



# Regulation of photosynthetic physiology in *Arthrospira* under light and nutrient stresses: from photoinhibition to metabolic acclimation

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## Interaction between light and nutrient stresses: integrated

Nutrient status critically influences the susceptibility of *Arthrospira* to photoinhibition. Nitrogen limited cells, characterized by reduced phycobilisome content and lower carbon assimilation capacity, often exhibit heightened sensitivity to high light stress (Ghafarizadeh & Madadkar Haghjou, 2024; Milia et al., 2022). Similarly, phosphorus limitation restricts ATP synthesis, thereby limiting the capacity for carbon fixation and downstream metabolism. Under such conditions, even moderate light intensities can induce photoinhibitory effects due to impaired coupling between light reactions and metabolic utilization (Markou et al., 2012). Iron limitation further compounds light stress by directly reducing electron transport capacity, increasing the likelihood of over-reduction and reactive oxygen species formation. These observations underscore that photoinhibition in *Arthrospira* is not solely a function of light intensity but is strongly modulated by nutrient dependent metabolic constraints (Jiang et al., 2020; Markou et al., 2012). Under high light and nutrient limitation, carbon flux is often redirected away from growth-associated pathways toward the accumulation of storage compounds, reflecting a shift in cellular priorities from proliferation to survival (Markou et al., 2012).

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## Abstract

*Arthrospira (Spirulina)*, a filamentous cyanobacterium, exhibits remarkable photosynthetic plasticity that enables survival under fluctuating light and nutrient conditions. This review synthesizes current knowledge on the physiological and metabolic regulation of photosynthesis in *Arthrospira* under light and nutrient stresses, highlighting mechanisms of short-term photoprotection, long-term metabolic acclimation, and the integration of multiple environmental signals. The interplay between nitrogen, phosphorus, and iron availability with photochemical processes is discussed, emphasizing the coordinated adjustment of photosystem stoichiometry, antenna size, and carbon metabolism.

## Introduction

The photosynthetic apparatus of *Arthrospira*, characterized by unstacked thylakoid membranes and phycobilisome antenna complexes, enables rapid acclimation to changes in irradiance and nutrient availability through coordinated photochemical, biochemical, and metabolic regulation (Ghafarizadeh & Madadkar Haghjou, 2024). Light acts both as an energy source and a stress factor, as excessive irradiance can induce photoinhibition via oxidative damage to photosystem II, while nutrient availability particularly nitrogen, phosphorus, and iron constrains the synthesis and maintenance of photosynthetic components (Jiang et al., 2020; Markou et al., 2012). This review synthesizes current knowledge on the regulation of photosynthetic physiology in *Arthrospira* under light and nutrient stress, with emphasis on the continuum from short-term photoinhibitory responses to long-term metabolic acclimation, and identifies key regulatory principles and existing knowledge gaps relevant to cyanobacterial photosynthesis.

## Photosynthetic responses of *Arthrospira* to light stress and photoinhibition

Light absorption in *Arthrospira* is primarily mediated by phycobilisomes, large supramolecular antenna complexes attached to the stromal surface of thylakoid membranes (Milia et al., 2022). Photoinhibition primarily affects photosystem II (PSII) and is associated with damage to the D1 protein of the PSII reaction center. Quantitative indicators of photoinhibition, particularly the maximum quantum yield of PSII (Fv/Fm), accurately assess photodynamic performance under light and nutrient conditions. A decline in Fv/Fm is a well-established marker of PSII damage and photoinhibitory stress in *Arthrospira*. Similar responses have been reported previously under high irradiance conditions (Milia et al., 2022; Jiang et al., 2020; Markou et al., 2012). The over-reduction of the photosynthetic electron transport chain under excessive irradiance enhances the formation of reactive oxygen species, which further exacerbate damage to photosynthetic components (Ghafarizadeh et al., 2017; Ghafarizadeh et al., 2016).