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Effects of Pesticides on Cyanobacterial Growth and Biochemical Parameters

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Abstract - Pesticides are chemicals that are used to keep pests out of a building. Herbicides, insecticides, and a variety of other compounds are included in the phrase "pesticide" (which may include insect growth regulators, termiticides, etc.) Cyanobacteria are among the oldest living forms on the earth, stretching back billions of years. They are necessary for photosynthesis and the global carbon and nitrogen cycles. There are cyanobacterial species with a wide range of physical properties that may live in a given habitat happily and mutually beneficially.

Keywords - Pesticides, effects, Cyanobacteria, Cyanobacterial growth, Biochemical parameters

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INTRODUCTION

Water is the source of life, the bedrock of society, and is essential for the survival of all living beings as well as environmental protection. As a result of unregulated industry and urbanisation, as well as the discharge of household effluents and agricultural operations, the level of pollution in the aquatic environment has increased in recent years. Industrialization and human activities have contaminated water bodies, introducing a variety of toxins, including heavy metals. Pollutants from numerous anthropogenic sources have been known to affect the aquatic environment's ecological integrity. The most important challenge we face today as a result of industrialization is the amount of waste water emitted in the form of liquid effluents from these firms, which include high amounts of heavy metals and cause environmental disposal problems as well as poisoning of aquatic bodies. Heavy metal contamination has emerged as one of the most pressing environmental concerns. Drinking this heavy metal-contaminated water causes a number of physical and physiological difficulties in living species, including humans. India is the world's tenth-largest industrial country, yet it is also one of the most polluted in terms of industrial pollution and hazardous waste.

Crop yields in emerging countries are being boosted by synthetic pesticides, which are being used on agricultural fields. Soil pH and salinity, fertility levels, and mechanical procedures have all been abandoned as a consequence of this. European efforts to reduce pesticide usage have failed despite a substantial increase in the previous two decades and the persistence of chemical contaminants in agricultural soils, groundwater supply and surface waterways. According to EU data, annual consumption did not decrease between 1992 and 2003 (1).

If the fossil record from that time period is to be believed, Cyanobacteria's evolutionary history predates that of any other group of life by about 3.45 billion years. One of the most important metabolic processes occurring in Earth's atmosphere is oxygenic photosynthesis, which generates and consumes energy in the form of ATP molecules. These fossilised biomarkers (molecular fossils) represent the earliest evidence for oxygenic photosynthesis and are found in 2.7-Gyr-old shales from the Pilbara Craton in Australia's Western Australia region. Carbon dioxide and water were formerly assumed to be the primary electron sources for photosynthesis in ancient cyanobacteria. The simultaneous release of free oxygen was one of Earth's most momentous historical events. Oxygenic photosynthesis, which originated in cyanobacteria and is definitely passed down to green plants, is the most critical method of harvesting solar energy. Cyanobacteria are a diverse range of unicellular to multicellular prokaryotic microorganisms that perform two key biological functions, such as oxygenic photosynthesis and nitrogen fixation, in the same cell/filament. The chemically bonded energy and reductant generated in light reactions are used for carbon dioxide fixation. As a result of oxygenic photosynthesis, carbon and oxygen are transformed on a regular basis, which helps to maintain the atmosphere's essential gaseous composition. The carbon pool in rice fields may be utilized by heterotrophic nitrogen fixers due to cyanobacteria, which also contributes about half of the carbon fixed worldwide (2).

Pesticides

Pesticides are chemicals that are used to prevent pests from invading a property. The word "pesticide" encompasses a wide range of chemicals, including herbicides, insecticides, and many more (which may include insect growth regulators, termiticides, etc.) Non-toxic and toxic pesticides are among the most often used. Among these are the most common ones such as the neonicotinoid family of chemicals (nematicides) and the carbamate family of chemicals (molluscicides). Pesticide usage is dominated by herbicides, which account for roughly 80% of all applications. Plant protection products (sometimes referred to as crop protection products) are the majority of pesticides, and their primary purpose is to keep plants free of weeds, fungi, and insects. Salvinia, an aquatic weed, is controlled with the fungus Alternaria solani (3).

