving as a stable food for 39 countries and nearly half of the world’s population (Juliano, 1993). Globally Rice account for 22% of total energy intake (Kainuma, 2004).

The agricultural importance of BGA in Rice cultivation is directly related with the ability of certain forms to fix nitrogen. Contrary to heterotrophic N$_2$-fixing bacteria, BGA represent a self supporting system capable of both photosynthesis and N$_2$ fixation, the energy bill for both process being "paid by the sun". Recent researches, conducted mainly in India, have shown the feasibility of using BGA as a cheap additional nitrogen source for Rice. Results concerning the effects of algalization in the presence of nitrogen fertilizers are controversial. Several reports indicate a failure of algalization in the presence of fertilizer N$_2$ experiment conducted in India indicates a beneficial effect of algalization On the other hand, a large scale even at very high levels of nitrogen.
De, (1939) who attributed the natural fertility of tropical Rice fields to nitrogen fixing blue green algae, first time recognized the potential of cyanobacterial nitrogen fixation in Rice fields in India.

Mitra, (1951) suggested that apart from the heterocysts-bearing Cyanobacteria some of the non-heterocysts forms also grow profusely in Paddy field soil. At the onset of the rainy season, the Paddy field became water logged, the spores of the Cyanobacteria begin to germinate in situ, still enclosed in parent sheath. He also studied the Cyanobacterial flora of certain Indian soil and included four samples of Paddy field soil from Allahabad (U.P.) and described 40 species of Cyanobacteria including 20 new species.

Fraenkel, (1959) proposed that the excursion of secondary compounds from plants previously considered as waste products of little importance might actually serve to determine palatability of these plants particularly with respect to insect herbivores.

Ehrlich and Raven, (1964) stated that plant secondary metabolites might actually facilitate what they termed the “coevolution” of herbivorous insects and plants. Spawning the field of “chemical ecology,” innumerable studies in the more than four decades that followed have elucidated countless roles of the secondary compounds of plants, insects, invertebrates, and even some microbes as allelochemicals that are involved in the interactions between organisms as it relates to their ecology. Algae include a large heterogeneous assemblage of
relatively simple plants that have little in common for their characteristic autotrophic mode of nutrition.

**According to Durell, (1964)** alkaline soil favors cyanobacterial growth. In another study he suggested that certain Cyanobacteria also found from soil having pH range 5.0-6.0 during field observations in India.

**According to Aiyer, (1965)** cyanobacterial strains like *Aulosira fertilissima* and *Calothrix brevissima* are ubiquitous in Kerala Rice fields where the pH ranged from 3.5 to 6.5.

**Stewart, (1967)** did extensive work to showed the significant role of Cyanobacteria in Paddy field, their concentration towards the nitrogen economy and improving soil fertility. Their interaction among themselves as well as with other cyanophytes especially those involving allelopathic effects assume great relevance in the present era, when Cyanobacteria as biofertilizers are gaining importance as environmental friendly inputs in agriculture.

**Renaudo et al., (1971)** stated that among the soil properties, pH is certainly the most important factor determining the algal flora composition. In culture media the optimal pH for growth of BGA seems to range from 7.5 to 10.0 and the lower limit is about 6.5 to 7.0.

**According to Chou et al., (1976)** in Paddy crop, most of the Paddy root parts remain in the field after its harvesting. Paddy root residues have been known to release some allelochemicals after decomposition that affected the growth and nitrogen fixing potential of Blue Green Algae. The basal portion of Paddy plant left in the field, due to use of harvester combines
or sickles is ploughed back or burnt which on decomposition release water soluble and
phytotoxic phenolic compounds/ allelochemicals that may be affecting the algal dynamics and
the subsequent crop.

Positive interaction between these residues and released allelochemicals i.e. more Paddy
residuals, the greater allelochemicals result in the amount of leachable nitrogen. The
allelochemicals at their low concentration cause promoting effect, which at moderate
concentration become inhibitory. These compounds also influence the nutrient status and hence
their uptake, thereby creating a concentration of nutrients stress, increase in the concentration
of phenolic compounds which influence the growth and nitrogen fixing potential by blue green
algae.

