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CYANOBACTERIA: As Sustainable BioSource.

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ABSTRACT:

Cyanobacteria have been identified as a rich source of biologically active compounds with anti-viral, anti-bacterial, anti-fungal and anti-cancer activities . several strains of cyanobacteria were found to accumulate polyhydroxyl alkanoates , which can be used as sustainable Way of degrading petrochemical based plastics . Keeping in mind the agro-ecosystem and environmental difficulties, current advances in biotechnology provide a more dependable method to addressing dietary needs for future generations while simultaneously resolving complex environmental problems. Several unique characteristics of cyanobacteria, such as oxygenic photosynthesis, a high biomass yield, advancement on non-arable lands and an extensive range of water sources (contaminated and polluted waters), production of beneficial by-products and biofuels, soil fertility enhancement, and reduction of greenhouse gas emissions, have collectively offered these bio-agents as a valuable bio-resource for sustainable development. Cyanobacterial biomass is an efficient bio-fertilizer source for improving soil physicochemical properties such as water retention and mineral nutritional status in degraded soils. Cyanobacteria are distinguished by their extensive distribution, quick generation period, and capacity to fix atmospheric N2. Cyanobacteria, like other prokaryotic bacteria, are being used as bio-inoculants to improve the fertility of the soil and environmental quality. Genetically modified cyanobacteria have been designed with unique genes for the production of a variety of biofuels such as bio-diesel, green-hydrogen, bio-methane, and therefore provide new pathways for the economically sustainable creation of bio-fuels.

KEYWORDS: cyanobacteria, agriculture, bioremediation, advantageous microorganisms, biofertilizers, Rich source of biologically compounds , anti-cancer, antibacterial.

INTRODUCTION:

The current global population of around 7.2 billion people is predicted to exceed 9.6 billion individuals by the year's end of 2050. To feed everyone by that time, cereal output must increase by nearly 50%, from 2.1 billion tonnes per year to 3 billion tonnes per year. This onerous aim places great strain on the agricultural sector in order to attain food security. However, such a QUANTUM jump in food production may be done by either bringing more area under cultivation or increasing the productivity of cultivable land available. The first option remains a distant dream in the light of limited land and growing population. The possibility of enhancing soil fertility and agricultural production with improved eco-friendly management technologies ensures effective food security. Current agricultural practises are heavily reliant on the use of synthetic fertilisers and pesticides, intensive tillage, and over irrigation, which have undoubtedly helped many developing countries meet their people's food requirements; however, these practises have raised environmental and health concerns, including deterioration of soil fertility, overuse of land and water resources, pollution of the environment, and increased agricultural production costs. A big question before the present-day agriculture is to enhance the agricultural production to meet the present and future food requirements of the population within the available limited resources, without deteriorating the environmental quality. The sustainable agriculture practices can - full fill the growing need of food as well as environmental quality. The current ideology of sustainable agriculture involves eco-friendly, low-cost farming with the assistance of local microorganisms.It also emphasises that farmers should use natural processes to conserve resources such as soil and water, while reducing the expense of agricultural output and waste creation, which has a negative impact on environmental quality. Such sustainable agricultural management practices will make the agro-ecosystem more resilient,self-regulating and also maintain the productivity and profitability.Microbes have long been recognised to contribute to soil fertility and sustainable green energy generation.. During the last decades, the microbial processes of green energy production have gained interest as the Methane (CH_4), ethanol, H_2, butanol, syngas, and other biofuels may be generated with this sustainable technique. Current research has revealed a notable increase in the production of cyanobacterial biomass for biofuels, food supplements (super foods), and bio-fertilizers for safe agriculture. They have been classed as both useful and harmful bio-agents based on their involvement in controlling plant production. In truth, these two distinct groups of microbes coexist in nature, and the dominance of one at any one moment is mostly determined by environmental circumstances. Soil microbiologists and microbial ecologists have been investigating the influence of helpful or efficient soil microorganisms for sustainable agriculture that not only contribute to soil fertility, crop development, and production, but also enhance environmental quality for many years. Nowadays, sustainable agricultural practises see these small microbes playing a vital part in ensuring food security without causing environmental difficulties.

The Recent trends of adopting bio-inoculants including beneficial soil bacteria over synthetic fertilizers, insecticides, and pesticides for agricultural production enhancement are a welcome development. As a beneficial microbe, cyanobacteria could play a potential role in the enhancement of agriculture productivity and mitigation of Emissions of greenhouse gases(Singh, 2011; Singhetal., 2011a). Recently, it has been postulated that cyanobacteria might be crucial bio-agents in the ecological rehabilitation of damaged soils.(Singh, 2014).Cyanobacteria are a type of photosynthetic organisms that can thrive on very little light, carbon dioxide (CO2), and water.(Woese, 1987; Castenholz, 2001). They are phototrophic and naturally exist in a variety of agro ecosystems such as paddy fields and from Antarctica to Arctic poles (Pandey et al., 2004). They complete their own nitrogen demand through nitrogen (N2) fixation and create certain bioactive substances that enhance crop development, protect crops from diseases, and improve soil nutrient status. Cyanobacteria are also useful for waste water treatment, and have the ability to degrade the various toxic compounds even the pesticides(Cohen, 2006).A conceptual model of cyanobacteria's involvement in sustainable agriculture and environmental management has been presented.. This review highlights the role of cyanobacteria in bio-energy production, ecological restoration, agriculture and environmental sustainability.

