Bangladesh J. Bot. **54**(4): 885-890, 2025 (December) DOI: https://doi.org/10.3329/bjb.v54i4.86560

LYNGBYA HELMETICA AZIZ A. SP. NOV. AND *SCYTONEMA SIMMERI* SCHMIDLE A NEW RECORD (CYANOBACTERIA) FROM BANGLADESH, AND THEIR POSSIBLE USES AS MEDICINES AND SUN SCREEN CREAM

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Keywords: *Lyngbya helmetica* Aziz sp. nov., *Scytonema simmeri* Schmidle, New record, UV-rays, Biosensors, Survivability, Medicines, Skin Protecting Cream, Cyanobacteria

Abstract

Lyngbya helmetica Aziz sp. nov. and *Scytonema simmeri* Schmidle a new record from an exposed south facing yellow painted wall under intense solar radiation (≈950 µE m^{-2} s^{-1}), ultraviolet exposer, high temperature (≈35° C), and severe desiccation, in Teknaf, Cox's Bazar, Bangladesh, Both the taxa formed dark compact patches composed of narrow filaments enriched with sheath-associated pigments, in addition to scytonemin and granular vermilion around the trichome. In *L. helmetica*, degradation of terminal trichome cells produced electrochemical biosensors those causes extensions of both outer and inner sheath tip interiorly forming outer and inner 'helmet' like protective structures retaining all the pigments inside. *S. simmeri* exhibited comparable protective responses through closing the sheath opening. UV rays and heat disrupt heterocyst–trichome connections. Microscopic observations indicate that sheath modification and pigment impregnation are key morphological adaptations facilitating survival on the desiccated wall. This study provides the formal description of *L. helmetica* sp nov., reports *S. simmeri* as a new record for Bangladesh, and documented stress induced sheath adaptations through electrochemical biosensors in cyanobacteria.

Introduction

Cyanobacteria comprise a diverse group of prokaryotic photoautotrophs occupying aquatic and terrestrial habitats worldwide (Desikachary 1959, Starmach 1966, Lee 2008). A common feature across these forms is the presence of a protective mucilaginous sheath, often containing small amounts of cellulose, which surrounds the trichomes (Aziz and Mohid 2020, Nobles *et al.* 2001). This sheath is integral to survival in extreme conditions, providing defense against desiccation, high irradiance, and particularly, ultraviolet (UV) radiation (Karsten *et al.* 1998). A key component in this protective strategy is the pigment scytonemin, a 544 Da hydrophobic compound that surrounds trichome and also impregnated in the sheath, often imparting a characteristic brown to black coloration of stressed filaments induced by electrochemical biosensors (Marlinda *et al.* 2025, Muehlstein and Castenholtz 1983,).

Scytonemin is highly stable and performs efficient UV-A and UV-B screening without requiring continuous metabolic investment (Muehlstein and Castenholtz 1983), Beyond its primary photoprotective role, it also exhibits significant radical scavenging and antioxidant activity, preventing cellular damage (Rastogi and Incharoensakdi 2014). Its synthesis is markedly enhanced under combined stressors such as high temperature and UV radiation (Gracia-Pachel and Castenholz 1998, Aziz 2018), and similar adaptive morphogenesis, like calyptra formation in *Trichodesmium erythraeum*, has been reported as a protective measure (Aziz and Mohid 2020). Optimal production conditions, including high temperature, strong light, and specific photoperiods, have been established for organisms like *Nostoc commune* (Takamatsu *et al.*1983). The bio-technological potential of scytonemin is considerable; its stability and water solubility

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under direct sunlight and elevated temperatures (Fleming and Kastenholz 2007, Aziz 2018) make it an attractive, cost-effective candidate for commercial applications such as antioxidant/ antiinflammatory medicines and sun skin cream, especially as it can constitute over 5% of cyanobacterial dry weight in culture (Rastogi and Incharoensakdi 2014, Aziz 2018).

Bangladesh harbors a rich but still incompletely documented cyanobacterial flora, particularly in extreme microhabitats like coastal structures subjected to intense solar and thermal stress. The morphological plasticity of the sheath is a critical survival mechanism in these environments. This study documents two filamentous cyanobacteria from the coastal region of Teknaf, Cox's Bazar, growing under such extreme stresses. The objectives of this study were to morphologically describe a novel species, *Lyngbya helmetica* Aziz sp. nov., to report the first occurrence of *Scytonema simmeri* Schmidle in Bangladesh, and to examine the sheath-based morphological adaptations employed by both taxa as a response to severe environmental conditions.