Prasad, (1978) observed that most BGA preferred a neutral or near neutral pH (6.5-7.5),
but others were also capable of thriving over a wider range (5.5-8.5).

According to Stainer et al., (1979) the blue green algae are distinguishable from other
algae by their structural and functional peculiarities. These organisms are oxygen-evolving
prokaryotes and are known as Cyanobacteria.

Agarwal et al., (1979) suggested that the salt affected lands are known in local parlance
by a variety of names in different parts of this sub-continent. By far the most common term used
is ‘Usar’, which is derived from the Sanskrit word “Ushtra” meaning sterile or barren and it is
usually applied collectively to all kinds of saline and alkaline soils in the common village
parlance of northern India. Saline-alkaline soils are those soils whose electrical conductivity
(EC) is greater than 4 mmhos cm⁻¹ at 25°C and ESP greater than 15. Alkali soils have their ESP
greater than 15 and EC less than 4 mmhos cm\(^{-1}\) at 25 °C. The pH of alkali soils usually ranges from 8.5 to 10, though in some cases pH value even exceeds more than 10. Recently, the term alkali has been replaced by ‘Sodic’ to designate precisely the major chemical element i.e. sodium on the soil complex. The main distinguishing chemical characteristics of different classes of salt affected soils as per USSL along with their Indian names are summarized in Table 2.1.

**Table 2.1:** Distinguishing characteristics and local names of salt affected soils of India (Agarwal *et al.*, 1979).

<table>
<thead>
<tr>
<th>Class</th>
<th>EC x 10(^{-3}) (mmhos cm(^{-1}))</th>
<th>ESP</th>
<th>pH</th>
<th>Indian local names</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saline</td>
<td>&gt;4</td>
<td>&lt;15</td>
<td>&lt;8.5</td>
<td>Thur, Uppu, Lona, Shura, Soulu, Pokhali, Khar and Khari</td>
</tr>
<tr>
<td>Alkali (sodic) soil</td>
<td>&lt;4</td>
<td>&gt;15</td>
<td>78.5</td>
<td>Usar, Rakkar, Bara, Chopan and Kari</td>
</tr>
<tr>
<td>Saline-alkaline</td>
<td>&gt;4</td>
<td>&gt;15</td>
<td>variable</td>
<td>Usar, kallar, Bari, Chopan, Bari, Reh and Jougu</td>
</tr>
</tbody>
</table>
Matsuguchi and Yoo, (1979) stated that soil pH has a selective effect on both the indigenous algal flora and the changes of the algal population. The development of a dense algal bloom on an acidic soil (pH 5.5) was observed in Japan by them.

According to Stewart, (1967) the most satisfactory method of determining the importance of N$_2$ fixing BGA is to measure Rice yield in the presence and absence of added BGA in long-term field experiments and to compare that yield with that obtained when nitrogenous fertilizer is added. Experiments conducted with ecological and physiological bases, relating the qualitative and quantitative evolution of the N$_2$ fixing algal biomass and the fixed nitrogen to the environmental parameters. He suggested to determine the following aspects for better yield response:

- The limiting factors for algalization,
- The relative importance of growth-promoting substances, compared to fixed N$_2$ in increasing grain yield,
- The availability of fixed nitrogen for Rice,
- The efficiency of algalization compared with that of agronomic practices, which enhance the growth of the indigenous N$_2$ fixing algae.

Stewart et al., (1979) stated that the photoautotrophic habit of Cyanobacteria and their luxurious growth in aquatic environment explain their ecological and agricultural importance. A
large variety of Cyanobacteria colonizes the Paddy field soils. Some of these strains are equipped with the specialized cells known as heterocysts. These heterocysts are dedicated to the process of nitrogen fixation.