SUSTAINABLE APPROACH: CYANOBACTERIA

Beneficial microbes are an alternative to other managements practices. The ability of the cyanobacteria to fix atmospheric N2, break down organic waste, and residues detoxify heavy metals, pesticides, and other xenobiotics, catalyse nutrient cycling, inhibit the growth of pathogenic microbes in the soil and water, and also create some beneficial substances, including as vitamins, hormones, and enzymes that support plant growth (Higa, 1991). These bio-agents can improve the soil quality and plant growth and minimise the crop production cost by supplementing the good crop management practises such as crop rotation, use of organic manures, minimum till age, and the biocontrol of pests and diseases. The use of cyanobacteria in agriculture promises definite beneficial effects on crop productivity, if used properly The currently practised traditional agricultural management techniques heavily rely on the use of chemical fertilisers and pesticides, as well as techniques like intensive tillage and excessive irrigation that would otherwise result in an increase in the cost of agricultural production, an overuse of natural resources like soil and water, and environmental pollution (Kumar et al., 2012). Now, there is need to adopt such sustainable agricultural practices which are not only eco-friendly, but are also cost- effective, and really help us attain the long-term food security. The production of safe and healthful foods, the preservation of natural resources, economic viability, and the restoration and preservation of ecosystem services are some of the main goals of sustainable agriculture. The long-term rise for a sustainable increase in productivity is provided by an eco-friendly management strategy for complex agro ecosystems without disrupting the interactions among several ecological components like water, edaphic and climatic elements, including the living components. It may be hypothesised that if the four primary ecological processes—energy flow, water cycle, mineral cycle, and ecosystem dynamics—all work in harmony and homeostasis, the cost of agricultural output will finally decrease. The use of cyanobacteria in soil and environmental management results in benefits for the economy (lower input costs), nutrient cycling, N2-fixation, and phosphorus bio availability water storage and movement, environmental protection and prevention of pollution and land degradation especially through reducing the use of agro-chemicals, and recycling of nutrients and restoration of soil fertility through reclamation.

The following benefits to the agro ecosystem are offered through use of cyanobacteria:

- enhanced mobility and solubilization of scarce nutrients.
- Limiting the mobility and transport of heavy metals and xenobiotics in plants.
- simple organic compound mineralization for direct absorption, like amino acids.
- protection of plants against disease-causing insects and other biological pest controls.
- stimulation of plant growth as a result of their characteristics that support plant growth.
- enhancing the soil's physicochemical state.

CYANOBACTERIA: UNDER ADVERSE ENVIRONMENTAL CONDITIONS.

Blue-green algae, sometimes known as cyanobacteria, are not actually eukaryotic algae. They are Gram-negative prokaryotes, perform oxygenic photosynthesis, and also fix atmospheric N2.They are ubiquitous in ponds ,lakes ,water streams ,rivers, and wetlands. They can easily tolerate severe settings including hot springs, hyper-saline water, sub-zero temperatures, and dry deserts (Singh, 2014). Cyanobacteria can survive in a temperature range of 45 to 70 C and at a pH of less than 4.5 (Pfennig, 1969, 1974), with an ideal range of 7.5 to 10. The ability of cyanobacteria to endure harsh climatic circumstances can be utilised to improve the salinity-affected soils since they can reduce salt content and increase levels of C, N, and P as well as moisture content.the salt affected soils. It has been noted that cyanobacteria promote soil aggregation and water permeability and are very helpful in enhancing the quality of poorly structured soils in dry or sub-arid regions. According to Rogers and Burns (1994), inoculation of cyanobacteria improved soil WHC and aeration while also improving the stability of the soil aggregate (important qualities of good soil). Such organisms reduce the compact ion and sodality of soils through improvement in the level of organic carbon, WHC, aeration and support the biodiversity of other microflora.

