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A REVIEW

Role of Cyanobacteria in crop production

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Abstract : Microorganisms make a deal in the field of agro-ecosystem and environment (7). Continuous in global human population may hamper in the field related to soil fertility, (39) energy crisis, food security for further generation (40). These conditions could be regulated by using synthetic fertilizers (8). Although synthetic fertilizers are effective but have deleterious effect on the field. This article focuses on the role of Cyanobacteria with context to the field of crop production (13). Cyanobacteria aka blue green algae belongs to aprimordialdescent of photo-oxygenic bacteria. They also form symbiotic association capable to fix atmospheric Nitrogen into utilise form and make it available to the plants. Its extra ordinary development rate shows its use in the field of biotechnology, medicine, agriculture, bio energy. The exo-polysaccharide of Cyanobacteria balances soil ecology and they have the ability to compete with flora and fauna. Several Cyanobacteria have high biomass yield, generation of useful by-products, bio fuel and enhancing sustainable development in the field of science. In this review article describes the latent use of the bacteria in the crop field, different area of science field and mass production of cyanobacteria bio fertilizer in agriculture to overcome the use of chemical fertilizers.

Key Words : Cyanobacteria, Crops, Morphology, Bio remediation, Bio fertilizers, Bio fuel

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INTRODUCTION

The continual demands of ever increasing population and their anthropogenic activities create a pressure to meet sustainability goals on the field of agriculture (1). Disease out breaks, food preservation, global warming, and energy crisis requires a elucidation that is parsimoniously sustainable, sustainable as well as practicable (2). To scale up their production, the excess use of chemical fertilizers which are effective for short time period but have deleterious long term effect on the human health as well as ecosystem. Cyanobacteria performs many roles in the soil biome to upkeep the soil productiveness [3].Cyanobacteria have been on the earth over 3 billion years and one of the most autotrophic, gram

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negative organism on earth (4). They are self-contained bacterium with photosynthetic abilities which can survive under any type of substrateand can be seen exhibiting wide ranges of nutritious and ecological skills (5 and 6).They can grow in environments like fresh and salty water, moist rocks, soggy soil, salt marshes, tree trunks, hot spring and frozen water. Many species of cyanobacteria are buoyant and will float to the surface, where they will form scum so that many people refer to cyanobacteria as "pond scum" (7). Seawater is considered as one of the richest sources of nutrients for refinement of cyanobacteria (8). Cyanobacteria could be used as fertilizers in organic agriculture due them being diazotrophs *i.e.* skill to race with innatefauna and flora (9).

Cyanobacteria can be associated with a range of colours like green, blue, brownor reddish-purple. It have the ability to estimate nitrogen in the range 20-30kg/ha (10) also have the capacity to assimilate soil by elevating them with the help of phosphorus, carbon, improving pH, conserve moisture, texture and ion exchange capacity (11). They are the natural antifungal andanti bacterial compound (12). Cyanobacteria are one of the very few botanical sources for all 20 essential amino acids (13). It degradesa wide variety of pollutants (14). Effective cyanobacteria that can fix nitrogen are *Aulosira* sp., *Nostoc* sp., *Anabaena* sp., *Calothrix* sp. (15).

Morphology:

Cell structure :

Cyanobacteria relatively show different morphological characters as compared to other prokaryotes. These are capable of oxygenic photosynthesis. Cyanobacteria may be unicellular for example in the order Chroococcales, colonial, or filamentous are varying greatly in shape and appearance. The diameter ranges vary from 1 to 10 micrometre (16 and 17). In Merismopedia occurs regular shape while Microcystis has the irregular distribution of cells having 4 layers of cell wall with present of peptidoglycan in the second layer. Their membranes contain chlorophyll-a, xanthophyll's and carotene, while in some other cases cyanobacteria possess chlorophyll-b (ex-Prochlorococcus) (18).

Flagella in cyanobacteria are not seen but they occur gliding movements. On the basis of pendulum like oscillating movements *Oscillatoria* is a example of common blue green algae.

Some are possess S-layers, which is help for filament motility (19). Cyanobacterial Cells often produce mucilaginous sheaths which is mainly composed of exopolysaccharides, which range from <1 μm to several times the filament thickness. Sheaths are provide some functions to protect the plant form UV rays and desiccation. PS-II is absent in Cyanobacteria but present of some thick walls which permit Only nitrogen gas into the plant not allow oxygen.

