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Review

Distribution of cyanobacteria and their interactions with pesticides in paddy field: A comprehensive review

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ABSTRACT

Cyanobacteria, also known as blue green algae are one of the important ubiquitous oxygen evolving photosynthetic prokaryotes and ultimate source of nitrogen for paddy fields since decades. In past two decades, indiscriminated use of pesticides led to biomagnification that intensively harm the structure and soil functions of soil microbes including cyanobacteria. Cyanobacterial abundance biomass, short generation, water holding capacity, mineralizing capacity and more importantly nitrogen fixing have enormous potential to abate the negative effects of pesticides. Therefore, investigation of the ecotoxicological effects of pesticides on the structure and function of the tropical paddy field associated cyanobacteria is urgent and need to estimate the fate of interaction of pesticides over nitrogen fixations and other attributes. In this regard, comprehensive survey over cyanobacterial distribution patterns and their interaction with pesticides in Indian context has been deeply reviewed. In addition, the present paper also deals the molecular docking pattern of pesticides with the nitrogen fixing proteins, which helps in revealing the functional interpretation over nitrogen fixation process.

1. Introduction

Cyanobacteria are gram-ve, oxygen evolving, ubiquitous prokaryotes originated since two billion years ago and still thriving on the earth (Sergeev et al., 2002). Earlier around 2.8 billion years ago, cyanobacteria were the only originator of oxygenic environment that were present in stromatolites and oncolites fossil forms (Rastogi and Sinha, 2009). Cyanobacterial life forms ranges from, free-living to symbiotic association with plants, fungi and animals adapted to various environmental conditions and characterized by great morphological diversity (Adams, 2000; Whitton, 2000; Singh et al., 2014). They play an important role in maintaining nutrient availability, porosity, soil pH, water holding capacity, reduction in salinity in soil, where as in plants also play important role in plant physiological and biochemical process (Fig. 1). Paddy fields have been considered as the important ecological niche for cynaobacterial functions such as, N_2-fixation, photosynthesis that helps in sustaining various physiochemical processes (Wilson et al., 2006; Singh, 2014).

Paddy or rice is an annual grass belongs to family Poaceae, along with 20 wild species and two cultivated species. Among them *Oryza sativa* is widely grown whereas *Oryza glabeerima* is limited only in the West Africa (Bernis and Pamies, 2008; Pareja et al., 2011). Paddy cultivation is largely depending upon their climatic conditions and season. It is an important staple food crop with high optimum calorie content for over 60% of the world's population. In India, about 45 million hectares cultivable land is used for rice production with the utilization of huge amount of chemical fertilizers (Prasanna and Nayak, 2007). Currently, the whole world is facing two major challenges; first one is the changing climatic conditions and other is population explosion. Recent reports estimated that population of the world is predicted to rise higher by 9 billion till 2050, which exert extra pressure for food production in the limited land resource (http://www.un.org/en/development/desa/news/population/2015-report.html).

Since ages paddy fields are grown in larger wet to lowlands tropical areas that favor the growth of diazotrophic, oxygenic cyanobacteria, by providing suitable temperature, nutrient and water facilities (Singh et al., 2014). Repeated cropping of rice followed by harvesting, maintain the level of nitrogen in the soil, due to the presence of cyanobacterial mats, thus rice cultivation is a sustainable practice for economic nitrogen conservation in rice soils (Dash et al., 2017a,b; Pabbi,

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Nomenclature list

N_2	Nitrogen
kg N_2 ha^{-1} $year^{-1}$	kilogram nitrogen per hectare per year
μmol m^{-2} s^{-1}	micromole per square meter per second
kg ha^{-1}	kilogram per hectare
ppm	parts per million
μM	micro molar
mg ml^{-1}	milligram per milliliter
μL^{-1}	micro per litre
μg ml^{-1}	microgram per milliliter
n mol L^{-1}	nano mole per litre