By means of free-living and symbiotic relationships with partners such water ferns Azolla, cycads, Gunnera, etc., cyanobacteria reduce atmospheric N2. Cyanobacteria that fix nitrogen dioxide in an abiotic environment have been described in Table1. Certain cyanobacterial species have specialized cells called heterocyst-thick-walled modified cells, which are thought to be where the nitrogenase enzyme fixes nitrogen. The complex enzyme converts molecular N2 into ammonia when it is reduced (Singh etal., 2011). Once a cell dies, the fixed nitrogen may be liberated in the form of ammonia, polypeptides, free amino acids, vitamins, and auxin-like compounds (Subramanian and Sundaram, 1986). Nitrogen-fixing ability has not only been demonstrated by hemi cyanobacteria but also by a number of non-hemi cyanobacterial unicellular filamentous taxa . Cyanobacteria can supply between 20 and 30 kg Nha1 as well as organic matter to the soil, which is important for economically struggling farmers who cannot afford to invest in expensive chemical nitrogen fertilisers (Issaetal., 2014). Few commercial goods or biofertilizers are known, although some cyanobacterial species, including Anabaena variabilis, Nostoc mucous, Tolypothrix tenu, have been discovered to be efficient biofertilizers. As an alternative to nitrogen fertilisers, many Asian nations, including China, Vietnam, India, etc., have been cultivating paddy using cyanobacteria (Venkataraman, 1972; Lumpkin and Plucknett, 1982). According to reports (Stewart et al., 1968; Petersetal., 1977; Singh and Singh, 1987), the application of cyanobacteria in agricultural environments, particularly in rice fields, has boosted N availability to plants. The inoculation of cyanobacteria (in vitro) in wheat crops has been researched and may increase plant shoot/root length, dry weight, and yield. Moreover, it has been proposed that cyanobacteria can increase the bioavailability of phosphorus to plants by resolving and mobilising the insoluble organic phosphates present in the soil with the aid of phosphatase enzymes. Cyanobacteria can liquefy the insoluble form of (Ca)3(PO4)2,FePO4; AlPO4, and hydroxy apatite [Ca5(PO4)3OH] in soils. the antagonistic effects of cyanobacteria against several plant diseases. According to Teuscher et al. (1992; Dahmset al. (2006), cyanobacteria create a variety of physiologically active chemicals with antibacterial, antifungal, antialgal, and antiviral properties. These biologically active substances are a subset of polyketides, amides, alkaloids, fatty acids, indoles, and lipopeptides (Abarzuaetal., 1999; Burjaetal., 2001). Moreover, cyanobacteria create a wide range of anti-algal chemicals that suppress pathogen growth by disrupting their metabolic and physiological processes (Dahmsetal., 2006).The cell constituents of cyanobacteria are known to reduce the incidence of Botrytiscinerea on strawberries and Erysiphe polygony causing powdery mild damping off disease in tomato seedlings ,besides reducing the growth of saprophytes—Chaetomiumglobosum, Cunninghamella Blakeslee Ana, and Aspergillu soryzae, and plant pathogens such as Rhizo ctoniasolani and Sclerotiniasclerotiorum (Kulik, \s1995). According to various research, substances like Fischerellin from Fischerella muscicola exhibit antifungal action against a number of plant pathogenic fungi. chas It was less efficient against Monilinia fructigena (brown rot) and Pseudo cercosporella herpotrichoides (stem break; Hagmann and Juttner, 1996; Papkeetal., 1997) than it was against Uromyces appendiculatus, Erysiphegraminis, Phytophthora infestans, and Pyricularia oryzae (rice blast). Nostocmuscorum, a cyanobacterium, has been demonstrated to be antifungal against soil fungi, particularly those that produce "damping off" (De Caireetal., 1990). One of the most polytheist plant diseases, Sclerotinia sclerotiorum is a fungus that mostly affects compositae, most notably lettuce (Lactucasativa L.) and other species of rosette plants (Tassara et al., 2008). In vitro growth of fungal plant diseases including S. sclerotiorum (Cottony rot of vegetables and flowers) and Rhizoctonia solani was prevented by extracts from N. muscorum (root andstemrots; Kulik, 1995). Nostoc sp., a known potential producer of cryptophycin, is the source of natural insecticides against fungus, insects, and nematodes, according to Biondi et al. (2004). According to Zulpa et al. (2003), N. muscorum also prevented the growth of other fungi responsible for the "woodbluestain" (a bluish or grey colouring of sapwood brought on by specific dark-colored fungi such as Aureobasidium, Alternaria, Cladosporium, etc). (Zulpa etal., 2003). It It would appear that effective cyanobacterial strains might be deployed as bio-control agents to ensure improved agricultural productivity. For the development of commercial products for sustainable agriculture, new assays are exploiting cyanobacterial metabolites. Yet, data on bio-controls reveals that most trials were carried out in laboratories and a relatively small number were undertaken in actual agricultural fields. In order to determine whether cyanobacteria can be used as possible bio-control agents against various plant diseases, extensive research is required.

CYANOBACTERIA: SOILS RECOVERED FROM SALINE AREAS

Cyanobacteria may have a function in the reclamation of salt-affected (often desert in some regions of India), dry, or sub-arid soils. Chemical methods of employing gypsum, sulphur, or excessive irrigation used for the amelioration of salt-affected fields (DharandMukherji, 1936) are neither cost-effective nor environmentally beneficial. In general, salt-affected soils (alfisol, sodic, alkaline, and saline) are stiff, impermeable to water, and less productive due to the presence of excessive salts in the upper layers. Depending on the amount of salt in them, they can be classed as either alkaline or saline. The alkaline soil is distinguished by a high pH, high exchangeable Na, detectable carbonates, and widespread clay dispersion (deflocculation due to the high zeta potential of active Na C). The soils become infertile due to inadequate hydraulic conductivity and decreased soil aeration. The saline soil has a high concentration of soluble salts (electrical conductivity greater than 4 dScm1), which gives plant roots a high osmotic pressure for absorbing water and nutrients (Pandeyetal., 1992). Singh (1961) first proposed that cyanobacteria may be utilised as a tool for reclamation of USAR soils because they form a thick stratum on the soil's surface, preserve organic C, N, and P as well as moisture, and transform Na C clay into Ca2 C clay. Such soils' organic content and cyanobacterial additions aid in the binding of soil particles, which enhances soil permeability and aeration (Singh, 1961).

Given that cyanobacteria can release nutrients from insoluble carbonate nodules through the production of oxalic acid (Fritsch, 1945; Singh, 1961), they enhance the physio-chemical properties of salty and alkaline oils by reducing pH, electrical conductivity, and hydraulic conductivity (Kaushik and Subhashini, 1985). There are certain physiological advantages associated with cyanobacteria which enable them to withstand these stresses:

- reduction of NaC inflow
- accumulation of organic or inorganic regulators (such as sugars, quaternary amines, etc.) such as the KC ion.

