International Journal of Engineering Technology and Applied Science
(ISSN: 2395 3853), Vol. 11 Issue 12 December 2025

Effects of Osmotic Stress on Growth, Photosynthesis, and Pigment Composition in the cyanobacterium *Nostoc muscorum*

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ABSTRACT

Aim: To investigate the effects of osmotic stress induced by sodium chloride (NaCl) on growth, photosynthetic efficiency, and pigment composition of the cyanobacterium *Nostoc muscorum*.

Methodology: Exponentially growing cultures of *Nostoc muscorum* were exposed to different concentrations of NaCl (0, 50, 100 and 150 mM). Growth was measured through optical density and specific growth rate. Photosynthetic oxygen evolution was determined using a Clark-type oxygen electrode. Chlorophyll-a, carotenoids and phycobiliproteins were estimated spectrophotometrically. Statistical analysis was performed using one-way ANOVA at $p<0.05$.

Results: Increasing osmotic stress significantly reduced growth, photosynthetic oxygen evolution and pigment content. Cultures exposed to 150 mM NaCl showed a reduction of 62.8% in growth and 58.4% in photosynthetic oxygen evolution compared with controls. Chlorophyll-a, phycocyanin and allophycocyanin contents declined significantly under severe osmotic stress. However, carotenoid content increased moderately, indicating activation of photoprotective mechanisms.

Conclusion: Osmotic stress adversely affects physiological and photosynthetic performance of *Nostoc muscorum*. Reduction in pigment composition and photosynthetic activity suggests impairment of the photosynthetic apparatus. Enhanced carotenoid accumulation appears to provide protective adaptation against osmotic stress-induced oxidative damage.

Keywords: *Nostoc muscorum, osmotic stress, salinity, photosynthesis, chlorophyll-a, phycobiliproteins, cyanobacteria.*

1. INTRODUCTION

Cyanobacteria are oxygenic photosynthetic prokaryotes capable of surviving in diverse environmental conditions. Among them, *Nostoc muscorum* is a filamentous nitrogen-fixing cyanobacterium that contributes significantly to ecosystem productivity and soil fertility. Environmental stresses such as salinity, drought, and osmotic imbalance are major constraints affecting cyanobacterial growth and metabolism.

Osmotic stress results from reduced water availability caused by elevated concentrations of dissolved salts. Excessive salinity leads to cellular dehydration, ionic toxicity, pigment degradation and inhibition of photosynthesis. Cyanobacteria respond to osmotic stress through physiological and biochemical adaptations including synthesis of compatible solutes, modulation of membrane composition and antioxidant defense mechanisms.

Photosynthetic pigments such as chlorophyll-a, phycocyanin, phycoerythrin and allophycocyanin are particularly sensitive to osmotic stress. Alterations in pigment composition directly affect photosynthetic efficiency and cellular productivity. Understanding these responses is essential for developing stress-tolerant cyanobacterial strains suitable for agricultural and biotechnological applications.

Therefore, the present investigation was undertaken to evaluate the effects of osmotic stress on growth, photosynthetic activity and pigment composition in *Nostoc muscorum*.

2. MATERIALS AND METHODS

Organism and Culture Conditions: *Nostoc muscorum* cultures were maintained in Chu No. 10 medium under controlled laboratory conditions at:

- Temperature: 28 ± 2°C
- Light intensity: 50 µmol photons m^{-2} s^{-1}
- Photoperiod: 16 h light : 8 h dark

Experimental Design: Four treatments were established:

Treatment	NaCl Concentration
Control	0 mM
T1	50 mM
T2	100 mM
T3	150 mM

Cultures were incubated for 12 days.

Growth Measurement: Growth was estimated by measuring optical density at 663 nm.
Specific Growth Rate:
$K = 2.303\ (\log N_2 - \log N_1)/(T_2 - T_1)$

Photosynthetic Oxygen Evolution: Photosynthetic oxygen evolution was measured using a Clark-type oxygen electrode and expressed as µmol O_2 evolved g^{-1} Chl-a h^{-1}.

