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# Cyanobacteria "the blue green algae" and its novel applications: A brief review

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**ABSTRACT:** Cyanobacteria are among the earliest of inhabitants of Planet Earth and are highly diverse members of the current global biodiversity and are making significant contributions to the Carbon and Nitrogen bio-geochemical cycles, particularly in the deep oceans. Cyanobacteria in recent year have gained importance because of their potential use in various areas of research. This diverse group has application in various fields like biotechnology, pharmacology, agriculture etc. Due to presence of wide spectrum of bioactive compounds cyanobacteria has possesses antiviral, antibacterial, antifungal and anticancer activities. Several strains of cyanobacteria are also rich in food supplements. Further nitrogen fixing capacity of cyanobacteria has attracted agriculturists and researchers and they used blue green algae as a component of biofertilizers to improve both the fertility of soil as well as growth of plants. Recent studies have also shown that cyanobacteria have capability to degrade environmental pollutants and are also being used as a promising source of alternative energy. In spite of all these investigation and research more efforts should be made in search of more strains of cyanobacteria and genetically modifying known strains to ensure maximum production of the desired products.

**KEYWORDS:** blue green algae, secondary metabolites, alternative fuel, xenobiotics, nitrogen fixation.

## 1 INTRODUCTION

Cyanobacteria a group of gram negative photoautotrophic bacteria are the one of the most primitive component of our mother earth and it was the cyanobacteria in the Archaean and Proterozoic Eras (2.7 billion years ago) that were responsible for creating our oxygenic atmosphere through their photosynthetic activities. Cyanobacteria were the first organisms to utilize two photosystems (photosystems I and II) and split $H_2O$ instead of $H_2S$ as other bacteria do. Cyanobacteria capture sunlight using chlorophyll a and various accessory pigments especially c-phycocyanin and perform photosynthesis as algae and plants. Although cyanobacteria perform oxygenic photosynthesis just like eukaryotic green algae and higher plants, they do not store food in the form of starch. Their principal storage product is cyanophycean starch and glycogen together with specialized intracellular storage compounds like lipids, protein containing cyanophycean granules and polyphosphate bodies [1]. Cyanobacteria are ubiquitous in nature and found commonly in lakes, ponds, springs, wetlands, streams, and rivers, and they play a major role in the nitrogen, carbon, and oxygen dynamics of many aquatic environments. Cyanobacteria not only have wide range of habitat but also have a range of organization that range from unicellular, to filamentous, to colonial. Cyanobacteria not only persist as free living but also form symbiotic associations like *Rickelia intracellularis* lives as endosymbionts in large diatoms. Cyanobacteria are also endosymbiotic in fungi (lichens), bryophytes (*Anthoceros)*, pteridophytes (*Azolla*), cycads (coralloid roots), angiosperms (*Gunnera*) and certain marine sponges and corals. It is also believed that the chloroplasts in plants and algae derived from an endosymbiosis in which a cyanobacterium was engulfed and retained within a colorless eukaryotic cell. Cyanobacteria are prokaryotic and lack internal organelles, a discrete nucleus and the histone proteins associated with eukaryotic chromosomes unlike eukaryotes and like all eubacteria, their cell walls contain peptidoglycan, not cellulose (like many algae and all plants). All cyanobacteria possesses chlorophyll a and also other pigments like the blue phycobiliproteins, phycocyanin and allophycocyanin, which gives cyanobacterial cells their characteristic blue-green color because of which they are dubbed as "blue green bacteria". Other taxa also contain the

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phycobiliprotein phycoerythrin, making the cells red, or sometimes black. Phycobiliproteins are found in specialized structure called phycobilisomes and these efficiently guides or monitors captured solar energy to the reaction centers of photosynthesis i.e. photosystem II [2]. Cyanobacteria also form symbiotic association with leguminous plant and play vital role in the growth and health of the plant. Cyanobacteria are among one of few organisms that convert atmospheric nitrogen into an organic form, such as **nitrate** or ammonia and thus they serve as inexpensive natural biofertiliser for the plants. Cyanobacteria are not only known for their role in ecology and evolution but also have a wide range of application in pharmacological and biotechnological applications. Cyanobacteria today are not only explored in agriculture as biofertiliser but also in pharmacology, in cancer treatment, bioremediation, as biofuel and also as a food supplements. In other words, we can say that cyanobacteria have ignited a revolution in wide area of health and agriculture.