Materials and Methods

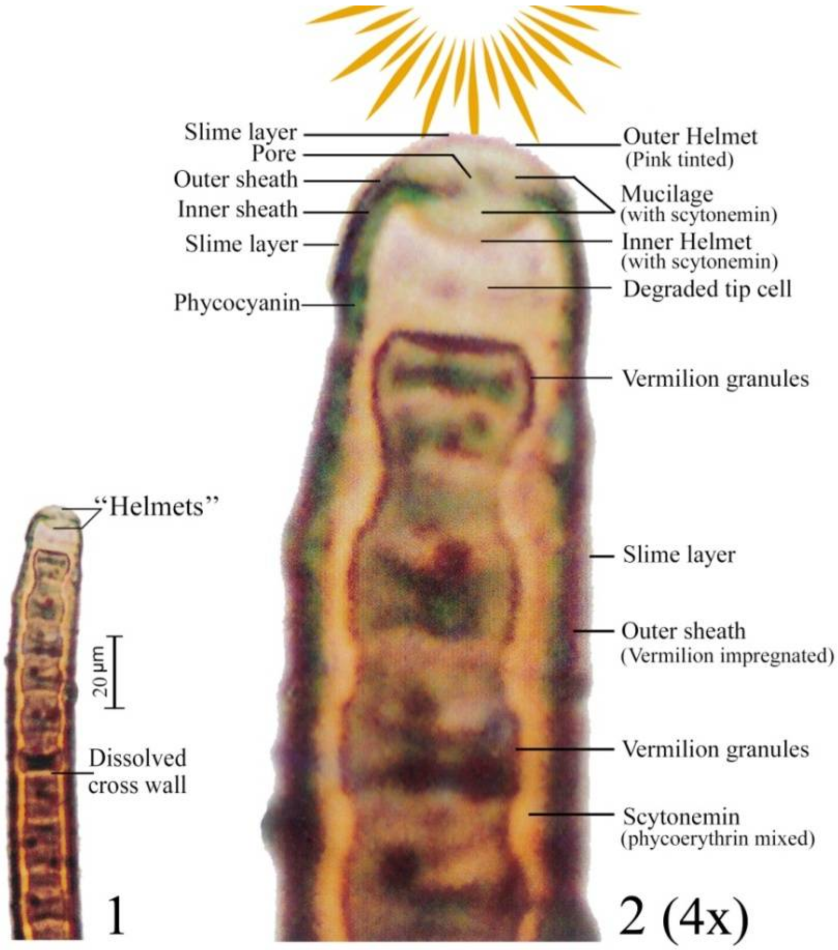
Samples were collected from a south-facing yellow-painted boundary wall in Teknaf, Cox's Bazar, Bangladesh (Tropical zone: 20° 44′ 45″ N, 92° 20′ 15″ E). The site was exposed to intense midday sunlight with photosynthetically active radiation of approximately 950 µE m^{-2} s^{-1}, accompanied by ultraviolet radiation and ambient temperatures around 35° C during mid-March.

Black patches of filamentous cyanobacteria were carefully scraped from the wall surface, transferred to clean containers, and preserved in 4% formaldehyde. Temporary and permanent slides were prepared and studied using standard microscopic techniques. Morphological measurements were conducted using a Nikon light microscope at 450× magnification, and photomicrographs were taken for documentation.