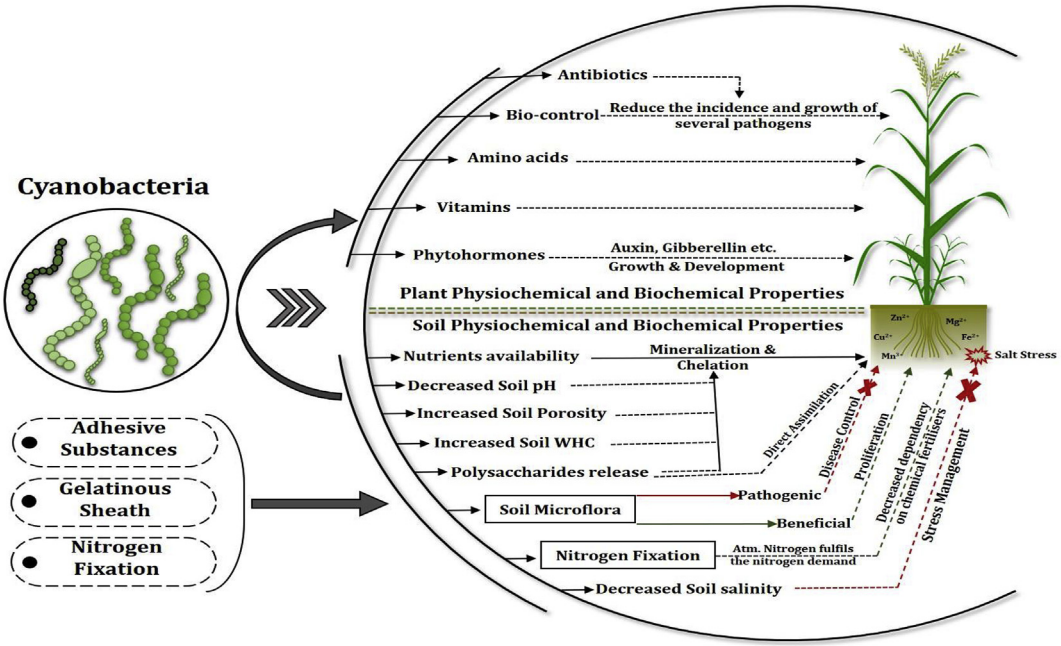

Fig. 1. An overview of beneficial effect of cyanobacteria on plant and soil.

2015; Singh et al., 2014).

Past studies witnessed the succession of cyanobacterial group during different stages of rice growth (Grant et al., 1986). Phytoplanktons mainly the chlorophyceans develop early in the cultivation cycle and keep on thriving until the tillering phase. Photosynthetic aquatic biomasses are seen up to the initiation of panicle stage with the dominance of both N_2-fixing and non-N_2-fixing cyanobacteria in some places. However, N_2-fixing cyanobacteria become dominant at harvesting stage (Fernández-Valiente and Quesada, 2004). Generally paddy is cultivated in a humid, temperate environment, therefore are prone to pest, fungi, insects, mites etc which affect the growth and production of crop. Currently, more than 70 harmful insect species have been documented, which directly or indirectly affect the rice crop. To overcome the problems of pest, pathogens and soil nutrient, farmers frequently utilized different types of pesticides and fertilizers. In Indian territory, the consumption of pesticides is unevenly distributed. Northern part of India consumes more pesticides as compared to the eastern and southern parts due to the variation in soil types as well as local climatic conditions (Zhang et al., 2012). Unbalanced pesticides applications in Indian agroecosystem demands analyses of risk associated impact on the non-target soil microorganisms including nitrogen fixing cyanobacteria (Kumar et al., 2008; Staley et al., 2015).

2. Distribution of cyanobacteria in paddy field

Paddy ecosystem harbor N_2-fixing cyanobacterial species mainly belongs to the *Nostoc, Anabaena, Tolypothrix, Aulosira, Cylindrospermum, Scytonema, Westiellopsis* and several other genera commonly flourishing in Indian paddy (Nayak et al., 2004). It has also been observed that cyanobacteria were more abundant in tropical and subtropical regions as compared to the temperate and sub-temperate regions (Shiozaki et al., 2015).

In context of Indian cyanobacterial research, Singh (1939, 1942, 1961), extensively studied the paddy fields of different region of India and observed *Aulosira fertilissima*, *Anabaena ambigua* and *Cylindrespermum gorakhperense*, as the most dominant species. In another investigation Prasanna and Nayak (2007) observed *Nostoc* and *Anabaena* as the most dominant genera in most of the sites whereas Saadatnia and Riahi (2009) reported *Anabaena* as an important occupants of paddy field rhizosphere. Apart from India, Reynaud and Roger (1978) noticed *Nostoc* and *Anabaena* almost in all the soils whereas *Scytonema* and *Calothrix,* were present in 50 and 15% in the rice soils of Senegal, respectively. Hashtroudi et al. (2013) reported *Anabaena* and *Nostoc* as a dominant species in Iran. A wide spread distribution of paddy field associated N_2-fixing cyanobacteria have been reported from diversified habitats of Marocco, South Africa (Renaut et al., 1975) and in Egypt (EL-Nawawy and Hamdi, 1975).

Quantitative observations of the cyanobacterial flora from different parts of India revealed the dominance of cyanobacteria. Out of 107 species of cyanobacteria reported from Balia and Ghazipur district (Uttar Pradesh), 74 sp. were members of Cyanophyceae, 27 sp. of Chlorophyceae and 6 sp. of Bacillariophyceae (Pandey, 1965 a,b). Out of 28 non-heterocystous filamentous isolates, 7 isolates (*Pseudoanabaena, Limnothrix, Phormidium, Microcoleus, Plectonema, Lyngya, Oscilateria*) were reported from Uttar pradesh (Tiwari et al., 2001). Nineteen isolates of the nitrogen fixing cyanobacteria were reported from the Central Bihar (Khare et al., 2014). In another study, out of 86 species from Kashmir paddy soils, 37 sp. belongs to Chlorophyceae, 35 sp. of Cyanophyceae, 12 sp. to Bacillariophyceae and 2 sp. to Euglenophyceae (Khan, 1957). Out of 19 species isolated from Kerala soils, 7 isolates were known as N_2-fixers (Aiyer, 1965). In another study, out of 71 species collected from 16 soil samples (from both north