Cyanobacterial application to organically poor semi-arid soils can play as significant role in the reclamation. The high compaction, low fertility, and water scarcity of the soils in these semi-arid and desert locations, as well as their association with salt and sodicity issues, lead to poor aeration and water infiltration and increased soil erosion (Nisha et al., 2007). poor diversity of microflora, etc. The poor physico-chemical characteristic of soils ultimately has an adverse impact on the plant growth and productivity. In the soil, cyanobacteria form a surface network of trichomes and filaments that not only bind soil particles but also cause them to mesh at depth (Nishaetal., 2007). As carbon and nitrogen fixers, cyanobacteria can help to enhance the status of organic carbon and nitrogen in arid soils. Salt tolerance ranged from 7 to 15 g/L in cyanobacterial species such Anabaena oscillarioides, A. aphanizomenoides, and Microcystis aeruginosa. They are also known to produce EPS, which help soil particles to bind together (Mazor et al., 1996), and thus play a major role in improvement of soil moisture owing to their hygroscopic nature. Flaibani et al. (1989) reported that exopolysaccharides from cyanobacteria also contribute to reclamation of the desert soils.

CYANOBACTERIA: APPLICATION IN BIOREMIDATION

As biological remediators, cyanobacteria have some benefits over other microorganisms due to their photoautotrophic nature, capacity to fix atmospheric N2, and ability to adapt to survive in polluted and highly polluted environments (Sokhoh et al., 1992). Cyanobacteria show a great potential for the treatment of various types of environmental contaminates such as pesticides (Megharajetal., 1994), crude oil (Sokhohetal., 1992; Al-Hasanetal., 1998, 2001), naphthalene (Cerniglia et al., 1980a,b), phenanthrene(Narroetal., 1992), phenol and catechol(Shashirekha etal., 1997), heavy metals(Singh \set al., 2011b), and xenobiotics (Megharajetal., 1987) either through their accumulation or degradation. Cyanobacteria have the potential to be used in the detoxication of a variety of industrial effluents, including those from the oil refinery, breweries, distilleries, paper, sugar, dye, and pharmaceutical industries. This is due to their high metal sorption capacity and high multiplication rate. According to Velchez et al. (1997), cyanobacteria may be employed for the tertiary treatment of urban, agricultural, and industrial effluents, which can help minimise eutrophication and metal toxicity issues in aquatic ecosystems. Some cyanobacterial species have additional benefits due to their photosynthetic nature, such as an interior pH that is almost two units higher than the surrounding conditions, which confers resistance to the mass transfer of pollutants out of their biofilms from the external environment and aids in the removal of heavy metals from wastewaters (Lieh et al., 1994; Vijayakumar, 2012). Cyanobacteria are being used effectively as low-cost bioremediating agents for treating N and P-rich dairy waste streams and turning those nutrients into biomass (Lincoln etal., 1996; Singhetal., 2011a). Cyanobacteria accumulate very high concentration of pesticides (Vijayakumar, 2012). Several organo-phosphorus and organo-chlorine insecticides are degraded by cyanobacterial members such Synechococcus elongatus, Anacystis nidulans, and Microcystis aeruginosa from the polluted aquatic systems (Vijayakumar, 2012). According to El-Bestawy et al. (2007), various cyanobacterial taxa, including Oscillatoria, Anabaena, Synechococcus, Nodularia, Nostoc, and Microcystis are capable of removing or degrading lindane residues. Forlani et al. (2008) state that cyanobacteria such Anabaena sp., Lyngbya sp., Microcystis sp., and Nostoc sp. breakdown a wide variety of organic phosphorous herbicides, and the mineralized glyphosate is absorbed as a source of phosphorus. Spirulina sp. was shown by Lipok et al. (2007, 2009) to be capable of degrading the pesticide glyphosate. Moreover, it has been reported that Synechocystis sp. successfully mineralized the herbicide anilox and utilised the result as a source of phosphate. It follows that growing cyanobacterium in wastewater lagoons may have a significant capacity to breakdown contaminants and pesticides, contribute to lowering the pollution load, and stimulate the growth of other microbial communities for lowering BOD and COD. The degradation of crude oil and other complex organic compounds like surfactants by cyanobacteria has been demonstrated in several studies (Radwan and Al-Hasan, 2000; Raghukumaretal., 2001; Mansy and El-Bestway, 2002). For instance, the cyanobacterial species Plectonematerebrans, Aphanocapsa sp., Synechococcus sp., and Oscillatoria salina grow in aquatic conditions and have effectively been used in the bioremediation of oil spills in various regions of the world (Raghukumaretal., 2001; Cohen, 2002). Not only oil-contaminated waters but also oil- contaminated soils be successfully remediate dusing a naturally occurring cyanobacterial–bacterial associations (Sorkhohetal., 1995). Microcoleus chthonoplastes and Phormidium corium, isolated from oil-rich sediments of the Arabian Gulf, were able to breakdown n-alkanes, according to Al-Hasanetal. (1998). According to Cerniglia et al. (1979, 1980a), Oscillatoria sp. and Agmenellum sp. oxidise naphthalene to 1-naphthol; oxidise biphenyl to 4-hydroxybiphenyl; and metabolise phenanthrene into trans-9,10-dihydroxy-9,10-dihydrophenanthrene and 1-methoxy-phenanthrene (Narro, 1985). The Table 3 describes the role of several cyanobacterial species in the removal of heavy metals in various ecologies. The degradation of crude oil and other complex organic compounds like surfactants by cyanobacteria has been demonstrated in several studies (Radwan and Al-Hasan, 2000; Raghukumaretal., 2001; Mansy and El-Bestway, 2002). For instance, the cyanobacterial species Plectonematerebrans, Aphanocapsa sp., Synechococcus sp., and Oscillatoria salina grow in aquatic conditions and have effectively been used in the bioremediation of oil spills in various regions of the world (Raghukumaretal., 2001; Cohen, 2002).