Reproduction :

Cyanobacteria shows a different types of reproduction factors

– Fragmentation.
– Budding.
– Binary fission
– Multiple-fission.

The reproduction of Cyanobacteria through binary fission may not be completely accepted as clonal organisms due to the flow of gene in horizontal manner and recombination (20 and 21). However, cyanobacteria have some interesting reproductive strategies. For instance, some unicellular cyanobacteria may produce baeocytes and exocytes, which are differentiated from the mother cell by size, shape, and successive multiple fission with subsequent release to the environment (22).

Besides vegetative cells the species of Nostoc may produce long-term reproductive cells called akinetes. Akinetes have the capacity to store large number of nutrients and as compared to vegetative cells it is larger .Akinetes present in the environment like lake sediments, soils etc. At the time of unfavourable conditions like drought, low temperatures, fall turnover in lakes, etc. (23 and 24). Akinetes of *Anabaena cylindrica* may survive the environment on Mars. Filamentous cyanobacteria may exhibit both false and true branching. False branching is present in all orders of filamentous cyanobacteria, while true branching has been observed only in members of *Nostocales*. Filamentous cyanobacteria form motile filaments of cells, called hormogonia, which travel away from the main biomass to bud and form new colonies (25 and 26). Each filament consists of a sheath of mucilage and one or more cellular strands called trichrome. Single trichromefilamentous may be of two types *i.e.* Homo-cysts (e.g. *Oscillatoria*.) and Hetero-cysts (E.g. Nostoc) (27).

Factors affecting bloom formation:

Cyanobacteria have some special properties those are helped in the communities of phytoplankton. There are some factors which affect the growth of Cyanobacteria in bloom formation. Temperature, nutrients composition, pH and light are among the most important factors that affecting the growth rate of blue green algae. The role of different Cyanobacterial taxa is not uniform because of their physical properties and their response to eco-factors. Increase the temperature of water resulting to bloom development in arid and semiarid zone. The growth rate is mainly affected by Nitrogen and Phosphorus. Many researchers say that Phosphorus is the selective nutrient in freshwater. The total number of biomass and tropic state of Cyanobacteria are responsible for presence of phytoplankton in water.

There are several factors which responsible for understanding their special characters.

Light intensity :

Cyanobacteria conducting photosynthesis in the presence of Chlorophyll-a. Photo periodicities, light intensity depends the change in photosynthetic parameters.They also contain phycobiliproteins pigments which include two more pigments of blue and red (28). These pigments situated in between 500-650m wavelength which is difficult to resist for some phytoplankton. The phycobiliproteins, together with chlorophyll a, possesses blue green algae to harvest energy frequently. Some selective cyanobacteria are sensitive to high light intensities. The growth rate of agardhii is not done above light intensities 180 µE m-2 s-1. Intensities above 320 µE m-2 s-1 are causes harmful for many species (29).

Gas vesicles :

Many phytoplanktonic cyanobacteria are filled with gas vacuoles (30). So the structures are show like vesicles which are filled with gas and the hollow chambers are with made of outer surface hydrophilic and the inner surface hydrophobic (31). With dissolved organic CO_2 and toxic elements are rapidly degraded by natural microbial community. The density of gas is about 1/10nth part of water (32) hence, cyanobacterial cell grow more suitable at the state of lower density of gas vesicle rather than water.

Growth rate :

As compare to many algal species the growth rate of blue green algae is very less (33). The growth rate of most common phytoplanktonic blue green algae is 0.3-1.5 at 20 degree Celsius, while in case of diatoms it doubling the growth rates of upto 1.3-2.3. For formation of bloom in Cyanobacteria at the stage slow growth rate it requires high water retention. This is the main cause that blue green algae to not bloom in short time period. An overview observe the growth rates of phytoplanktonic blue green algae under various field conditions (34) is determined by applying high concentrations of phosphorus and nitrogen. This assumption also recorded even though algal blooms often occurred when different concentrations of dissolved phosphates are applied at in lower state. That means Cyanobacteria can compete other phytoplankton organisms under both favourable and Unfavourable conditions of phosphorus or nitrogen limitation. Cyanobacteria have a substitute storage capacity for phosphorus because it contains high nutrient, which corresponds to a 4-32 fold increase in biomass. If the ratio between nitrogen and phosphorus concentrations is low then may affect the growth rate. If the ratio between N: P is 16:23 shows the optimum rates for eukaryotic algae and the ratio 10:16 molecules in between N:P, shows that the ratio is lower for cyanobacteria (35).

