Botany and Plant Pathology, Oregon State University

Cyanobacteria – an Underappreciated Threat to Agriculture?

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Cyanobacterial toxins can poison plants

Surface waters across the entire U.S. are experiencing increased occurrence of potentially toxic cyanobacterial blooms. Cyanobacteria, or blue-green algae, are photosynthetic bacteria that are common in all freshwater systems. Many are benign, but a number found in the U.S. produce toxins that can damage plants and affect human health.

Common toxin producers are in the genera *Microcystis*, *Anabaena*, *Aphanizomenon*, *Lyngbya*, *Nodularia*, *Planktothrix*, *Nostoc*, and *Cylindrospermopsis*. The toxin microcysyin-LR is one of many toxins (there are 95 analogs of microcystin alone) produced by cyanobacteria. Much of the current research focuses on this compound because it is widespread, produced by many species of cyanobacteria and is hydrophobic under certain conditions. This may allow microcystin-LR to diffuse across cell membranes, but the exact mechanism of uptake is not known.

Microcystin is a potent inhibitor of protein phosphatases in both animals and plants. Protein phosphatases are key regulatory enzymes that catalyze de-phosphorylation of serine/threonine residues in phosphoproteins. In plants, these enzymes regulate important processes such as ion channel activity, carbon and nitrogen metabolism, tissue development and photosynthesis.

Seedlings can take up microcystin, resulting in inhibitory effects on development, root growth and photosynthesis (**Figure 1**). Necrotic lesions on leaves are also observed and likely due to microcystin induced oxidative stress.

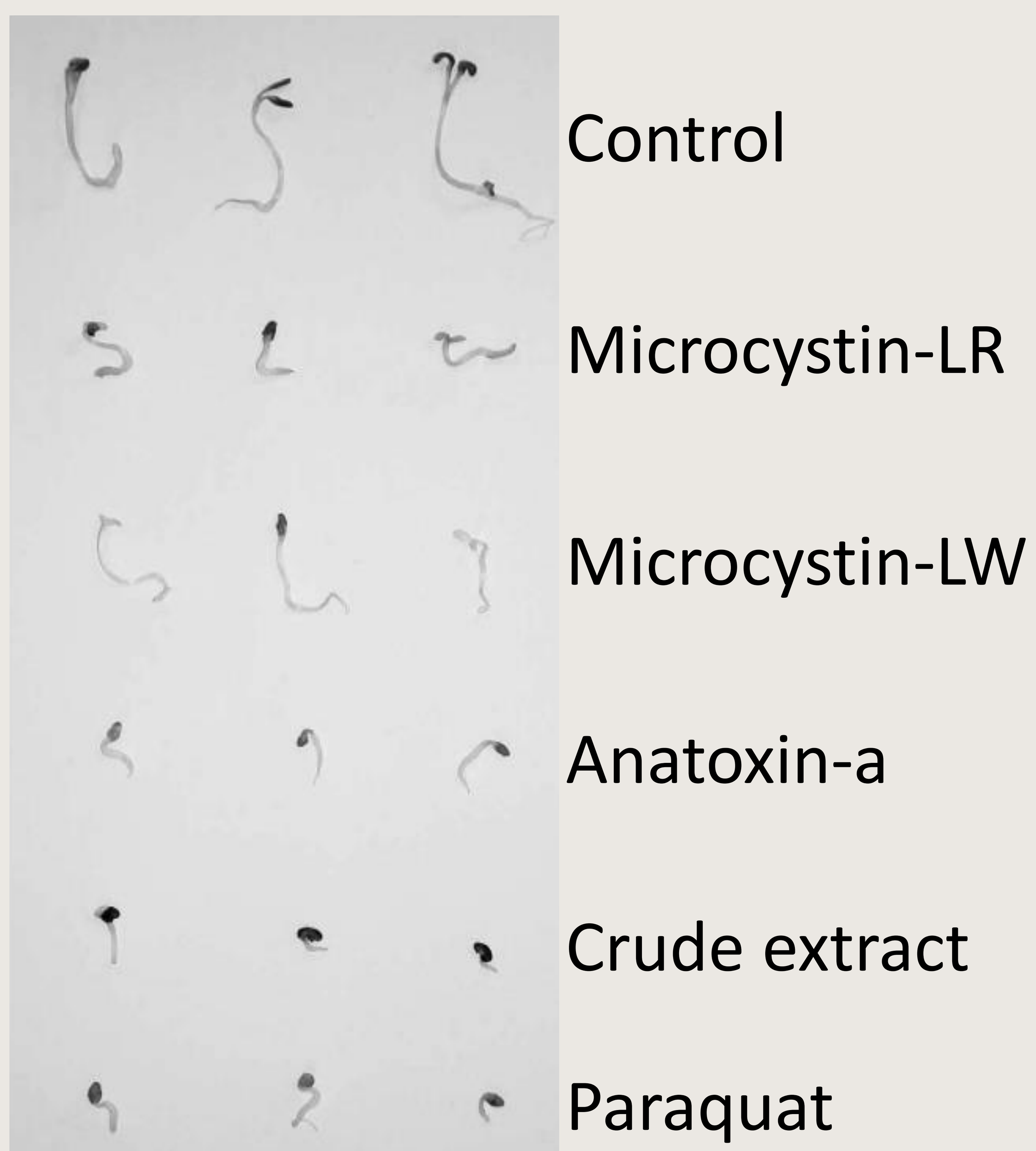

Figure 1. Effect of Cyanobacterial toxins on alfalfa growth. 5.0 μg L^{-1} of cyanobacterial toxins (microcystin-LR [MC-LR], microcystin-LW [MS-LW], and anatoxin-a), cell-free cyanobacterial crude extract, and the herbicide paraquat (positive control) [1].