Pigment Analysis:
Chlorophyll-a: Estimated according to methanol extraction method.
Carotenoids: Measured spectrophotometrically at 480 nm.
Phycobiliproteins

- Phycocyanin (PC)
- Allophycocyanin (APC)
- Phycoerythrin (PE)

were estimated according to standard cyanobacterial protocols.

2.6 Statistical Analysis

Data were analyzed using one-way ANOVA followed by Tukey's multiple comparison test. Values are expressed as Mean ± SEM.

3. RESULTS

Table 1. Effect of Osmotic Stress on Growth Characteristics of *Nostoc muscorum*

NaCl (mM)	Growth (OD663)	Specific Growth Rate
0	0.85 ± 0.03	0.79 ± 0.02
50	0.66 ± 0.02	0.61 ± 0.02
100	0.48 ± 0.02	0.43 ± 0.01
150	0.32 ± 0.01	0.27 ± 0.01

Growth progressively declined with increasing NaCl concentration.

Table 2. Effect of Osmotic Stress on Photosynthetic Oxygen Evolution

NaCl (mM)	Photosynthetic O_2 Evolution (μmol O_2 g^{-1} Chl-a h^{-1})
0	562 ± 18
50	468 ± 16
100	352 ± 12
150	234 ± 11

Photosynthetic oxygen evolution decreased significantly under osmotic stress.

Table 3. Effect of Osmotic Stress on Chlorophyll-a and Carotenoid Content

NaCl (mM)	Chlorophyll-a (mg g^{-1} FW)	Carotenoids (mg g^{-1} FW)
0	13.8 ± 0.4	2.8 ± 0.1
50	11.7 ± 0.3	3.1 ± 0.1
100	9.2 ± 0.3	3.4 ± 0.2
150	6.4 ± 0.2	3.8 ± 0.2

Chlorophyll content decreased whereas carotenoid content increased under stress.

Table 4. Effect of Osmotic Stress on Phycobiliprotein Composition

NaCl (mM)	Phycocyanin	Allophycocyanin	Phycoerythrin
0	9.5 ± 0.3	5.8 ± 0.2	3.7 ± 0.1
50	7.8 ± 0.2	4.9 ± 0.2	3.1 ± 0.1
100	5.6 ± 0.2	3.8 ± 0.1	2.5 ± 0.1
150	3.4 ± 0.1	2.3 ± 0.1	1.6 ± 0.1

All phycobiliproteins declined significantly with increasing osmotic stress.

4. DISCUSSION

The present study demonstrates that osmotic stress severely affects growth and photosynthetic performance of *Nostoc muscorum*. Reduced growth observed under NaCl treatment may be attributed to cellular dehydration, reduced nutrient uptake and disruption of metabolic processes.

The decline in photosynthetic oxygen evolution indicates damage to photosystem II and reduced electron transport efficiency. Similar observations have been reported in several cyanobacterial species subjected to salinity stress.

Chlorophyll-a degradation under osmotic stress suggests destabilization of pigment-protein complexes and impairment of light harvesting efficiency. The reduction in phycobiliproteins further indicates disassembly of phycobilisomes, a common adaptive response to environmental stress.

Interestingly, carotenoid accumulation increased with rising salinity. Carotenoids function as antioxidants and protect photosynthetic membranes from oxidative damage by scavenging reactive oxygen species generated during stress.

These findings indicate that osmotic stress influences multiple physiological processes simultaneously and ultimately affect productivity and survival of *Nostoc muscorum*.

5. CONCLUSION

Osmotic stress induced by NaCl significantly inhibits growth, photosynthetic oxygen evolution and pigment synthesis in *Nostoc muscorum*. The reduction in chlorophyll-a and phycobiliproteins reflects impairment of the photosynthetic machinery. Increased carotenoid accumulation represents a protective response against oxidative damage. These observations contribute to understanding stress adaptation mechanisms in cyanobacteria and may assist in developing salt-tolerant strains for agricultural and environmental applications.

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