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CYANOBACTERIA: GROWTH FACTOR FOR PLANTS

Among of the chemicals released by cyanobacteria that are classified as hormones include auxin, gibberellins, cytokinin, and auxin as well as abscisic acids. Others are explained in terms of vitamins, especially vitamin B (Grieco and Desrochers, 1978) or amino acids, antibiotics, and poisons (Vorontova et al., 1988). Describes how certain possible cyanobacteria produce phytohormones. The majority of research on the cyanobacteria's plant growth-promoting activities connected to daddy crop indicated that cyanobacterial inoculation might increase seed germination, root growth, and shoot growth . Also, co-inoculating cyanobacteria with wheat can increase root dry weight and chlorophyll (Obrehtetal., 1993). Although the agronomic efficiency was not assessed, Gantaretal. reported that extracellular chemicals generated by cyanobacteria that colonise wheat plant roots exhibited a substantial effect on plant growth. The ability of cyanobacteria to flourish in a range of environments, even those unsuitable for agriculture, can be exploited due to their inherent diversity. The extensive range of commercial applications for cyanobacterial species as plant growth promoters is made possible by their quick cell development and basic nutritional needs, which are primarily water, sunshine, and CO2 (Ruffing, 2011).

CYANOBACTERIA: AS A BIOSOURCE OF ENERGY

Due to its straightforward cell structure, low food requirements, and ability to make bioenergy like biodiesel, bio-or syngas, bio-hydrogen, etc., cyanobacteria are the only category of photosynthetic biological agents that can develop quickly. During photosynthesis, cyanobacteria absorb carbon dioxide (CO2) to transform it into carbon-rich lipids that may be utilized in the creation of biofuels. Moreover, cyanobacteria create molecular hydrogen (H2), which can be the optimal replacement for fossil fuels and the best alternative. According to, these bacteria can create a variety of feedstocks for energy generation, including H2 (through photosynthesis), lipids for biodiesel, jet fuel, and hydrocarbons, isoprenoids for gasoline, and carbs for ethanol production. The Fischer-Tropsch process and gasification or liquefaction for the generation of H2 may also be used to treat the cyanobacterial biomass that contains lignocellulosic chemicals for the creation of syngas. The benefit of using molecular H2 as a clean fuel is that it is one of the most plentiful elements in the universe and has the most energy per unit weight (122 KJg1). H2 has the highest heating value of all known fuels, according to calculations based on weight, with 141.65 MJKg-1 (Ali andBasit, 1993). It can be stored as gas-metal hydride or as liquid, and has greater energy conversion efficiency than petroleum. H2 won't harm the environment if utilised as fuel because its only byproduct is water. According to several studies (Masukawa et al., 2001; Parmar et al., 2011; Nozzi et al., 2013), some cyanobacterial species, such as Anabaena, Calothrix, Oscillatoria, Cyanothece, Nostoc, Synechococcus, Microcystis, Gloeobacter, Aphanocapsa, and Chroococcidiopsis, are . Cyanobacteria create H2 in two ways (Pinzon-Gamezetal., 2005).

While being a clean and environmentally friendly technology, cyanobacterial H2 generation has a constraint that prevents it from being commercially viable (Tiwari and Pandey, 2012). There are certain flaws in these procedures that make scaling up the generation of H2 from cyanobacteria difficult. The concomitant creation of O2 creates a major constraint since the hydrogenase enzyme that produces H2 is particularly sensitive to O2. The method by which cyanobacteria manufacture H2 has advantages and disadvantages in terms of production and technology. Clearly, it can be inferred from the study reports that this topic is still in its infancy and has no prospective applications in real life. These procedures still need to be assessed and adjusted for productivity and cost in order to commercialise H2. The cyanobacterial biomass can be utilised to make biogas by anaerobic digestion or fermentation in addition to producing biofuel and molecular H2. In order to create biogas, the organic biopolymers (carbohydrates, lipids, and proteins) in the cyanobacterial biomass are hydrolysed and broken down into monomers (mixture of CH4 and CO2). CO2 is the second significant component (about 25–50%) that may be removed to create bio-methane during the manufacture of biogas. By eliminating CO2 during the synthesis of bio-methane, the calorific value of biogas can be greatly increased. Vehicles may run on compressed natural gas, or CH4, which is more ecologically friendly than fossil fuels like petrol, diesel, and petroleum products. Reported biogas generation and purification utilising a two-step bench-scale biological system, consisting of fed-batch pulse-feeding anaerobic digestion of mixed sludge, followed by CH4 enrichment of biogas by the employment of the cyanobacterial species Arthrospira platensis. The ratios of CH4 and CO2 are respectively between 70.5-76.0% and 13.2-19.5%. The data on CO2 removal from biogas demonstrated a close association between the rates of A. platensis growth and CO2 removal from biogas, allowing the assessment of cyanobacterial biomass's carbon utilisation efficiency to the amount of about 95%.