To keep pests at bay, pesticides use chemicals (such carbamate) or biological agents (such as a virus, bacteria, or fungus). There are a wide range of pest species that might damage your property or transmit illness. These include insects and plant diseases as well as other invasive species such as birds, mollusks and nematodes (roundworms). Aside from the potential for damage to people and other animals, pesticides provide a number of benefits.

Any substance or mixture of substances intended for preventing, destroying or controlling any pest, including vectors of human or animal disease, unwanted species of plants or animals causing harm during or otherwise interfering with the production or processing, storage and transport of food and agricultural commodities, wood and wood products or animal feedstuffs" is defined by the Food and Agriculture Organization (FAO). Chemicals that may be used to control plant growth, defoliate the foliage, or dry up the fruit are included in this category.

To categorise pesticides, we must look at their intended target organism (e.g., weedkillers and insecticides), chemical structure (e.g. organic, inorganic, synthetic or biological (biopesticide)) and physical state (e.g. gaseous) (fumigant). Biopesticides include, but are not limited to, microbial pesticides and biochemical pesticides. When it comes to "botanicals," which are plant-based pesticides, things are moving quickly. pyrethroids, nicotinoids, strychnine, and scilliroside are all included in this group (4).

Insecticides may be grouped into chemical families for ease of reference. There are three primary groups of insecticides: organochlorines, organophosphates, and carbamates. Organochlorine hydrocarbons may yield chlorodiphenyl ethanes, cyclodiene compounds, and other related substances (e.g., DDT). Because they disrupt the sodium/potassium balance in the nerve fibre, they make it transmit all the time. Although their toxicity varies greatly, they have been phased out due of their persistence and propensity for bioaccumulation. Organophosphates and carbamates have mostly replaced organochlorines. Both inhibit the enzyme acetylcholinesterase, enabling acetylcholine to transmit nerve impulses indefinitely and resulting in a wide range of symptoms, such as weakness and paralysis. Carbamates have been utilised as a substitute for organophosphates in certain cases because they are less hazardous. Thiocarbamates and dithiocarbamates are subclasses of carbamates. Triazines(e.g. atrazine) and ureas (e.g. diuron) are examples of herbicides of the phenoxy and benzoic acid (e.g. 2,4-D) families (e.g. alachlor). Rather than grasses, broad-leaf weeds are the primary target of phenoxy herbicides. As a result of herbicides like phenoxy and benzoic acid acting as plant growth hormones, the plant's ability to absorb nutrients is severely impaired. Triazines interfere with photosynthesis: Glyphosate is not one of these classes of herbicides used on a regular basis.

An effective way to apply pesticides is to disperse the chemical in a solvent-surfactant solution (typically hydrocarbon-based). Studies on virus lethality in mice done back in 1977 showed no correlation between pretreatment with a single herbicide and enhanced viral lethality, but that pretreatment with combinations combining different surfactants and the solvent did.

The biological mechanism function or application technique of pesticides can be used to classify them. The majority of insecticides act by poisoning insects. Following absorption by the plant, a systemic pesticide goes inside the plant. This migration is usually upward (via the xylem) and outward with insecticides and most fungicides. As a result, efficiency may improve. Bees and other pollinators may be killed by systemic pesticides, which poison pollen and nectar in blooms.

Paldoxins are a novel class of fungicides that was first announced in 2010. These function by utilising phytoalexins, which are natural defensive compounds generated by plants and detoxified by fungi using enzymes. The fungi's detoxifying enzymes are inhibited by the paldoxins. They are thought to be safer and more environmentally friendly (5).