Salinity :

In contrast, marine Cyanobacteria are not more toxic compared to fresh water Cyanobacteria. Freshwater species have quite wide salinity tolerance. (Anabaenaopsis and Nodularia) The factors other than salinity are allowing Cyanobacteria growth at the region where they previously not exist.

Population stability :

Cyanobacteria are not allowed to gazed for same extent and the impact of grazing by some specialised by ciliates and rhizopod protozoans.To prevent sedimentation they have some characters and some natural inhibitors may causes the low population rate in Cyanobacteria. Cyanobacteria are infected by viruses, bacteria and actino-mycetes, but the importance of these natural enemies for the breakdown of populations is not well understood.

Temperature:

Another most important factors which is responsible for the growth rate is temperature. Optimal growth rates are attained by most cyanobacteria in between 25-35 °C (36). In comparison with other phytoplankton taxa, it is typically lower growth rate at colder temperatures and higher growth rate in high temperature condition.

Applications of cyanobacteria

Biofuel creation :

These have fascinated the fuel arcade at greater gage, as their future will pave the way of sustaining energy security. Biofuel research must incorporate the use of by-products produced during the dispensation, thus making them biologically safe and parsimoniously sustainable (38).

Bio-energy potentials have been ineffective on both ends; however, microorganism-based options could be used and because of their photosynthetic abilities, smaller development age and oil matters cyanobacteria are a very preferable choice. *Synechococcus* and *Synechocystis* are perceived to be the forth coming supply of bio fuels (37).

Catalysts for Co-Products :

Cyanobacteria can act as a biocatalyst forturing carbon dioxide into fuels, construction of subordinate metabolites from organic products and manufacturing vitamins, coloretc.

Carotenoids and phycobili-proteins;largelyused in bio-industry. They have extra ordinary marketable value. Major carotenoids such as zeaxanthin, canthaxanthin, beta-carotene and Nostocxanthin, could be used as add-ons in feeds, food condiments and food dyes. These are antioxidants that could play a role or two in preventing diseases and regulator of human wellbeing insituations as cataracts, cardiac illnesses and malignancy (22).

Spirulina is a huge source ofvitamin B12, thiamine,riboflavin and,beta-carotene (23).

EPS extracted from *Pseudomonas* sp. has a developed nourishment preservation ability and thus, the prospective for being used in makeup's and healing goods (24).

In food supplements :

These are considered as sources of dietary and nutritive additions; proteins, complex sugar, active enzymes, phycocyanin, amino acids, beta-carotene, fatty acids, chlorophyll, minerals, vitamins and carbohydrate. Species of *Spirulina* are used as a complete food or dietary supplements. It is culturedglobally and used as feed supplements in aquaculture, poultry and aquariums (28).

Bio-fertilizers :

It can be used as bio-fertilizer thus, adding to greater crop output in different types of agronomic and environmental circumstances (31). In the agronomic sub division, phosphorus is one of the vital elements obligatory for plant development and enlargement. Cyanobacteria help in increasing earth phosphate bythe construction of organic acid (32). For example, *Nostoc* and *Anabaena* have exceptional abilities to fix the dirtsalinizization matter by nitrogen fixation and production of extra-cellular matrix (30). Cyanobacteria in soil always results in decreasing soil salinity, weed decay and increased soil biomass (33).

Metabolic and genetic engineering :

For years these have been documented to require significant applications in metabolic engineering. Divergent strains have effectively been engineered to yield biofuel and related chemicals. Relative to microalgae, cyanobacteria are extra exposed to applications in genetics, which includes biofuel-producing bio-chemical pathways.They also have an augmented acceptance level to external genes.