According to Zhong et al. (2012), one of the key variables impacting CH4 generation during anaerobic digestion is the C/N ratio. As compared to terrestrial plants, cyanobacterial biomass has a high protein content (low C/N ratio), which causes a strong ammonia release during aerobic digestion, which prevents the anaerobic micro-flora from producing CH4 . When the protein-rich cyanobacterium Spirulina maxima, which contains up to 60–71% proteins, is digested anaerobically, an unusually high quantity of ammonia (up to 7000mgL1) is released. The methanogens are perhaps among the most sensitive micro-flora to high NH3. Nonetheless, it is important to keep in mind that methanogenic bacteria may adapt to high ammonium concentrations Sialve et al (2009). It is proposed that cyanobacterial biomass combined with carbon-rich maize straw can significantly improve CH4 synthesis (Sialve etal., 2009). The C/N ratio of 20/1 was determined to be the best in terms of CH4 production, which rose by 61.69% during the trial as compared to control, according to their output results. Consequently, it may be advised that one of the possibilities for effective CH4 synthesis and waste treatment is the co-digestion of cyanobacterial biomass containing high protein contents but low C/N ratio with plant residues but low protein contents or high C/N ratio. The cultivation of these green bio-agents (cyanobacteria farming) can efficiently be doneat different scales, lesser space,time and underdiverse conditions (fresh as well as waste and unused waters) to achieve high valuebio-fuel products. As polluted and waste waters may be utilised for large-scale biomass production while also treating wastewater to eliminate contaminants, filamentous cyanobacteria may be advantageous. The amount and quality of the cyanobacterial biomass may be altered using a variety of physico-chemical processes to produce the required cyanobacterial biomass with high-quality bio-fuel products. Using cyanobacteria for biofuel production has a number of benefits over employing other bio-agents, such as:

- With limited resources, cyanobacteria's rapid growth and multiplication abilities can satisfy the high demand for biofuels.
- Compared to croplands, cyanobacterial agriculture uses less freshwater, and the production of biomass from waste waters is similarly feasible.
- The production of cyanobacterial biomass is more efficient at increasing CO2 levels.
- Crop field emissions of greenhouse gases, such as nitrous oxide and CH4, can be reduced by growing cyanobacteria for bioenergy.
- Growing cyanobacteria to produce biofuels may be more sustainable, cost-effective, and environmentally beneficial than growing crops for food.

It appears that genetically modified cyanobacteria have the potential to be employed for the economically viable production of a variety of biofuels, including acetone, butanol, ethanol, alkanes, etc. Nevertheless, before energy products from recombinant cyanobacteria can be produced, several biotechnological, environmental, and economic difficulties must be addressed. Also, it has been successfully demonstrated to get high-quality biofuels from cyanobacteria using both the production method and downstream processing of the finished goods.

Cyanobacteria: CO2 Sequestration and Climate Change Mitigation

Carbon di oxide is one of the purported GHGs, primarily responsible for global warming and needs to be mitigated. Energy conservation, the creation of renewable biofuels, and CCS are the solutions for reducing CO2 emissions', an available tool, needs to be investigated to increase the effectiveness of such a strategy. Several approaches are being taken into consideration, including (a) the capture of point-source CO2 from power plants or other industrial sources and subsequent injection of the concentrated CO2 underground or into the ocean (Benson and Orr, 2008); and (b) the expansion of biological carbon sequestration of atmospheric CO2 through measures like reforestation, changes to inland use procedures, increased .Growing knowledge of cyanobacteria's role in reducing the impact of growing CO2 concentrations in the atmosphere . Because they are photosynthetic, cyanobacteria contribute significantly to the overall photosynthetic conversion of solar energy and CO2 assimilation.

Cyanobacteria fix CO2 at a pace 10 to 50 times quicker than terrestrial plants. Consequently, the employment of these biological organisms is thought to be one of the successful strategies to lower atmospheric CO2 concentration and so aid in mitigating potential global warming (Chisti, 2007).The CO2 can be stored as organic molecules in the cyanobacterial biomass and utilized in a variety of ways after that.In paddy field soils ,the cyanobacteria contribute significantly to both organic and nitrogenous contents.Phytoplankton, which mostly consists of cyanobacterial individuals, is predicted to contribute to half of the world's photosynthesis. Only two effective marine cyanobacterial taxa, Synechococcus and Prochlorococcus, may account for around 25% of the total world photosynthetic activity (Rohwer and Thurber, 2009). As many cyanobacteria are halophilic, they may be grown in saltwater drainage systems, marine waters, petroleum refinery brines, or CO2 injection sites without harming freshwater sources (Jansson and Northen, 2010). The primary source of flue gas emissions worldwide—a combination of N2, CO2, O2, and water vapors—is the combustion of fossil fuels including coal, oil, gas, and others.

The adoption of thermophilic cyanobacterial species that are tolerant of both high CO2 and temperature may be warranted given that the fluegas emitted from power plants includes high concentrations of CO2 and has high temperatures (around 120C). For a range of cyanobacterial species, including Aphanothe cemicroscopica, biomass production and CO2 absorption in cyanobacteria exposed to elevated CO2 levels from fluegas or other streams have been monitored (Jacob-Lopesetal., 2008).