## 2 CYANOBACTERIA AS A NATURAL BIOPHARMACEUTICALS

Now a days there are many modern approaches for drug discovery even though drug development have not gained much pace due to lack of proper lead in biomolecules, which is crucial to designing newer drug [3].Hence there is a need to switch to newer natural bioresources that could act as the reservoir for such molecules and this lead to the researchers for screening of cyanobacteria for discovering new drugs .Cyanobacteria are Gram-negative eubacteria and are known for their morphological diversity leading to the development of natural biopharmaceuticals due to presence of structurally diverse groups of compound [4], [5]. Cyanobacterial secondary metabolites have been isolated from a number of cyanobacterial genera from different geographical locations and represent a vast diversity of structures which is a result of the cyanobacterial capacity to integrate both Non-Ribosomal Peptide Synthethases with Polyketide Synthases. Cyanobacteria have a wide range of enzymes responsible for methylations, oxidations, tailoring and other alterations [6], resulting in chemically diverse natural products such as linear peptides [**7**], cyclic peptides [**8**], linear lipopeptides [**9**], depsipeptides [**10**], cyclic depsipeptides [**11**], fatty acid amides [**12**], swinholides [**13**], glicomacrolides [**14**] or macrolactones [**15**].

During the last two decades, cyanobacterial secondary metabolites have attracted the attention of researchers mainly due to two reasons; (i) acute toxicity of toxins produced by several bloom forming cyanobacteria in freshwater system and their harmful effect on animals and human health, and (ii) potential therapeutic use of several secondary metabolites [16], [17], [18]. The cyanobacterial secondary metabolites include several biological activities like antibacterial, antifungal, antialgal, antiprotozoan, and antiviral activities.

### 2.1 ANTIBACTERIAL ACTIVITY

Bacterial resistance towards antibiotics has been the main factor responsible for the increase of morbidity, mortality and health care costs of bacterial infections. The defense mechanism against antibiotics is widely present in bacteria (eg : *Pseudomonas, Klebsiella, Enterobacter, Acinetobacter, Salmonella, Staphylococcus, Enterococcus* and *Streptococcus*) and became a worldwide concern. So there is rising interest of researchers for natural products for the discovery of new antimicrobial and antioxidant agents in the last three decades. Secondary metabolites with antibacterial activity are widely produced by cyanobacteria [19]. These compounds are effective against both Gram-positive and Gram-negative bacteria. It has also been found by the researchers that both toxic and nontoxic strains of cyanobacteria are potent producers of antibacterial compounds that are distinct from cyanotoxins [20]. Literature survey revealed that Malyngolid from *Lyngbya majuscule* [17], Norharmane (*N. insulare*) [21], Kawaguchipeptin B (*Microcystis aeruginosa*), cyclic undecapeptides, lyngbyazothrins A, B, C , and D from the cultured *Lyngbya* sp.have antibacterial activity against number of bacteria (eg *Micrococcus flavus, Bacillus subtilis*, *Escherichia coli*, *Pseudomonas aeruginosa*, and *Serratia marcescens, Mycobacterium smegmatis* and *Streptococcus pyogenes* [22]. Some author also reported the production of antimicrobial agents from *Nostoc communes, Cytonema hofmanni, Hapalosiphon fontinalis, Anabaena spp., Nostoc spongiaeforme, Microcystis aeruginosa, Synechocystis* and *Synechococcus, Phormidium sp.,* and *Fischerella sp* and extracts of *Spirulina platensis* obtained by different solvents exhibited different degrees of antimicrobial activity on both Gram-positive and Gram-negative organisms [23]. Many investigators also found that the acetone extract of Cyanobacteria have antimicrobial activity *Nostoc commune* on *E.coli, Bacillus subtilis* and *Pseudomonas aeruginos*a [24], [25]. Many more antibacterial compounds are also isolated from various other Cynobacterial strains such as Noscomin [26]. from Nostoc commune, Carbamidocyclophanes are paracyclophanes isolated from Nostoc sp. CAVN 10 [27]. Nine ambiguines from Fischerella sp. are isolated , which showed antimicrobial activity [28]. Two new norbietane compounds, showing antibacterial activity against various Gram positive and Gram negative bacteria, were isolated from Micrococcus lacustris [29].