An unexplained pathology

A processor in western Oregon contacted OSU in 2008 with the concern of unhealthy crops. We visited the farm, near Gaston, and found that several crops (red beets, blackcap raspberries, and cauliflower) as well as weeds and grasses were exhibiting severe stunting and leaf chlorosis. A preliminary examination of plants in the field did not indicate root rot, vascular wilt, insect injury, or herbicide injury; the exception was clubroot in some of the cauliflower. Plant samples were collected for further examination.

A toxic cyanobacterial bloom detected

The Tualatin River near Gaston is partly fed by the diked Wapato Lake, which is normally drained before summer, but in 2008 had been kept diked longer to allow work on dam infrastructure. A cyanobacterial bloom developed as summer temperatures rose. During a July storm, a dike failed on the lake, releasing cyanobacteria-laden waters into the river, causing a fish kill. Crop damage was noted shortly after irrigation water was pulled from the river during the cyanobacterial release and fish kill. Subsequent to the release, cyanobacterial toxins were detected downstream (**Figure 2**).

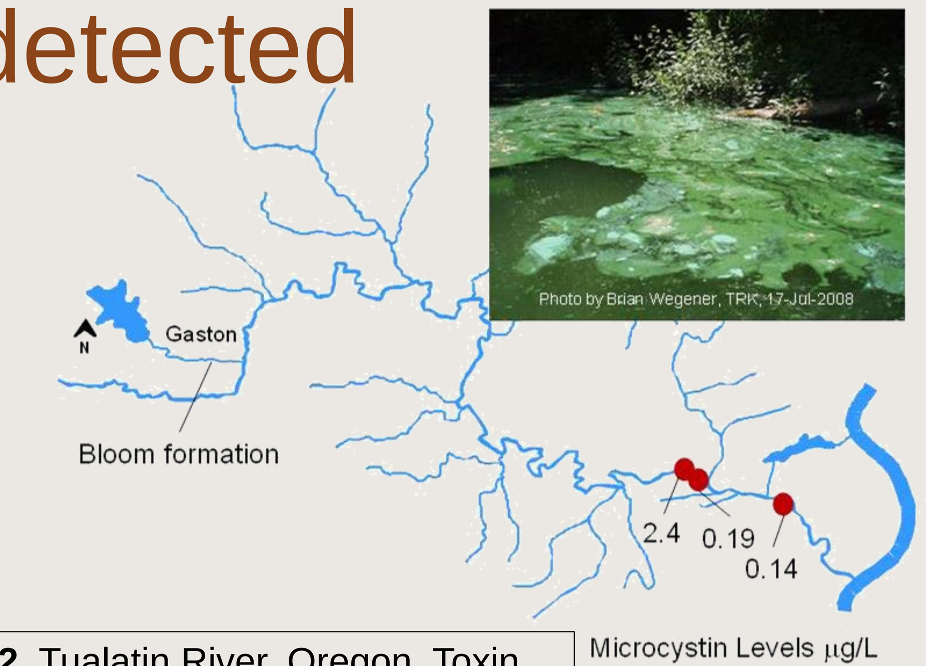

Figure 2. Tualatin River, Oregon. Toxin measures provided by Stewart Rounds and Kurt Carpenter. United States Geological Survey, Portland, OR.

Forensics

Figure 3. Blackcap raspberry plants from a field irrigated from Wapato Lake. Undersides of the leaves showed veinal necrosis, suggesting uptake of a toxic substance. Field history did not indicate herbicide injury as a possibility. Affected plants did not fruit.

Figure 4. Beets irrigated with Tualatin River water were half the size of those irrigated from other sources. Symptoms were non-specific and indicative of stress. The possibility of fungal, bacterial, viral, and herbicide etiology were eliminated by testing and field history.

Cyanobacterial toxins detected in crops

From affected crops (cauliflower, beets, blackcap raspberries), we collected 12 tissue and 7 soil samples. Control plant tissues were also collected from nearby fields that were not irrigated with Tualatin River water. All control tissues tested negative for the presence of microcystin-LR. A single blackcap raspberry tissue sample was found to have 38 ng/g microcystin-LR. At this toxin load, 2 oz. of plant material would exceed the consumption limit.

A look into the literature

To date, 15 common crops have been examined in the laboratory for accumulation of microcystin-LR [2,3]. Crop plants have been observed to accumulate toxin in shoots and roots to levels such that consumption of even a small amount of plant material (0.7 - 9 ounces) would exceed the WHO recommended consumption limit.

Cyanobacterial toxins can accumulate in crop plants, resulting in injury and yield loss; human health may be affected. Impacts of field crop exposure to cyanotoxins in irrigation water are unknown.

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References

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[3] Peuthert, A., S. Chakrabarti, and S. Pflugmacher, Uptake of Microcystins-LR and -LF (cyanobacterial toxins) in seedlings of several important agricultural plant species and the correlation with cellular damage (lipid peroxidation). Environmental Toxicology, 2007. **22**:436-442.

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WPDN Western Plant Diagnostic Network

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