Data on sequencing of cyanobacterial genome is widely available, which could help in promoting growth of genome-scale models for assorted species (39). *Synechococcus elongates* have produced ethanol (40), while production ofiso-butyl-aldehydeand ethylene is seen in *Synechococcus* sp. (41).

Medicinal claims :

These have acquired interest from researchers due to the creation of bioactive amalgams which have uses in both health domains and profit making. Even though these could yield contaminants, they also yield compounds vital in terms of anticancer, antibiotic, and antifungal properties. Products associated with cyanobacteria also show immuno suppressant, antibacterial, antimicrobial, anti-inflammatory, antiviral events (42-45).

In mid-1980 to late 1990, more than 75% of the approved anticancer and antibacterial drugs were detached from natural creation foundations. Cyanobacteria's were used as additions to expand wellbeing. Spirulina (rich in Fe, Cu, vitamin B1 and B3, proteins) has strong anticancer, antioxidant, anti-inflammatory, low density of triglyceridesandlipo-polysaccharide. It can also be used to regulate blood sugar effects lower blood pressure, expand immune functions and reinforcing physiques. Also could be seen promoting aids in cardiac diseases (45 and 46).

Ecological consequences :

These could be used for bioremediation of toxins like heavy metals, oil, insect repellent, naphthalene, phenols etc. [44]. *Anabaena* sp., *Nostoc* sp. are also accommodating in eliminating the toxins of glyphosate herbicide from ripe domains (48).

Chemotrophic bacteria could be used as oil digesters in the waste waters and oil-contaminated locations (47).

Cyabobacteria in crop production:

Use of chemical nitrogen stimulants in agriculture has becomea worldwide concern. To survive and sustain our soil we have to find alternatives to chemical fertilizers. Biological nitrogen fixation alters nitrogen available in atmosphere toplant useable. The system offers a parsimoniously striking and environmentally sound means of plunging chemical inputs and refining biological possessions (22).

These are present in the biogeochemical cycle of carbon, nitrogen and oxygen. Also they stay alive in wet dirt and change the dietary position, organisational permanency and crop throughput (49). Their metabolites could be used by agronomically and economically (24). The exo-polysaccharides produced by cyanobacteria can act as glue for aggregation of soil elements, organic substance build-up and upsurge in liquid holding capacity of the upper coating of earth. PGPRs and EPS producing cyanobacteria can subsidize to the development and recovery of barrenness of soil (38-40).

As the nitrogen fixer :

Watanabe *et al.* proved that the non-symbiotic nitrogen fixing properties of these algae can lead upto 25% increase in grain yield (12-14). According to Mishra *et al.* If inoculation of cyanobacteria could be done for 3-4 crop season repeatedly, there are chances that they can organize themselves everlastingly (160). Nitrogen fixers in the phyla cyanobacteria are *Anabaena, Nostoc, Trichodesmium, Calothrix, Cyanotheca, Aulosira, Plectonema and Tolypothrix*. Nitrogen fixation is an enzyme mediated mechanism, where the major role is played by nitrogenase. Being an aerobic enzyme, it is sheltered by the superoxide dismutase activity mixed with high respiration rate. Hetero-cysts are devoted for nitrogen fixation and vegetative cells complete photosynthesis and other cellular events (18). The taken nitrogen is firstly fixed as ammonia and is available to the crops either after the death and from the decaying body or by the excreta's of the organisms. Plants apart from rice that could use cyanobacteria are tomato, barley, oats, sugarcane, wheat, maize and cotton (19 and 20). Besides fixing nitrogen they also serve as the tank of phosphorus, sulphur, carbon and other micronutrients.

By symbiotic association :

Photosynthetic cyanobacteria provide nitrogen to the host, while fixed carbon is provided by non-photosynthetic. Cyanobacteria cancreate an association with variety of hosts like fungi, protists, sponges, bryophytes, pteridophytes, gymnosperms, angiosperms and animals. These associations can help in maintaining an overall nutrient description of an area. *Richeliaintracellularis* which are found in northern Arabian Sea are the main regulators of the nitrogen pool of that zone (22). The cyanobacteria-bryophyte association is a key regulator of the carbon pool along with being a litter producer and thermal insulators in the northern ecosystem. This symbiotic relationship affects the net principal efficiency and respiration (28).