### 2.2 ANTIFUNGAL ACTIVITY

Fungi, as a major disease causing agent, were realized after 1980, especially among the immunocompromised and other serious diseases [30]. There are limitations with regards to antifungal drugs because of their price and side effects [31]. So, the researchers are exploring biodiversity for search of new lead compounds with minimum or no toxity. In this regard cyanobacteria came out to be a novel organism. Antifungal compounds include fisherellin A, hapalindole, carazostatin, phytoalexin, tolytoxin, scytophycin, toyocamycin, tjipanazole, nostocyclamide and nostodione produced by cyanobacteria belonging to Stigonematales, Nostocales and Oscillatoriale [32], cyclic depsipeptide Lyngbyabellin B was also isolated from *L. majuscula* which show toxicity against brine shrimp and fungus *Candida albicans* [33]. Studies done by Vijayakumar Madhumathi et. al. also reavaled antifungal activitiy of various strains of cyanobacteria. It was found that acetone extract of *Phormidium corium,* methanol extract of *Lyngbya martensiana* and diethyl ether extract of *Microcystis aeruginosa* have antifungal activity. In addition, *Oscillatoria latevirens, Chrococcus minor and Microcystitis aeroginosa* were also found to have antifungal activity on *Candida albicans.* Other authors also reported that methanolic crude extract of *Aphanothece bullosacrude* was found more potent antifungal in comparision to *Lyngbya aestuarii* and crude extract and pure compounds from other freshwater cyanobacteria such as Anabaena, Nostoc, Aphanocapsa, Synechocystis, Synechococcus, Oscillatoria, Nodularia,Calothrix have shown antifungal activity [34], [35], [36], [37], [38], [39].The extracts of Oscillatoria latevirens, Chrococcus minor and Microcystitis aeroginosa were found to have antifungal activity on Candida albicans [40].

### 2.3 ANTIVIRAL ACTIVITY

In contrast to the large amount of antibacterial and antialgal compounds isolated from cyanobacteria there are only a few compounds that show antiviral propertie, although 2–10% of extracts of different cyanobacterial species have been shown to have antiviral activity [41]. These include acetylated sulfoglyco-lipids from *Oscillatoria raoi* and spirulan from *Spirulina platensis.* The compounds isolated from *Lyngbya lagerhaiman*i and *Phormidium tenue* has been shown to have anti-HIV activity [42]. Study carried out by researchers shown that hot water extract of spirulina part of the fractionated product inhibited the replication of several viruses, especially those with an envelope such as the measles virus, and the HIV-1 virus, in human T cells, peripheral blood mononuclear cells and Langerhans cells. This component was found to be a sulfated polysaccharide, calcium spirulan [43], [44]. In addition, in undernourished children spirulina has been found to improve weight gain and correct anemia in both HIV-infected and HIV-negative cases [45].