Several thermophilic cyanobacterial, Synechococcus aquatilis, Chlorogloeopsis sp., and other members with the capacity to withstand higher temperatures can be employed to sequester CO2 from flue gas. Although the high temperatures of flue gas and the presence of NOx, SOx, and other pollutants of the fossil fuel utilised are the primary issue related to the cyanobacterial or biological utilisation of CO2 (Kumar etal., 2011). Nevertheless, Jansson and Northern believe that using thermophilic and increased CO2 tolerant cyanobacterial species in large water reservoir studies can address the issue of NOx, SOx, etc. on CO2 sequestration from flue gases (2010). According to Miller et al. (2007), the temperature ranges that thermophilic cyanobacteria like Synechococcus lividus and Mastigocladus laminosus occupy are 63–64°C and 73–74°C, respectively. Overall, the large-scale activities involving CO2 sequestration from flue gas due to the use of thermophilic cyanobacteria may be possible economically as follows:

- The use of thermophilic cyanobacteria may minimize the cost of cooling the flue gas,
- The use of thermophilic cyanobacteria may reduce the cost of cooling the flue gases, municipal wastewater-mediated nutrient supply may reduce the cost of operation.
- freshwater and marine cyanobacterial species may be used for a broad range of survival.
- Thermotolerant cyanobacterial strains may be unaffected by the NOx and SOx in flue gases.

Other elements that will have a substantial impact on CO2 sequestration include the availability of light, pH, O2 removal, appropriate experimental system design, culture density, and optimum system agitation. The potential CO2 mitigation technique of cyanobacterial CO2 fixation in photobioreactors has lately attracted considerable interest. Studies on this approach for CO2 sequestration have been done during the last few decades. The main benefits of using photobioreactors over open-pond systems are controlled environmental conditions, optimal space and volume utilization, which increases cyanobacterial productivity, efficient use of land, higher water use efficiency because water loss due to evaporation could be easily avoided, and improved harvesting efficiency. Moreover, genetically modified cyanobacterial strains may be employed when suitable without affecting the surrounding ecosystem.

Cyanobacteria have the capacity to absorb CO2 from flue gases and store it as precipitated CaCO3/CaHCO3 through photosynthesis and calcification. Many terrestrial, marine, and lacustrine ecologies are rich in calcium. The possible calcium supplies for the calcification process can be preserved by employing halophilic cyanobacteria, saltwater, or brines, for instance agricultural drainage water, saline water derived from petroleum operations, or geological CO2 injections. Calcification can be increased even further by adding calcium from gypsum (Mazzone) or silicate minerals, possibly in connection with biologically accelerated weathering. Identification and characterization of cyanobacterial species that exhibit high CO2 absorption rates at increased temperatures are still needed. We need to examine calcification at greater CO2 concentrations, such as in flue gas, and figure out how to automate photosynthesis and light harvesting in cyanobacteria grown in open pond environments or photobioreactors. A better understanding of the biochemical and genetic mechanisms that carryout and regulate cyanobacteria-mediated CO2 sequestration should put us in a position to further optimize these steps by application of advanced technique of genetic engineering.

CYANOBACTERIA: METHANE EMISSION REDUCTION

Methane (CH4) is a powerful GHG with detrimental effects that are roughly 20 times more severe than those of CO2 (Singh, 2011). Natural emissions make up the remainder of the rise in global CH4, with anthropogenic activities accounting for the bulk. Fossil fuel usage, animal farming, land filling, and burning of biomass are all human-caused sources of CH4 emissions. Estuaries, rivers, lakes, permafrost, gas hydrates, wetlands, seas, wildfires, plants, termites, and wild animals are all natural sources of CH4. Due to methanogenesis occurring in anaerobic flooded paddy soils, flooded paddy fields are another important factor in the atmospheric CH4 concentration increasing. It is believed that as human populations and food needs rise, more garbage is produced, and fossil fuels are used more often, the quantity of CO2 in the atmosphere will almost certainly continue to rise. Hence, addressing the CH4 problem will require a practical, feasible, and eco-friendly instrument. Cyanobacteria may offer a significant opportunity to combat the global warming issue brought on by GHGs produced by human activity. Cyanobacteria may be able to reduce CH4 emissions from flooded rice soils at the production, transportation, and consumption stages. In conjunction with cyanobacteria, bio-agents like methanotrophs may remove a considerable proportion of the most potent and hazardous GHGs, including CH4, from the soil of diverse ecosystems (Singh, 2013a; Singh and Pandey, 2013; Singh and Singh, 2013a). There is currently no knowledge of how cyanobacteria and methanotrophs interact with regard to the management of methane flow in paddy fields . It is assumed that cyanobacteria may increase the oxygen content in the paddy rhizosphere and subsequently may increase the methane-absorption activity of methanotrophs. In addition, these biological agents—aside from their capacity to fix atmospheric N2 in the paddy soils—can limit the global warming potential from flooded paddy. The oxygen (O2) produced during photosynthesis by cyanobacteria in wet soils might escape into the soil and generate an anaerobic environment that is unfavourable for CH4 genesis (Prasannaetal., 2002). In addition, by increasing the number and activity of aerobic methane-oxidizing bacteria (methanotrophs) in flooded paddy soils, the O2 produced by cyanobacteria can accelerate CH4 oxidation. The Combining organic amendments like FYM and cyanobacteria can increase paddy production while also providing other benefits.

