Toxicon 211 (2022) 21–35

Contents lists available at ScienceDirect

Toxicon

journal homepage: www.elsevier.com/locate/toxicon

Cyanotoxins uptake and accumulation in crops: Phytotoxicity and implications on human health

Chanusha Weralupitiya [a,b], Rasika P. Wanigatunge [b], Dilantha Gunawardana [c], Meththika Vithanage [a,d,*], Dhammika Magana-Arachchi [d,**]

[a] *Ecosphere Resilience Research Center, Faculty of Applied Sciences, University of Sri Jayewardenepura, Nugegoda, 10250, Sri Lanka*
[b] *Department of Plant and Molecular Biology, Faculty of Science, University of Kelaniya, Kelaniya, 11600, Sri Lanka*
[c] *Research Council, University of Sri Jayewardenepura, Nugegoda, 10250, Sri Lanka*
[d] *Molecular Microbiology & Human Diseases Project, National Institute of Fundamental Studies, Kandy, 20000, Sri Lanka*

ARTICLE INFO

Handling Editor: Glenn King

Keywords:
Accumulation
Cyanotoxins
Phytotoxicity
Human health
Plant uptake

ABSTRACT

The invasive nature of cyanotoxin-producing cyanobacteria and the adverse effects concerning their toxic impacts have gained heightened scientific attention of late. The persistence of cyanotoxins in irrigation water leads to bioaccumulation in plants, the development of phytotoxic effects, and the threat of groundwater contamination. The accumulation of cyanotoxins in plants is caused by several factors leading to severe toxic effects, including reduced plant growth and seed germination, enhanced oxidative stress, lowered rate of mineral uptake, decreased photosynthetic efficiency, and loss of chlorophyll content. The uptake and accumulation of cyanotoxins in plants can be concentration-dependent, as reported in a myriad of studies. Even though several studies have reported phytotoxic effects of cyanotoxin contamination, field-related studies reporting phytotoxic effects are particularly inadequate. Paradoxically, at realistic conditions, some plants are reported to be tolerant of cyanotoxins. Furthermore, the breadth of adverse impacts of cyanotoxins on human health is significant. Cyanotoxins cause major health effects including cancer, oxidative stress, organelle dysfunction, DNA damage, and enzyme inhibition. This review intends to present compelling arguments on microcystins (MCs), cylindrospermopsins (CYN), β-N-methylamino-L-alanine (BMAA), and anatoxin-a (ANTX-a), their uptake and accumulation in crop plants, phytotoxic effects on plants, and potential health implications to humans. The accumulation of cyanotoxins implants cultivated as food crops, resulting in phytotoxic effects and adverse impacts on human health are serious issues that require scientific inputs to be addressed.

1. Introduction

Cyanobacteria, a fusion of cyan (blue) and bacteria (a prokaryotic organism), constitutes both positive and negative impaction humans (Buratti et al., 2017). Being photosynthetic, cyanobacteria play an important role as primary producers (Machado et al., 2017; Bittencourt-Oliveira et al., 2014). Favourable environmental conditions combined with nutrient availability help the proliferation of cyanobacteria and the formation of cyanobacterial blooms. These blooms can cause severe environmental and health effects (Pelaez et al., 2010). Artificially or naturally-induced water eutrophication and climatic changes are identified as primary reasons for the occurrence and flourishing of cyanobacterial blooms (Machado et al., 2017). Certain cyanobacterial isolates belonging to specific cyanobacterial species can produce a highly toxic range of secondary metabolites known as cyanotoxins (Table 1). The true purpose of toxins still baffles the scientific community (Cirés et al., 2017; Zanchett and Oliveira-Filho, 2013).

Recent studies on cyanotoxins have highlighted the importance of understanding their presence in agricultural lands since a significant fraction of global freshwater is potentially contaminated and utilized for agricultural practices (Lee et al., 2021). The primary portal of releasing cyanotoxins to the soil is using water contaminated with cyanotoxins or cyanotoxin-producing cyanobacteria for agricultural purposes as a fertilizer (Bouaïcha and Corbel, 2016; Corbel et al., 2014a, 2014b; Machado et al., 2017; Mohamed et al., 2022). The persistence of cyanotoxins in agricultural lands can lead to severe concerns due to their

* Corresponding author. Faculty of Applied Sciences, University of Sri Jayewardenepura, Nugegoda, 10250, Sri Lanka.
** Corresponding author. National Institute of Fundamental Studies, Kandy, 20000, Sri Lanka.
E-mail addresses: meththika@sjp.ac.lk (M. Vithanage), dhammika.ma@nifs.ac.lk (D. Magana-Arachchi).

https://doi.org/10.1016/j.toxicon.2022.03.003
Received 2 December 2021; Received in revised form 3 March 2022; Accepted 7 March 2022
Available online 11 March 2022
0041-0101/