**Venkataraman, (1981)** studied about the effect of different fertilizers as a top dressing on the fertility of Paddy soil. Algalization of Paddy soil is one of such means capable of meeting a considerable preparation of Paddy nitrogen demand and the regulation of nitrogen status of the Paddy ecosystem. Application of these algae to the Paddy field at least for 3-4 consecutive cropping seasons result in an appreciable biomass build up, unless unfavorable ecological condition operate in specific localities. He again stated that the Paddy field ecosystem provides a favorable environment for the growth of BGA with respect to their requirements for light, water, high temperature and nutrient availability, this may account for the higher abundance of BGA in Paddy soils compared to other cultivated soils. The agricultural importance of BGA in Rice cultivation is directly related with the ability of certain forms to fix nitrogen. Contrary to heterotrophic N₂ fixing bacteria, BGA represent a self-supporting system capable of photosynthesis and the sun pays energy bill for N₂ fixation processes. Recent researches, conducted mainly in India, have shown the feasibility of using BGA as an additional nitrogen source for Rice.

**Roger, (1982)** well studied the Rice and BGA relationship. He stated that among the algae detrimental to Rice, because of their mechanical effect on the young plants, BGA can be considered as incidental. Even where they produced a bloom at the beginning of the cultivation cycle, their effect on yield was rarely negative. BGA exudates *viz.*, oxygen, organic acids, growth promoting substances and nitrogen. Oxygen production by BGA in anaerobic soils may prevent development of sulphate reduction processes harmful to Rice. Organic acids increase phosphorus availability. Besides increasing nitrogen fertility, BGA have benefitted to Rice plants
by the production of growth-promoting substances. The additive effect of algalization in the presence of a high level of N₂ fertilizer interpreted as an index of this growth promoting effect, but such an interpretation has still not been demonstrated in the field.

**According to Gapocktika and Karaush, (1985)** some algae acquire resistance to the hazardous allelochemicals released by plant residues and present in the environment and get acclimatized accordingly.

**Karaush, (1985)** stated that Blue Green Algae are the most sensitive microorganism to phenolic environment and can not survive in such conditions.

**According to Roger, (1985)** inoculation of BGA in Rice field may affect plant size, nitrogen content, and the number of tillers, ears, spikelets, and filled grains per panicle. The most frequently used criterion for assessing the effects of algalization has been better grain yield. Results of field experiments conducted mainly in India report an average yield increase of about 14% over the control, corresponding to about 450 kg grain ha⁻¹ per crop, where algal inoculation was effective. A higher grain yield increase was observed when algalization was in combination with Calcium, Phosphorus and sometimes Molybdenum application. Unfortunately, it is not possible to separate the direct effect of Phosphatic and Potassic fertilizers on Rice from its indirect effect upon the growth of indigenous or introduced algae. He also suggested that use of algalization along with N₂ fertilizers is controversial. The beneficial effect of algalization in the presence of N₂ fertilizers was most frequently interpreted as resulting from growth promoting substances produced by algae or also by a temporary immobilization of added N₂ followed by a slow release through subsequent algal decomposition permitting a more efficient utilization of N₂ by the crop.
Kannaiyan *et al.*, (1992) studied the performances of Cyanobacteria under normal and saline soils. Cyanobacterial metabolites encompass a wide range of chemical classes, particularly including a diversity of nitrogen rich alkaloids and peptides which have been suggested to both pose threats to human and environmental health worldwide, and equally hold considerable potential for development of pharmaceuticals and other biomedical applications. However, despite this extraordinary evolution of the chemical repertoire of Cyanobacteria, very little remains known about the functional role of these compounds in the physiology, ecology and natural history of these organisms.