Results and Discussion

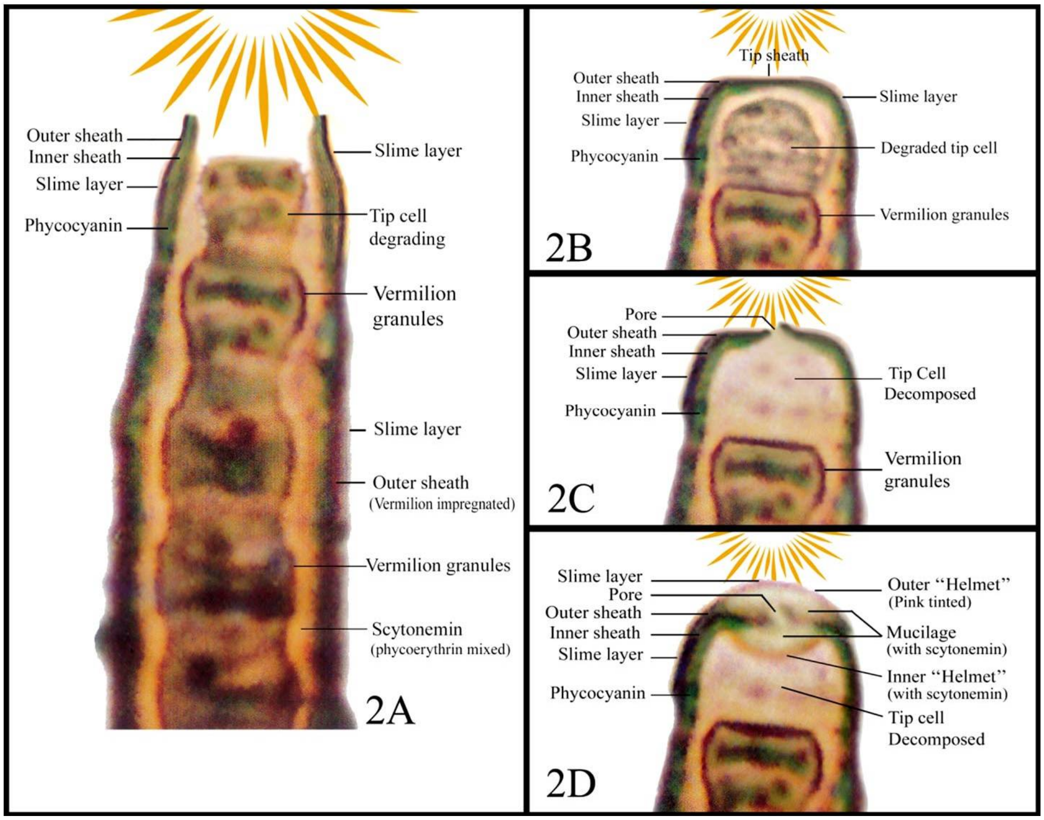
The newly described species *Lyngbya helmetica* Aziz A. sp. nov. was found forming narrow, dark red to black filaments firmly attached to a desiccated wall surface. A representative fragment measured 127 µm in length and 18-20 µm in breadth, featuring a distinctive two-layered sheath where the outer layer was uneven and covered by a 1 µm thick protective slime layer (Figs 1-2). The enclosed trichome was 5-6 µm broad, with cells 8 µm long, yielding a trichome-to-sheath ratio of 1.69:1. The most novel morphological adaptation was the formation of a terminal, outer and inner 'helmets' following the degradation of apical cells under extreme stress from high sunlight (950 µmol m^{-2} s^{-1}), UV-A/B radiation, and temperatures above 35° C. This structure, consisting of an outer 'helmet' (4.13 µm thick at the base, circumference 43.0 µm) and a slightly smaller inner 'helmet' (4.9 µm thick at the base, circumference 31.4 µm), functions as a specialized mechanism to seal the filament apex and retain the photo-protective pigment scytonemin (Figs 1-2).

The morphogenesis of the helmet is a complex, programmed survival response. An animated sequence illustrates the process where a degraded terminal cell within an open sheath induces the inward bending and fusion of sheath layers to form a sealed cap (Figs 2A-2D). Subsequent decomposition of the enclosed cell creates internal pressure, rupturing the sheath tip to form a central pore (Fig. 2C). This precise morphogenesis is mediated by electrochemical biosensors within the degraded cell, which generate specific signals (Signal No. 1 and No. 2), those react selectively with the outer and inner sheath layers, to form the outer and inner 'helmets' respectively, showcasing a highly specific biological response to environmental cues (Marlinda *et al.* 2025, Figs 2A-D).



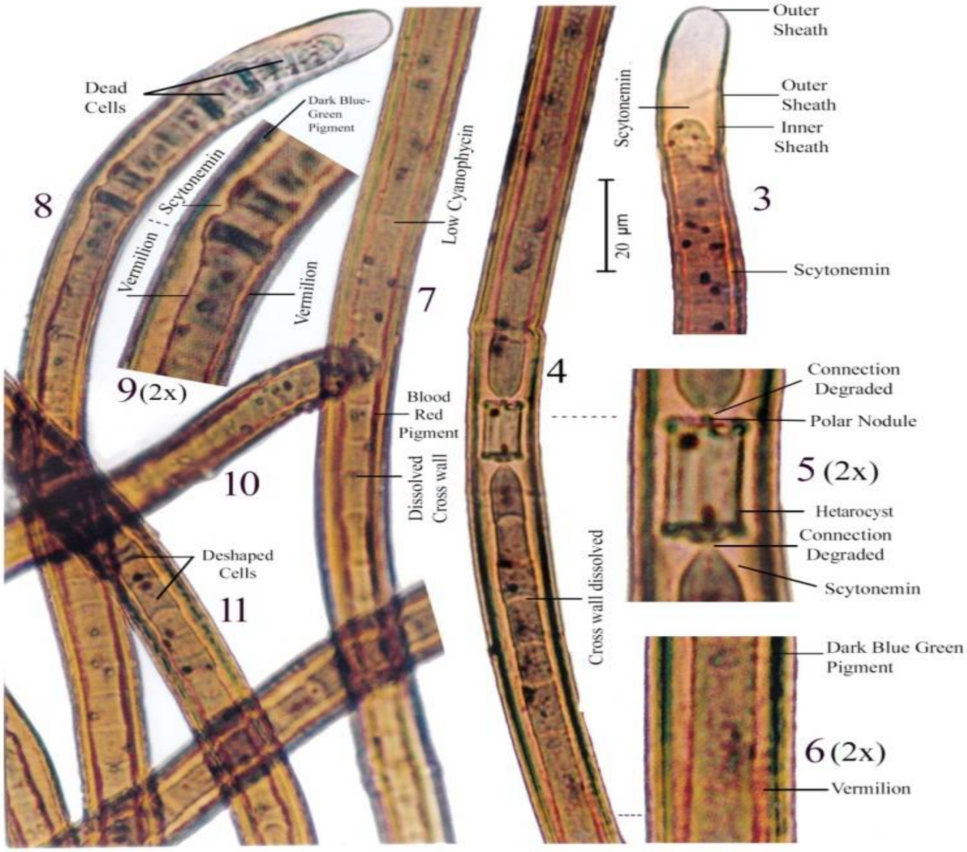
Figs 1-2. *Lyngbya helmetica* Aziz A. sp. nov. 1: A fragment of filament showing a trichome surrounded by scytonemin and thick sheath; empty space of dissolved tip cell, followed by 4 degraded cells and dissolution of partition walls behind. 2: Anterior part enlarged showing details of trichome with huge pigments of several types, and terminal outer and inner 'helmets' and pigmentation under sunlight.