### 2.4 ANTICANCER ACTIVITY

One of the most important treatments currently available for cancer and other diseases is chemotherapy which has limited effectiveness due to some serious life-threatening side effects (like fatigue, irritation of oesophagus that can cause difficuty in swallowing and inflammation of lungs). It may also cause vomiting, neutropenia, anemia, another infectious complicatios [46] and development of drug resistance cancerous cells. The side effects of the anticancer drugs not only prevent effective chemotherapy, but also compromise the quality of life of the patients [47]. One Effective solution of the problem mentioned above can be using natural anticancer products. Presently 50% of the drugs used in the cancer treatment comprises of the natural sources like bacteria, actinomycetes, fungi sponges, plants and animals. Cyanobacterial anticancerous metabolites have also showed positive response. The presence of the bioactive compounds present in the crude extract of *Oscillatoria boryana* may posses the anticancer activity against the breast cancer cell lines (MCF-7)[48]. Marine cyanobacteria were found to produce a wide range of compounds that revealed apoptotic properties. It is reported that HL-60 cells exposed to aqueous extracts of *Synechocystis* sp. and *Synechococcus* sp. strains, presented cell shrinkage showing that cells were developing apoptosis, and membrane budding, that occurs when cell is fragmented into apoptotic bodies [49]. Biselyngbyaside, a macrolide glycoside produced by *Lyngbya* sp., was found to induce apoptosis in mature osteoclasts, revealed by nuclear condensation [50]. Marine benthic *Anabaena* sp. extracts were found to induce apoptosis in acute myeloid leukemia cell line, with cells showing several described typical morphological markers, such as chromatin condensation, nuclear fragmentation, surface budding and release of apoptotic bodies [51]. The potential of marine benthic cyanobacteria as a source of anticancer drug candidates was assessed in a screen for induction of cell death (apoptosis) in acute myeloid leukemia (AML) cells. Of the 41 marine cyanobacterial strains screened, more than half contained cell death-inducing activity. Several strains contained activity against AML cells, but not against non-malignant cells like hepatocytes and cardiomyoblasts. Ovarian carcinoma and breast carcinoma cells which are multiply drug resistant due to over expression of P-glycoprotein are markedly less resistant to cryptophycin than they are to vinbiastine, colchicine, and taxol. So, cryptophycin is a new antimicrotubule compound which appears to be a poorer substrate for P-glycoprotein than are the Vinca alkaloids. This property may confer an advantage to cryptophycin in the chemotherapy of drug resistant tumors [52]. Other cyanobacterial metabolites such as curacin A, dolastatin 10 ,Symplostatin 3 and Belamide A have been in preclinical

and/or clinical trials as potential anticancer drugs. In addition, these molecules served as drug leads for the development of synthetic analogues, e.g. compound 4, TZT-1027, ILX-651, and LU- 103793, usually with improved pharmacological and pharmacokinetic properties [53], [54], [55].

## 3 ANTIOXIDANT

'Antioxidants' are substances that neutralize free radicals or their actions [56]. Nature has endowed each cell with adequate protective mechanisms against any harmful effects of free radicals: superoxide dismutase (SOD), glutathione peroxidase, glutathione reductase, thioredoxin, thiols and disulfide bonding are buffering systems in every cell. α-Tocopherol (vitamin E) is an essential nutrient which functions as a chain-breaking antioxidant which prevents the propagation of free radical reactions in all cell membranes in the human body. Ascorbic acid (vitamin C) is also part of the normal protecting mechanism. Other non-enzymatic antioxidants include carotenoids, flavanoids and related polyphenols, α-lipoic acid, glutathione etc. Studies also indicate that cyanobacterial pigments carotenoids, phycobiliprotein, and c-phycocyanin are the compounds with higher antioxidant activity. Carotenoids isolated from the marine *Trichodesmium* are responsible for an antioxidative protection, observed with ferric reducing/antioxidant power assay [57]. In the same study, extracts from marine strains of *Anabaena*, *Cyanothece*, *Prochlorothrix* and *Synechococcus* showed antioxidant properties, but mainly in the protein extract. Also the major phycobiliprotein, c-phycocyanin, from both *Lyngbya* and *Phormidium*, is capable to scavenge ROS, in particular peroxyl and hydroxyl radicals [58]. It was also suggested that this antioxidant capacity is resultant from the covalent linked tetrapyrole chromophore with phycocyanobilin [58].