Roger and Ladha, (1992) stated the following points to clear about the Rice field ecosystem and occurrence of BGA during cultivation cycle:

- A low pH, which favored the development of chlorophyceae but not of BGA.
- An absence of plant cover and a corresponding highlight intensity at the air-water interface that was also favorable for the development of chlorophyceae and diatoms but unfavorable to BGA.
- A high level of CO caused by soil remoistening which favored green-algae.
- During the cultivation cycle, a decrease in light intensity and N level related to Rice growth and an increase in pH value favored BGA growth.
- The non evolution of algal flora under a weak plant cover indicated the important role of light in regulating the algal composition.
According to Gopalasowamy et al., (2002) there are 83 forms of Cyanobacteria, which have been isolated from different paddy growing areas in India. Out of which 56 belong to Utter Pradesh, 23 from West Bengal, 27 from Andhra Pradesh and 7 from Assam. Very little information is available on the performance of Cyanobacteria in acidic soil.

According to Mishra and Dhar, (2004) The term ‘algalization’ is now applied to the use of a defined mixture of cyanobacterial species to inoculate soil, and research on algalization is going on in all major Rice producing countries. On the other hand in biological systems, nitrogen fixation in Cyanobacteria is brought about by an enzyme known as nitrogenase. Due to important characteristic of nitrogen fixation, the utility of Cyanobacteria in agriculture to enhance production is beyond doubt. Many studies have been reported on the use of dried Cyanobacteria to inoculate soils as a means of aiding fertility, and the effect of adding Cyanobacteria to soil on Rice yield was first studied in the 1950s in Japan. Among the oldest organism on earth, dating back in the fossil record to nearly 3.5 billion years ago, the Cyanobacteria (blue-green algae) have evolved to produce an impressive array of biologically active compounds.

Codd, et al., (2005) and Stewart et al., (2006) have been described about a number of incidents of human and non-human animal poisoning and several good references on the human health effects of cyanobacterial toxins which have been previously published.
2.1 Allelopathic potential of algae:

Keating, (1977) demonstrated quite elegantly that extracellular components from cultures of dominant Cyanobacteria isolated during succession of a single freshwater pond specifically showed inhibitory effects on predecessor strains, but not successor strains, from this system, supporting a clear role of extracellular compounds in the succession of cyanobacterial populations.

Francis, (1878) first time reported about toxicity of cyanobacterial metabolites with regard to their effects on human and environmental health. He also stated about death of livestock in South Australia, after consumption of Cyanobacteria-contaminated drinking water from Lake Alexandria.

Mason et al., (1982) reported the identification and characterization of a chlorinated γ–lactone, named cyanobacterin from a freshwater species of Scytonema that specifically inhibited a range of algae, including Cyanobacteria and green algae, at micromolar concentrations, but had little effect on non-photosynthetic microbes. Toxins produced by the blue green algae aquatic ecosystem inhibited the growth of aquatic macrophytes Elodea (duckweed).

Kirpenko, (1986) stated that a concentration of 10-7% and 10-1 % of toxin inhibited the inflorescence and germination in case of Poppy.
Sivonen et al., (1986) stated that the compounds produced by blue green algae specially Aphanezomenson flosaquae, Nodularia squimigena, Microcystis species and Oscillatoria species have been reported to be toxic, either to other plants or to their own population.

According to Gerwick et al., (1989) algae during their growth period produce certain chemicals having allelopathic properties. Majority of allelochemicals are acidic or phenolic in nature. Toxins related to marine blue green algae, Microcystis species and Oscillatoria species have peptide nature.

Vepritskii et al., (1991) identified two compounds from strains of Nostoc linckia that specifically inhibited photosynthetic algae, named cyanobacterin LU-1 and LU-2. Both compounds, however inhibited electron transport in photosystem II, and LU-1 was found to be inhibitory to Cyanobacteria and other algae, but not for non-photosynthetic microbes, whereas LU-2 inhibited Cyanobacteria only.
Inderjeet and Dakshini, (1994) suggested four ways through which the allelopathic behavior of algae can be easily understood:

i. Allelopathic effect of algal toxins on the growth of micro-organisms.