Water fern Azolla forms a symbiotic association with *Anabaena*, where *Anabaena* fixes nitrogen and acquires carbon and a thriving atmosphere in return. This nitrogen is available when Azolla decays (31). Developed leaves of Azolla houses Anabaena on the dorsal side and both organisms carry out photosynthesis. This complex is one off the best bio-fertilizer and green manure. It could also be used for bio-gas production, wild plant governor, mosquito repulsive, and water purifier, human and animal feed.

For plant growth :

Recent information strongly supports the creation of hormone (s) by cyanobacteria and their interesting effect on plants. *Phormidium* sp. MI405019, which is a mangrove root-associated with cyanobacteria, was reported to produce IAA (38). The cyanobacteria in paddy fields are very skilled in creating and deliveringgibberellic acid for the growth of plants. Interesting fact being, that the gibberellins produced by the cyanobacteria are very capable to overcome salt stress in rice (40). Molecules such as carbohydrate, vitamins, proteins, lipids, glycolipids or glycoproteins from cyanobacteria are known to help in creation of subordinate metabolites in plant cell cultures (42 and 43).

Phycocyanin a Spirulina platensis could be used as an elicitor to enhance the build-up of capsaicin and anthocyanin (47).

Cyanobacteria transgenic :

The cyanobacteria are more effective in carrying out photosynthesis than C3 and C4 plants; action of CA, both extracellular and intracellular and CCM (49). This genetic approach has mostly been tested in wheat and rice for improving photosynthesis and WUE.

Reaction of plants to stress conditions varies greatly. Different types of stress mostly lead to similar reactions. At the cellular level, water deficit (drought and salinity) causes a reduction in pressure potential. Cyanobacteria are also having been recognized on the basis of their superior salinity limit for development. Most of them also accumulate disaccharides, sucrose synthase (SS) and glycerol in response to salt stress (50 and 51).

Future scenario:

Above all, it addresses the enormous scope for the healthy agro-ecosystem including Cyanobacteria sustainable the nature and natural resources and improve the nutrients status of soil and control biological pest and diseases May leads a vital role in agriculture, maintain diversity and ecosystems. (S) In the case of poor farmers it is not easy to afford chemical fertilizers so that we can say Cyanobacteria ensuring economical viability. It enrich the organic carbon, nitrogen and phosphorus to bio-availablility form which can improve the soil health and helps to provide sufficient food production in safer living for both human as well as other livestock. So that it is carried out for futuristic goal to reach out the target of sustainable agriculture and. Cyanobacteria is a multi-functional bio-agent along with eco-friendly so that to improve their utility in agricultural sector needs some serious attention. In addition to product development there is a long way to go for the use of Cyanobacteria to produce better health. Future research must be address to the improvement of Cyanobacteria to achieve high quality food and bio fuel and maintain the growth rates under environmental condition. Cyanobacteria possess a several remarkable work on the field of genetic engineering to improve the production a large scale of bio fuel. Also have bioremediation experts for various herbicides, insect repellent, and heavy metals (52). Hence, by implementing genetic engineering, strains with high productivity could be studied further in Cyanobacteria. The newly described taxations will help to increase productivity, upkeep of development rate and potential cell enhancement for survival in stress and to maintain the eco system.

Conclusion:

Cyanobacteria play a role for the best substitute to chemical fertilizers in the field of agriculture. Reported literature suggested that these Photosynthetic prokaryotes areseveral application including to improve the crop productivity, pharmaceutical drugs, bio-fuel, maintain soil integrity and fertility, preventing colonization of the pathogenic micro organism and other valuable co-products. Hormone production by blue green algae raises the plant seed germination naturally. The Polysaccharide secretions from cyanobacteria help to utilize CO_2,water, and nutrients. Several studied indicate application of cyanobacteria in bio medical ranging the antibiotics against microbial infection. In non- bio medical application including herbicides and insecticides poses to utilize the biological compounds. Therefore, evaluation of this sustainable approach for development in crop production and crop protection is exhibited by cyanobacteria. Considering the unique characteristics and application used by researcher, scientists, cyanobacteria can be used wide range in the multidirectional benefit towards agriculture. Hence, uses of bio fertilizers prepared from cyanobacteria in crop production are beneficial, economical and environment-friendly.

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