## 4 CYANOBACTERIA IN DIET

Strains of *Spirulina, Anabaena* and *Nostoc* are consumed as human food in many countries including Chile, Mexico, Peru and Philippines. *Arthrospira platensis* is grown in large scale and marketed in the form of powder, flakes, tablets and capsules. It is used as a food supplement because of its richness in nutrients and digestibility. It contains more than 60% proteins and is rich in beta-carotene, thiamine and riboflavin and is considered to be one of the richest sources of vitamin B12. *Nostoc commune* is rich in fibres and proteins and can play an important physiological and nutritional role in the human diet. Gamma linolenic acid (GLA) found rich in *S. platensis* and *Arthrospira sp*. is medically important since it is converted in the human body into arachidonic acid and then into prostaglandin E2. This compound has a lowering action on blood pressure and plays an important role in lipid metabolism. Some of the marine cyanobacteria constitute potential sources for large-scale production of vitamins, such as vitamins B and E. Futher, it has been also reported that Spirulina is rich in proteins, carbohydrates, polyunsaturated fatty acids, sterols and some more vital elements such as calcium, iron, zinc, magnesium, manganese and selenium. It is a natural source of vitamin B12, vitamin E, ascorbic acid, tocopherols and a whole spectrum of natural mixed carotene and xanthophylls phytopigments. *Spirulina* as a supplement serves to provide these nutrition requirements and seems to be a 'wonder food'. It has been stated by NASA that the nutritional value of 1000 kg of fruits and vegetables equals one kg of spirulina. Therefore in long-term space missions NASA (CELSS) and European space agency (MELISSA) proposed that spirulina serves as a major source of food and nutrition [59]. The United Nations has hailed spirulina as the possible "**best food for the future**" in its world conference held during 1974. Spirulina can be harvested by simple methods and can be processed into a variety of final forms such as powders, tablets, flakes, syrups, etc [60].

## 5 BIOREMEDIATION

In this present scenario industrial revolution has harmed our environment to much extent. Effluents released have contaminated water bodies and causing several serious health problems. Water bodies receiving the effluent show high BOD, COD and chloride levels that are well above the stipulated concentrations prescribed by the Indian Standard Institute (ISI). So there is a need to remove all these pollutants from our water bodies. There are several approaches for remediating pollutants among those is **"**Bioremediation". Bioremediation is gaining importance as a less expensive alternative to physical and chemical means of decomposing organic pollutants. Pathways of biodegradation have been characterized for a number of heterotrophic microorganisms, mostly soil isolates, some of which have been used for remediation of water. Recently, there has been increasing awareness about using cyanobacteria as bioremediation and pollution control agents, either as wild-type, mutant, or genetically engineered forms. As bioremediating agents, cyanobacteria possess many advantages over other microorganisms isolated from soil. These include their photoautotrophic nature and the ability of some species to fix atmospheric nitrogen. This enables them to be producers, as opposed to consumers, and makes their growth and maintenance inexpensive [61]. Blue green algae have been shown to be highly effective as accumulators and degraders of different kinds of environmental pollutants, including pesticides [62], crude oil [63], [64], naphthalene [65], [66],

phenanthrene [67], phenol and catechol [68], [69], and xenobiotics [70] blue green algae could also serve as effective biosorbant for removing heavy metals from contaminated waters [71], [72]. Worldwide, cyanobacteria have been used efficiently as a low-cost method for remediating dairy wastewater by converting the dissolved nutrients into biomass [73] and for biotreatment (removal) of dissolved inorganic nutrients from fish farms [74].The studies conducted by various shown biodegradation and biosorption capacity of some potential cyanobacterial species: *Oscillatoria* sp., *Synechococcus* sp., *Nodularia* sp., *Nostoc* sp. and *Cyanothece* sp. dominated the effluents. Some author also reported natural ability of two filamentous cyanobacteria *Anabaena* sp. and *N. ellipsosporum* degrade a highly chlorinated aliphatic pesticide, lindane (g-hexachlorocyclohexane) and this ability can be enhanced by genetic engineering. Soil bacteria [75], [76], [77], fungi, and an *E. coli* strain from rat feces [78] that use lindane as a primary carbon source degrade it to g-2,3,4,5,6-pentachlorocyclohexene, a-, b-, and g-tetrachlorocyclohexene, or pentachlorobenzene, depending on the strain.

Chromium is a heavy metal and its toxicity can cause serious carcinogenic, genotoxic and immunotoxic effects in humans and animals. Conventional methods used for the removal of hexavalent Cr use chemical procedures, which are expensive and lack specificity. So an alternative method was proposed by Kannan. V et al for the removal of chromium present in tannery effluent. Filamentous Cyanobacteria *Anabaena flos-aquae. Anabaena flos-aquae was found to grow* in effluent at various dilutions [79].