May also help rice farming produce less CH4 than when FYM alone is used. Use of cyanobacteria decreases methane flow without impacting rice yields and can be utilised as a viable mitigation strategy to minimise the global warming potential of flooded paddy ecosystems and boost N2 fixation (Prasannaetal., 2002). It seems that broadening the variety of microorganisms, including cyanobacteria and methanotrophs in paddy fields, can be an inventive technique to boost crop output and decrease long-term CH4 emissions from agricultural areas (Singh and Singh, 2012; Singh, 2014). It is suggested that using cyanobacteria and their contributions as a substitute for fertilizer would be a more affordable, environmentally friendly, and secure way to restore degraded land as well to preserve long-term methanotrophic diversity and CH4 consumption.

CYANOBACTERIA: FOOD SUPPLEMENTS

Cyanobacteria dietary supplements for people are sold on the market in a variety of formats, including pills, capsules, and liquid. They are said to improve the nutritional content of pasta, snack meals, candy bars, gummies, and drinks (Liang etal., 2004). According to Nelis and DeLeenheer (1991), Borowitzka (1999), Soletto etal. (2005), they can serve as a source of natural food colours or operate as nutritional supplements. Because of its high protein content and great nutritional value, Spirulina (Arthrospira) is the most popular cyanobacterial strain utilised for human nutrition. In many countries including Chile, Mexico, Peru and Philippines; several members of the cyanobacterial genus Nostoc, Anabaena, and Spirulina are eaten by humans. Spirulina platensis, also known as Arthrospira platensis, is produced on a large scale using either raceway ponds or advanced photobioreactors, and it is sold as powder, flakes, pills, or capsules. It contains more than 60% proteins, is high in thiamine, riboflavin, and beta-carotene, and is regarded as one of the finest sources of vitamin B12 (Plavsicetal., 2004; Prasannaetal., 2010). Because of its high nutritional content and digestibility, it is utilised as a dietary supplement (Brown et al., 1997; Bandaranayake, 1998; Sinha et al., 1998). According to Kulshreshtha et al. (2008), spirulina includes a wide range of preventative and therapeutic elements, including B-complex vitamins, minerals, and proteins. Super antioxidants like b-carotene, vitamin E, trace elements, and several unidentified bioactive substances, as well as g-linolenic acid.

CONCLUSIONS:

It is crucial for a healthy agro ecosystem to achieve sustainability in the genuine sense in order to maintain the richness and variety of the ecosystems as well as the preservation of nature and natural resources. It supports and maintains enough food supply for the growing global population, assures economic viability, and promotes safer living conditions for people and other livestock. Above all, it addresses the present-day environmental concerns. Poor farmers (particularly those in developing nations) find it difficult to both afford the expensive chemical fertilizers and pesticides and feel concerned about environmental concerns. In this situation, cyanobacteria may be highly useful for enriching soil with organic carbon and nitrogen and improving the plants' ability to absorb phosphorus. Heavy metals, herbicides, and compounds including oil are just a few of the environmental pollutants that cyanobacteria are adept at accumulating or degrading. Such common bio-agents can be utilized to capture and store CO2, which may also result in climate change mitigations through photosynthesis and biological calcification. Furthermore, they are the best source of a wide range of bioactive chemicals with strong antagonistic activities. There is a huge potential for the development of bio-agents, such as cyanobacteria, for sustainable agriculture, which also focuses on improving the soil's nutrient status and biologically controlling pest diseases, which may ultimately result in lower agricultural costs (Singh, 2013b; Singh and Singh, 2013b). However, more research must be done in order to harness cyanobacteria in order to fulfil the objective of sustainable agriculture and the environment. Due to rising human activity and diminishing soil health and production, maintaining environmental sustainability will be a difficult undertaking.

Cyanobacteria serve a variety of purposes in agriculture and environmental sustainability, among other things. To improve their utility in agriculture and associated sectors needs serious attention. Thus, it is vital to solve several important problems with improved cyanobacterial exploitation. Furthermore, the use of molecular biology has increased our understanding of how to enhance healthy and sustainable agro ecosystems. There appears to be a long way to go because the utilization of cyanobacteria to manufacture important compounds, including dietary supplements, is largely understudied. Future research must focus on strain improvements of useful cyanobacteria to produce high-quality food and fuel products, sustain high growth rates, and survive in difficult environmental conditions in addition to product advances. These will be the crucial elements that enable the transition from small-scale, unprofitable biofuel production to large-scale, sustainable agricultural, ecological, and environmental development.

Genetic alterations can increase the usefulness of cyanobacteria in sustainable agriculture and the environment. Yet, the use of genetic engineering to enhance cyanobacterial biofuel production is still in its infancy. Future cyanobacterial genetic and metabolic engineering is predicted to play significant roles in improving the economics of cyanobacteria-mediated biofuel generation. According to Volkmann and Gorbushina (2006) and Volkmann et al. (2006), cyanobacteria can be genetically modified to potentially increase their growth and photosynthetic efficiency, biomass yield, lipid and carbohydrate productivity, improve temperature tolerance, and decrease photo-inhibition and photo-oxidation. Yet, the transition from the lab to the field will not be simple since there are many challenges to be addressed, including social relevance, political lobbying, and compliance with regulatory standards. In addition to this, it is advised that difficulties with cross-contamination when using closed photobioreactors in place of open ponds be extensively addressed before implementation.

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