Impact of pesticides on growth and biochemical parameters

These oxygen-loving bacteria may be found in hot springs, Antarctica's frozen lake, salty oceans, and scorching deserts. Cyanobacteria are an extremely varied collection of organisms. It's no secret that cyanobacteria are among of the planet's earliest life forms, dating back billions of years. Photosynthesis and the global carbon and nitrogen cycles rely on them. There are cyanobacterial species with a broad variety of physical characteristics that may coexist peacefully and mutually beneficially in a certain environment. Essential minerals, water retention, soil texture, and the amelioration of high-salt-content soils have been discovered to be affected by these organisms. Many key ecological functions are supported by rice fields, including nitrogen fixation and organic matter synthesis through photosynthetic processes relying on a variety of cyanobacteria species (6).

There are 20 wild and two domesticated species of rice (Oryza sativa), an annual Poaceae plant. There is a strong correlation between the yield of paddy crops and the environment in which they grow. About 45 million acres of Indian farmland are heavily dependent on the use of a wide range of agrochemicals in the production of rice. Blue-green algae species thrive in warm, nutrient-rich environments, such as lowland agricultural areas, where rice is widely grown because of the copious water supply. An increase in rice output is not only good for keeping soil nutrients (particularly nitrogen) in balance but also gives insight into the creation of sustainable agricultural practises that take the lives of small living organisms in order to do so.

Distribution and action pattern of pesticides

The expanding global population has been one of the most serious issues for agronomists, farmers, and politicians for several decades, and they have continued to work on this aspect to manage or reduce its negative influence on the environment, socioeconomics, and human health (7). The current global population is 7.2 billion people, with a projection of 9.3 billion people by 2050. In order to survive in the limited land resources, this growing population will require additional food. When it comes to farming, farmers use pesticides in an unequally distributed way to increase crop yields or to protect crops from pests and pathogens by replenishing minerals like nitrogen, phosphate, and potassium in soil. Around 25% of total agricultural output has been lost to pests and diseases during the development stage or during postharvest storage, according to a study.

Cyanobacteria

Cyanobacteria (also known as blue-green algae) are regarded to be among the most ancient creatures on the planet. They are one of the few organisms capable of both oxygenic photosynthesis and nitrogen fixation in the atmosphere. The evolutionary durability of these two excellent metabolic pathways is due to their successful combination. They can survive in a variety of environments, from the coldest parts of Antarctica to hot springs. Cyanobacteria are responsible for 20–30% of the earth's photosynthetic production and use sunlight to power photosynthesis. This is a process in which light energy is utilised to divide water molecules into oxygen, protons, and electrons, with the energy liberated by the electrons travelling through the electron transport chain later being used to fix atmospheric CO_2 (8).

Many heterocystous cyanobacteria produce akinetes, which are spore-like reproductive structures produced by the differentiation of vegetative cells under energy constraints. Akinetes have a thick envelope surrounding them and hold a substantial amount of reserve material in the form of glycogen and cyanophycin polypeptides. Some members of the Nostocaceae, Rivulariaceae, and Stigonemataceae families have been observed to form akinetes, which serve as a means of perrenation in these organisms and provide the capacity for growth into new filaments by germination under favourable conditions even after. Limitations in nitrogen, carbon, iron, trace elements, light, phosphate and sulphate.

In filamentous cyanobacteria, hormogonium develops from vegetative cells (both heterocystous and non-heterocystous). Cell form and, in some species, cell motility and the presence of gas vesicles separate them from vegetative cells. Hormogonia differentiation is influenced by a variety of environmental parameters including as temperature, light spectral quality, and changed N-metabolism (9).