<table>
<thead>
<tr>
<th>Algae</th>
<th>Effect</th>
<th>Suggested by</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Rhodomela larix</em></td>
<td>Allelopathic interference on gram positive and gram negative bacteria by production of Bromophenols</td>
<td>Mautner et al., (1953); Rice (1984)</td>
</tr>
<tr>
<td><em>Sytonema hofmanni</em></td>
<td>Growth inhibition of <em>Bacillus brens</em> Bacteria and promote the growth of Actinomycetes</td>
<td>Mason and Gleason, (1981)</td>
</tr>
<tr>
<td><em>Chlorella vulgaris, Scenedesmus quadricauda, Chlamydomonas reinhardii</em> (Ether and Ethanolic extracts), <em>Chlorella vulgaris</em> (filtrate)</td>
<td>Inhibitory effect on <em>Bacillus subtilis</em></td>
<td>Jorgensen, (1962)</td>
</tr>
</tbody>
</table>
ii. Chemical/allelopathic interactions between different algal genera.

<table>
<thead>
<tr>
<th>Algae</th>
<th>Family</th>
<th>Effect/Study</th>
<th>Suggested by</th>
</tr>
</thead>
<tbody>
<tr>
<td>From filtered canal water</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>from canal water</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><em>Chlorella pyrenoidosa</em></td>
<td>Chloraceae</td>
<td>Growth inhibition of <em>Nitzschia palea</em> and stimulated to <em>Scenedesmous genera</em></td>
<td>Jorgensen, (1956)</td>
</tr>
<tr>
<td>(filtrate)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Chlamydomonas reinhardii</em></td>
<td>Chlamydomonadaeae</td>
<td>Killing/ growth inhibition of <em>Haematococcus pluvialis</em></td>
<td>Procter, (1957)</td>
</tr>
<tr>
<td>and <em>Scenedesmus quadricauda</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Platydorina caudata</em></td>
<td>Volvocaceae</td>
<td>Growth inhibition of <em>Volvox globator</em>, <em>V. tertius</em> and <em>Pandorina chrkowiensis</em></td>
<td>Harris, (1970)</td>
</tr>
</tbody>
</table>
iii. Algal autotoxicity.

<table>
<thead>
<tr>
<th>Algae</th>
<th>Nature</th>
<th>Suggested by</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Chlorella vulgaris</em></td>
<td>Productions of autotoxins</td>
<td>Pratt and Fong, (1940)</td>
</tr>
<tr>
<td><em>Nitzschia palea, Asterionella formosa</em></td>
<td>-Do-</td>
<td>Jorgenson, (1956)</td>
</tr>
<tr>
<td><em>Hormotila blennista</em></td>
<td>Autostimulatory</td>
<td>Monahn and Trainor, (1970)</td>
</tr>
<tr>
<td><em>Platydorina caudate</em></td>
<td>High growth &gt; reduction &gt; death due to auto-toxicity</td>
<td>Harris, (1970)</td>
</tr>
</tbody>
</table>

iv. Effect of algal toxins on the growth of higher plants.

<table>
<thead>
<tr>
<th>Algae</th>
<th>Effect</th>
<th>Suggested by</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Scytonema hofmanni</em></td>
<td>Inhibited growth of the aquatic weed <em>Lemna gibba</em> and the terrestrial angiosperm species such as <em>Setaria viridis, Avena fatua, Rumex crispus, and Polygonum convolvulus</em> while killing seedlings of <em>Zea mays</em> and <em>Pisum sativum</em></td>
<td>Gleason and Case, (1986)</td>
</tr>
<tr>
<td><em>Oscillatoria sp.</em></td>
<td>Inhibited the growth of an aquatic angiosperm <em>Spirodela polyrhiza</em> and terrestrial angiosperms such as wheat, pigeon pea, black gram, coriander and mustard</td>
<td>Chauhan <em>et al.</em>, (1992)</td>
</tr>
</tbody>
</table>
Zwain, (1999) studied the allelopathic effect of decomposing plant residues on the growth and biological nitrogen fixation of blue green algae. He found that the decomposing plant residues significantly stimulated growth of BGA, *Anabaena cylindrical* and *Nostoc musicirum* algae but inhibited the rate of biological nitrogen fixation.