Heavy metals nickel (Ni) released into the environment over a long period of time through various anthropogenic activities like burning of fossil fuels and residual oils, coal mine spoils, sewage sludge, production of Ni-Cd batteries are the primary source of Ni and exhibit toxic effect on biota [80]. Remediation of nickel (Ni) by Anabaena doliolum has been suggested by M.K. Shukla et al in view that nickel ion has been shown to be an essential micronutrient for many microorganisms as it plays important role in four microbial enzymatic activities [81], [82]. In several other studies it was found that cultures of Oscillatoria sp. BDU 30501, Aphanocapsa sp. BDU 16 and a halophilic bacterium Halobacterium US 101 were used to treat a factory effluent and resulted in reduction of calcium and chloride to levels that did not inhibit survival and multiplication of fish [83]. Phormidium valderianum BDU 30501 was used to reduce phenol concentrations [84] while Oscillatoria boryana BDU 92181 was used to eliminate melanoidin pigment from distillery effluents [85]. Further in an study conducted by Slotton et al [86] it was found that *Spirulina platensis*, a cyanobacterium contained detectable levels of mercury and lead when grown under contaminated conditions implying that this cyanobacterium was taking up the toxic metal ions from its environment.

J. L. Gardea-Torresdey has also added a new approach in bioremediation techniques. They have silica-immobilized inactivated cells of *Synechococcus sp*. PCC 7942 to used as a biosorption resin for the removal and recovery of metal ions such as copper(II), lead(II), nickel(II), cadmium(II), and chromium(III) ions. from contaminated waters. Biosorption resin can also be used after one cycle of adsorption/desorption In further experiment it was also demonstrated that metallothionein were capable of binding more metal ions. [87]

Cyanobacteria based biosensor has also been generated that could be used to detect herbicides and other environmental pollutants. freshwater cyanobacterium, *Synechocystis* sp. strain PCC6803, was chromosomally marked with the luciferase gene *luc* (from the firefly *Photinus pyralis*) to create a novel bioluminescent cyanobacterial strain and expression of the *luc* gene during growth of *Synechocystis* sp. strain PCC6803 cultures was characterized by measuring optical density and bioluminescence [88].

### 5.1 BIOFUEL

#### 5.1.1 BIODIESEL

Cyanobacteria are well suited for synthetic biology and metabolic engineering approaches for the phototrophic production of various desirable biomolecules, including substances with cytotoxic, antifungal, antibacterial and antiviral activities [89], [90]. Lipids, carotenoids, pigments, vitamins and aromatic compounds are also found in cyanobacteria. Lipids (accumulated in the thylakoid membranes) are associated with high levels of photosynthesis and rapid growth rate and are of particular interest, since they can be used as lipid feedstock for biodiesel production [91], [92], [93]. Microalgae accumulate large amounts of lipids as reserve material, but only in conditions of stress and slow growth [94]. Thus, cyanobacteria have a natural advantage to produce lipids in high-speed growth. The biosynthesis of fatty acid-based biofuels in cyanobacteria includes two steps, production and transesterification of fatty acids (FAs) to form alkyl FA esters [95]. Considering that fuel properties are largely dependent on the FA composition of the feedstock from which biodiesel is prepared. The presence of double bonds in the FAs from cyanobacterial lipids is related to their morphological complexity [96]. *Synechococcus* sp. PCC7942, *M. aeruginosa* NPCD-1 and *Trichormus* sp. CENA77 had the best set of properties to be

used as a feedstock source in the synthesis of biodiesel. They showed appropriate values of biomass and lipid productivity, as well as FA profiles similar to the oil seeds already used successfully in the synthesis of biodiesel.

#### 5.1.2 HYDROGEN PRODUCTION

As we all know cyanobacteria are photosynthetic organism and have caliber to convert water to hydrogen by captured solar energy due to the presence of multiple hydrogen-producing enzymes. This ability of cyanobacteria has been demonstrated in production of biofuel in the form of hydrogen. In this procedure captured solar energy by the two photosystems is used to split water, producing oxygen, and generate a high-energy, low-potential reductant capable of reducing protons to hydrogen via a hydrogenase enzyme, a process that has been called biophotolysis. This method is more reliable and simple since we are using an abundant substrate, water, and a ubiquitous energy source, solar energy, to produce a highly diffusible and energy-dense fuel, hydrogen. It has been also observed that heterocystous cyanobacteria are mostly involved in hydrogen production due to the presence of nitrogenase provide a quasi-anaerobic microenvironment which allows the oxygen-sensitive nitrogenase to function and evolve hydrogen in case of an environment supersaturated with oxygen [97].