The activity of nitrogenase is affected by the amount of oxygen present. As a result, organisms that can perform both oxygenic photosynthesis and oxygen-sensitive nitrogen fixation, such as cyanobacteria, have found techniques to accommodate both functionalities in the same organism. They either split the two processes where nitrogen fixation and photosynthesis alternate in time. Others divide these two processes into separate sections. Cyanobacteria's vegetative cells can differentiate into a specialised cell termed a heterocyst, which has an extra envelope that protects the enzyme nitrogenase from oxygen. Nitrogen fixation, the ATP-dependent process of converting ambient nitrogen to ammonia by the enzyme nitrogenase, is the final step in heterocyst formation. Nitrogenase is only generated in heterocysts in many heterocyst-forming cyanobacteria, including Anabaena PCC 7120, where it is shielded from irreversible inactivation by oxygen. Some heterocyst-forming cyanobacteria, on the other hand, have an additional set of nif genes that allow nitrogen fixation in vegetative cells under anoxic circumstances. Nitrogenase is a well-preserved enzyme that consists of two parts: dinitrogenase (Mo-Fe protein) and dinitrogenase reductase (Fe protein) in all nitrogen-fixing organisms (10). Dinitrogenase reductase transfers electrons to dinitrogenase from electron donors like ferredoxin and flavodoxin. Some cyanobacteria have an alternate nitrogenase that utilises a vanadium cofactor in addition to the typical molybdenum nitrogenase. Changes in the photosynthetic machinery and carbon metabolism accompany heterocyst development in order to generate ATP and reductants for nitrogen fixation. The cytochrome C oxidase in the lungs produces ATP for nitrogen fixation and contributes to the microoxic environment.

Factors influencing the cyanobacterial occurrence

Cyanobacteria can thrive in a variety of situations, including a salty environment, a wide pH range, osmoticum, and increased quantities of gases like CO2. However, some of the aforementioned characteristics may have a negative impact on their proliferation as well as physiological and metabolic processes. Salinity-induced changes in the composition of nitrogen fixers associated with saline microbial mats were explained as a result of alterations in the expression of nitrogen fixation genes and hence overall nitrogen reduction to ammonia activity.

Hydrogen ion concentration in the soil is an additional component that affects cyanobacteria biological activity and diversity. pH neutral to slightly alkaline is ideal for cyanobacteria growth (11). Cyanobacteria are known to be inhibited by an acidic pH of 45, which is contrary to conventional assumption.

Pesticides impact on the nontarget cyanobacteria

Researchers, legislators, and the government are continually working to find ways to counteract pesticides' detrimental impacts on human health, the environment, and the economy. Only 0.1 percent of pesticides used are recognised by the target insect, while the remainder residue effects nontarget microbiota, texture or soil productivity, and environmental health. This ecosystem has a wide range of microbial communities, all of which contribute significantly to soil quality and production.

As a result of pesticide use in aquatic environments, natural microflora and fauna are adversely affected, as well as the ecosystem's ability to produce, feed itself, and recycle nutrients. cyanobacteria's development and form are influenced by pesticide buildup in the aquatic habitat (12). When it comes to cyanobacteria blooms, pesticides act as growth stimulants, resulting in an increase in the growth of some cyanobacterial species and the creation of anoxic conditions, which result in the death of various natural microflora due to anoxic conditions and degrade the quality and nutrient status of water.

Use of cyanobacteria as a biofertilizer

The world's population is growing at a rapid pace, and it will reach 9.7 billion people in 30 years. India would contribute the lion's share of the population. The need for contamination-free, healthful food has grown in direct and indirect proportion to the increase in population. By 2029, the World Health Organization estimates that global food production will have increased by 50%. "Green Revolution" approaches are also helping to boost agricultural productivity while lowering the risk of chemical-based fertilisers harming human health and the environment. Researchers have therefore employed 'green technology' to create an eco-friendly atmosphere by utilising bacteria. Green Technology goes into great depth on the usage of cyanobacteria to increase agricultural yield and soil fertility (13). Cyanobacteria can breakdown a wide range of contaminants and play a variety of roles in the soil ecosystem, all of which help to maintain soil fertility.