Martin et al., (1990) and Kato, (2002) reported that Rice crop residual left after harvest, have adverse effect on the subsequent crop and soil flora and fauna. This residue at the time of its decomposition releases some chemicals which have inhibitory effect on micro-algae and crop. Sometimes these get accumulated in soil and have very adverse effect. There are reports on allelochemicals produced from the crop residue and inhibiting the seed germination of Maize and Soyabean and Lettuce (*Lattuca sativa* L.).

According to Chung et al., (2001) Rice straw left in the field release phenolic compounds during decomposition which inhibited the growth of nitrogen fixation of *Anabaena cylindrical* and had an inhibitory effect on subsequent crop Soyabean and Wheat.

According to Nakai and Hosomi, (2002) the compounds extracted and isolated from the macrophyte *Typha* species and *Myriophyllum spicatum* had shown selective inhibitory response on blue green algae. In another experiment growth inhibition of macrophytes by algal populations was also observed. This was one of the important attribute towards the allelopathic behavior of algae.

Vardi et al., (2002) presented compelling evidence to suggest reciprocal non-nutritional control of population growth between microcystin producing *Microcystis* species and the dinoflagellate, *Peridinium gatunense* in the mesotrophic Sea of Galilee based on apparent
allelopathic compounds, including microcystins and unknown components of the *P. gatunense* culture medium.

**Chakraverty et al., (2002)** stated about role of cyanobacterial secondary metabolites as chemical defenses against potential planktivores and role of these compounds in allelopathy.

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**According to Mishra and Tiwari, (2002)** in a wetland Rice ecosystem, nitrogen fixation by free-living Cyanobacteria also significantly supplements soil nitrogen. Allelopathic interaction between Rice residue and algal growing in the field, are of great importance because these can affect the biological nitrogen fixation status of algae and it may pose potential danger for the subsequent crops over a long time. Thus, it is worthwhile to study the algal flora from the paddy field and the effect of algal leachates on the growth of Rice production.

**According to Benson, (2008)** among the oldest organism on earth, dating back in the fossil record to nearly 3.5 billion years ago, the Cyanobacteria (Blue Green Algae) have evolved to produce an impressive array of biologically active compounds.

**John et al., (2008)** stated about the reputed role of cyanobacterial secondary metabolites as chemical defenses against potential planktivores and other grazers, emerging evidence also suggests a role of these compounds in allelopathy. According to him, Allelopathy has been well described in terrestrial plant systems, which are involved in the use of biologically active metabolites by one species to inhibit the growth of sympatric species that might potentially compete for natural resources.
According to Sana and Brahim, (2011) Cyanobacteria are photosynthetic prokaryotes which frequently form blooms in eutrophic water bodies. Some species of cyanobacteria are able to produce toxins (cyanotoxins) that can cause aquatic environment and diverse organisms living there to be at a serious risk. One of the more serious impacts of eutrophication on aquatic ecosystems is the disappearance of submerged macrophytes and the shift to a phytoplankton-dominated state.

The above literature concludes that the application of high input technologies significantly increase agriculture production. There is, however, a growing concern about the adverse effects of indiscriminate use of chemical fertilizers on soil productivity and environmental quality. Cyanobacteria offer an economically attractive and ecologically sound alternative to chemical fertilizers for realizing the ultimate goal of increased productivity, especially in Rice cultivation. In a wetland Rice ecosystem, nitrogen fixation by free living Cyanobacteria also significantly supplements soil nitrogen. Allelopathic interaction between Rice residue and algal growing in the field, are of great importance because these can affect the biological nitrogen fixation status of algae and it may pose potential danger for the subsequent crops over a long time. Thus, it is worthwhile to study the algal flora from the paddy field and the effect of algal leachates on the growth of Rice production.