PHYSIOLOGICAL AND BIOCHEMICAL ASSESSMENT OF SISTANCHE SPECIES DISTRIBUTED IN THE DESERT ZONES OF THE KHOREZM REGION

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ABSTRACT

This study investigates the physiological and biochemical characteristics of Sistanche species naturally distributed in the desert zones of the Khorezm region. The plant, known for its parasitic lifestyle and its association with desert hosts such as Haloxylon, Tamarix, and Atriplex, demonstrates remarkable tolerance to extreme aridity and high soil salinity. Field samples collected from various ecological habitats were analyzed for morphological traits, water-retention capacity, pigment composition, ion homeostasis, and key biochemical markers including proline, phenolic compounds, and antioxidant activity. The findings reveal that Sistanche possesses a highly integrated system of stress adaptation involving osmotic regulation, selective ion management, and elevated synthesis of protective metabolites. This highlights the plant's ecological resilience as well as its significant potential as a valuable source of medicinally important bioactive compounds.

The desert landscapes of the Khorezm region represent one of the harshest ecological environments of Central Asia, characterized by extreme temperature fluctuations, intense solar radiation, minimal annual precipitation, and highly saline sandy soils [1]. These conditions impose severe physiological stress on the local vegetation, limiting plant diversity to only those species possessing highly specialized adaptive mechanisms. One of the most distinctive representatives of this flora is *Sistanche*, a chlorophyll-lacking parasitic plant from the family Orobanchaceae, which attaches to the roots of xerophytic hosts such as *Haloxylon*, *Tamarix*, and *Atriplex* [2]. Its unique lifestyle, remarkable environmental tolerance, and rich chemical composition have attracted increasing scientific interest, particularly regarding its ecological role in arid ecosystems and its growing value as a medicinal resource [3].

Field investigations were conducted in various desert habitats across Khorezm, including the highly saline sands of Qo'ng'irot, the semi-saline arid substrates of Hazorasp, and the extensive dunes of Shovot–Gurlan. These areas differ in groundwater depth, soil salinity, and microclimatic conditions, allowing a broad examination of the plant's adaptive responses. Samples were collected during the peak vegetative season in

May–June, when *Sistanche* produces its prominent fleshy flowering stalks. Morphological parameters such as stem length, diameter, biomass, and reproductive intensity were documented, along with physiological measurements including relative water content (RWC), pigment concentrations, carotenoid levels, and ionic composition involving sodium and potassium. Biochemical analyses focused on proline accumulation following the Bates method [8], phenolic content assessed through the Folin–Ciocalteu assay, antioxidant activity via the DPPH method, and soluble protein quantification using the Bradford protocol.

The plant demonstrated clear morphological adaptations to the environmental stresses of the region. Samples from highly saline soils often exhibited reduced stem length, a strategy interpreted as a conservative response to limited water availability and osmotic stress [4]. Nevertheless, despite reductions in vegetative growth, reproductive development remained consistently high. This indicates a survival strategy in which the plant prioritizes rapid reproduction to ensure successful propagation in environments where mortality risks are elevated due to drought, shifting sands, and salinity. Such reproductive persistence is typical of many desert parasitic plants that must complete their life cycle quickly in response to unpredictable environmental conditions.

Physiological analyses revealed that *Sistanche* maintains moderate relative water content under drought, with values reflecting the ability of its tissues to retain moisture even in extremely arid conditions [5]. Although lacking chlorophyll, the plant benefits indirectly from the photosynthetic activity of its hosts, yet still synthesizes carotenoids and other pigments involved in protective processes. Elevated carotenoid levels serve to mitigate oxidative stress by neutralizing reactive oxygen species generated under desert temperatures and radiation [6].

Ion homeostasis is one of the plant's most significant adaptive mechanisms. The accumulation of sodium in tissues increased substantially in samples from more saline sites, while the potassium-to-sodium ratio consistently declined. This shift indicates that *Sistanche* employs a halophytic-like ion regulatory mechanism, selectively compartmentalizing sodium to avoid cytotoxic effects and maintaining essential ionic balance for metabolic function [7]. Such strategies are vital for survival in the saline desert soils characteristic of Khorezm.

Biochemical markers provided further insight into the plant's stress-adaptation strategies. Proline concentrations were notably high, supporting its function as an osmoprotectant that stabilizes proteins and membranes under drought and salinity stress [8]. Proline also serves as a major antioxidant molecule, contributing to the cellular defense system of the plant. Phenolic compounds were present in high concentrations, consistent with their known roles in scavenging free radicals, reinforcing cell wall structures, and participating in signaling pathways associated with stress tolerance [9]. The strong antioxidant activity detected through DPPH assays reflects the protective capacity of these metabolites. Low levels of soluble proteins correspond to the plant's parasitic nature, relying primarily on host-derived nutrients for its metabolic needs [10].

Beyond ecological resilience, *Sistanche* holds considerable medicinal importance. Its stems contain a rich array of phenylethanoid glycosides, including echinacoside and acteoside, which are widely recognized for their antioxidant, anti-inflammatory, neuroprotective, and immunomodulatory effects [11]. These bioactive compounds have led to the plant's increasing use in traditional medicine and its rising prominence in modern pharmacological research. The species is considered a promising natural resource for developing herbal supplements,

adaptogenic formulations, and antioxidant therapeutics. Its ability to accumulate valuable secondary metabolites even under extreme desert conditions further enhances its biotechnological potential, suggesting that environmental stress may stimulate the synthesis of medicinally important compounds.

The ecological role of *Sistanche* in desert ecosystems is also noteworthy. As a root parasite, it influences the nutrient dynamics of host plants, potentially regulating desert plant community structure. Its flowering stalks provide nectar to specialized desert pollinators, contributing to local biodiversity. Moreover, the species plays an indirect role in stabilizing sand dunes through its association with host shrubs that anchor desert soils, thus supporting the resilience of fragile desert ecosystems.

Taken together, the results of this study provide a comprehensive understanding of the physiological and biochemical strategies employed by *Sistanche* in the extreme desert conditions of the Khorezm region. Its adaptive mechanisms—including osmotic regulation, ion management, antioxidant defense, and reproductive strategies—demonstrate a sophisticated response to aridity and salinity. Coupled with its substantial pharmacological value, these features position *Sistanche* as both an ecologically significant and economically promising plant species. The findings underscore the importance of conserving desert ecosystems and highlight the potential for sustainable utilization of *Sistanche* as a source of natural bioactive compounds.

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