Cyanobacteria are a new type of bacterium that can help with long-term agricultural development. Diazotrophes are cyanobacteria that can be used to make inexpensive and environmentally beneficial biofertilizers. They can help plants with nitrogen deficit, soil aeration, water holding capacity, and vitamin B12 supplementation. Nitrogen-fixing cyanobacteria that are most effective in rice crop growing region include Nostoc linkia, Anabaena variabilis, Aulosiira fertilisima, Calothrix sp., Tolypothrix Sp., and Scytonema sp. Anabaena and Nostoc thrive on the surface of soil and rocks, where they may absorb up to 20–25 kg of nitrogen per hectare. For each hectare of land, Anabaena can fix 60 kg of nitrogen throughout the growing season. Without a host, cyanobacteria are able to grow, mature, and create important organic compounds. For nitrogen fixation and nutritional enrichment, the Azolla-Anabaena symbiotic relationship may be found in the rice paddy area. Lyse and release substances from the cell wall that cause the organism to proliferate excessively. All of these crops have been reported to employ biofertilizers, including: oats, barley, radishes, radishes, cotton and sugarcanes (14).

Cyanobacteria as a biofertilizer source for sustainable agriculture

The four orders of cyanobacteria have been recognised as Chroococcales, Nostocales, Oscillatoriales, and Stigonematales, and their phyla are Chroococcales, Gloeobacterales, and Pleurocapsales, according to a classification proposed in 1985. Cyanobacteria have been linked to plant emergence periods. Cyanobacteria have played a critical role in shaping the course of evolution and ecological changes throughout the Earth's history. For the origin of eukaryotes, cyanobacteria began to take up residence within specific eukaryote cells in the late Proterozoic or early Cambrian epoch, a phenomenon known as endosymbiosis. They have the ability to fix atmospheric nitrogen, making them suitable for use as a biofertilizer in the production of economically significant crops like rice and beans. Cyanobacteria's outermost layers are made up of three separate layers: a mucilaginous layer, a cell wall, and the innermost plasma membrane. There are pigmented lamellae in the cytoplasm that are not grouped into plastids. Chlorophylls, carotenes, xanthophylls, c-phycoerythrin, and c-phycocyanin are among the pigments, with the last two pigments being found in bluegreen algae (15).

Potential roles of cyanobacteria in sustainable agriculture

Around the globe, concerns have been raised about the growing use of artificial nitrogenous fertilisers in agriculture. Environmental issues need the development of alternatives to nitrogen fertilisers as soon as feasible. A microbiological process known as Biological Nitrogen Fixation (BNF) may be used to convert atmospheric nitrogen into a form that plants can utilise as nutrients. Reduce external inputs while increasing internal resources by using nitrogen fixing solutions that are both cost-effective and ecologically benign (16).

Inorganic nitrogen fertilisers have a very high production cost. Biofertilizer is used to address nitrogen deficiency in crops in a sustainable manner. Biofertilizers like cyanobacteria can fix less than 10 kg of nitrogen per hectare. Dense mats of cyanobacteria fix about 10–30 kg of nitrogen per hectare per year.

Cyanobacteria have a role in the carbon, nitrogen, and oxygen biogeochemical cycles. They can live in moist soils and have a substantial impact on crop nutrition, structural stability, and yield. Molecular changes are necessary for life in circumstances of extreme UV light (280–400 nm), dryness, temperature fluctuation and high salt concentrations in the environment (17). All of these factors work in your favour and protect you from other competitors and grazers. Agronomically and economically, these cyanobacterial metabolites are essential.

Other uses for symbiotically related cyanobacteria include bioremediation of contaminated soils and aquatic systems, as well as exopolysaccharide synthesis (EPS). The EPS acts as a glue agent, allowing soil particles to aggregate, organic matter to accumulate, and the upper layer of soil's water holding ability to expand. PGPRs, in combination with EPS-producing cyanobacteria, may help increase and restore soil fertility (18).

CONCLUSION

The accumulation of heavy metals in the food chain at different trophic levels makes them harmful to organisms since they are non-biodegradable. As a result, they have a wide range of health consequences. As a result, environmental research on water pollution remediation is a high priority. For heavy metal removal, a physico-chemical process that costs a lot of money is utilised. If you want to eliminate the heavy metals from the water, you'll need a cost-effective option. Because it can collect heavy metals even at extremely low concentrations, cyanobacteria are the best alternative source in the current situation.

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