## 6 BIOFERTILISER

Biofertilizer has gained much importance in recent years and play vital role in maintaining long term soil fertility and sustainability by fixing atmospheric dinitrogen (N=N), mobilizing fixed macro and micro nutrients or convert insoluble phosphorus in the soil into forms available to plants, thereby increases their efficiency and availability. It has been observed that by applying biofertilizers crop production can be enhanced by 20-30% if are used properly. The microorganisms (Azotobacter, Blue green algae, Rhizobium Azospirillum) in biofertilizer are the major component promoting the adequate supply of nutrients to the host plants and ensuring their proper development of growth and regulation in their physiology. Biofertilizer can also protect plants from soil born diseases to a certain degree. The need for the use of biofertilizer has arisen, primarily for two reasons. First, because increase in the use of fertilizers leads to increased crop productivity, second, because increased usage of chemical fertilizer leads to damage in soil texture and raises other environmental problems. Due to the important characteristic of nitrogen fixation, cyanobacteria have a unique potential to contribute to enhance productivity in a variety of agricultural and ecological situations. Cyanobacteria play an important role to retain soil fertility by consequently increasing the yield by converting atmospheric nitrogen into an available form of ammonium. Dominant nitrogen-fixer blue-green algae are *Anabaena, Nostoc, Aulosira, Calothrix, Plectonema* etc. The activities of algae include: (1) Increase in soil pores with having filamentous structure and production of adhesive substances. (2) Excretion of growth-promoting substances such as hormones (auxin, gibberellin), vitamins, amino acids [98], [99]. (3) Increase in water holding capacity through their jelly structure. (4) Increase in soil biomass after their death and decomposition [100]. (5) Decrease in soil salinity [101]. (6) Preventing weeds growth [102]. (7) Increase in soil phosphate by excretion of organic acids [103]. Beneficial effects of cyanobacterial inoculation were also reported on paddy crop grown both under upland and low land conditions and on a number of other crops such as barley, oats, tomato, radish, cotton, sugarcane, maize, chilli and lettuce (126). BGA are not only source of N2 but also provides other advantages such as algal biomass accumulates as organic matter; produces growth promoting substances which stimulate growth of rice seedling; provides partial tolerance to pesticides and fungicides and also helps in reclamation of saline and alkaline soils.

## 7 CONCLUSION

Cyanobacteria are the most primitive organism and are known for creating oxygenic atmosphere through their photosynthetic activities. Cyanobacteria perform photosynthesis as plant and algae does by capturing sunlight by using chlorophyll a and various other accessory pigments. They are ubiquitous in nature and play a major role in the nitrogen, carbon, and oxygen dynamics of many aquatic environments. Cyanobacteria are found not only as free living organism but are also found in symbiotic association with plant and other organisms. In recent year cyanobacteria have gained importance in various areas of research viz agriculture, drug discovery, treatment of deadly disease such as HIV and cancer, bioremediation and now a days it is also exploited as alternative source of fuel i.e. biofuel. Various pharmacological effect of cyanobacteria are due to the presence of bioactive compounds found in cyanobacteria and are being used in agricultural field due to its ability to fix atmospheric nitrogen into ammonium which promote growth of plants. Cyanobacteria has also attracted attention of environmentalist in bioremediation due to its ability to degrade pollutants including pesticides, crude oil, naphthalene ,phenanthrene, phenol and catechol () and xenobiotics , could also serve as effective biosorbant for removing heavy metals from contaminated water bodies. Not only has this cyanobacteria might be used to solve problem of food crisis and malnutrition. Several strains of cyanobacteria eg *Spirulina, Anabaena* and *Nostoc* are consumed as human

food in many countries including Chile, Mexico, Peru and Philippines. *Arthrospira platensis*. *Spirulina* as a supplement serves to provide nutrition requirements and seems to be a 'wonder food'. It has been stated by NASA that the nutritional value of 1000 kg of fruits and vegetables equals one kg of spirulina. Inspite of all these advantages and discovery cyanobacteria need to be explored more and more research should be conducted so that more fruitful results will come out.

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