Co-occurring with *L. helmetica* was *Scytonema simmeri* Schmidle, with filaments 2.5-3.0 cm long and 23-25 µm broad, and a trichome-to-sheath ratio of 2.26:1 (Figs 3-11). Under the same stressed environment, *S. simmeri* exhibited clear stress-induced anomalies. These included terminal sheath closure analogous to *L. helmetica* (Figs 3, 8), mid-filament trichome degradation evidenced by cross-wall dissolution and fading (Figs 4, 7-8, 11), and critically, the dissolution of connections between heterocysts and vegetative cells (Fig. 5). This heterocyst disruption likely leads to the cessation of nitrogen fixation, inducing nitrogen deficiency. The protective role of sheath pigments was confirmed by the observation that filament tips remained undamaged when shielded by an overlying filament (Fig. 10) but were degraded when fully exposed (Fig. 7), directly linking the damage to UV radiation and heat.



Figs 2A-D: Showing animation of changes that occurred at different stages. 2A: Degraded tip cell surrounded by open sheath. 2B: Terminal sheath layers bended inwardly and joined end to end forming a sheath layer, closing the tip. 2C: Degraded tip cell decomposed, that created enormous pressure from inside on the tip sheath that breaks down the tip sheath in the centre forming a pore. Scytonemin pigment also released. 2D: Outer and inner 'helmets' are formed induced by two electrochemical biosensors, where one of the biosensor formed outer 'helmet' using outer sheath layer, and another biosensor formed inner 'helmet" using inner sheath layer, thus completely protected the tip of the filament from harsh environment and release of scytonemin.

The morphological adaptations observed in both species, including thickened and pigmented sheaths as well as terminal closures, along with the unique 'helmet' formation in *L. helmetica*, represent convergent strategies that are critical for persistence in extreme, exposed habitats. The significant scytonemin content in both organisms indicated by the heavily pigmented sheaths and the additional vermilion granules in *L. helmetica*, highlights their substantial biotechnological potential. Scytonemin is an UV-absorbing pigment with proven antioxidant and anti-inflammatory properties (Rastogi and Incharoensakdi 2014, Aziz 2018). Natural release of scytonemin from *L. helmetica* upon drying and the nitrogen-fixing capability of *S. simmeri*, which could reduce cultivation costs, make these species promising candidates for the commercial-scale production of 'Sun Skin Cream' and Antioxidant/Anti-inflammatory Capsules. This demonstrates how sophisticated environmental sensing and morphological adaptation in cyanobacteria can directly inform and enable their development as sustainable sources of high-value bioproducts.



Figs 3-11. *Scytonema simmeri* Schmidle showing various under stressed environment.

This study documents a new cyanobacterial species, *Lyngbya helmetica* Aziz sp. nov., and reports *Scytonema simmeri* Schmidle for the first time from Bangladesh. Both taxa exhibit pronounced sheath-based morphological adaptations that facilitate survival under extreme solar and thermal stresses. These findings contribute to the understanding of cyanobacterial diversity and stress tolerance in exposed terrestrial habitats of Bangladesh, and possible uses of whole organisms as Antioxidant and Antiinflammatory medicines and preparing Sun screen cream.

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(Manuscript received on 30 October, 2025; revised on 06 December, 2025)