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DEVELOPMENT OF INNOVATIVE TECHNOLOGY FOR PHYTOMELIORATION OF DESERT AREAS BASED ON 6-AMINOPURINE-MODIFIED HYDROGELS

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Abstract: *The study focuses on the development of innovative technology for the phytomelioration of desert areas using 6-aminopurine-modified hydrogels. These hydrogels serve as water-retaining and biologically active materials that enhance plant growth and survival under arid conditions. The synthesis and physicochemical characterization of the modified hydrogels were carried out to determine their swelling capacity, stability, and biodegradability. Experimental trials with Haloxylon aphyllum (saxaul) demonstrated that 6-aminopurine-modified hydrogels significantly improve seed germination, water retention in soil, and drought tolerance. The results indicate the potential of such bioactive materials for restoring vegetation and mitigating desertification. This approach represents a sustainable solution for improving soil fertility and promoting ecological balance in dry ecosystems.*

Keywords: *6-aminopurine, hydrogel, phytomelioration, desertification, saxaul, drought resistance, soil restoration, bioactive polymer.*

Introduction. Desertification is one of the most critical environmental challenges threatening the sustainability of ecosystems, agriculture, and biodiversity worldwide. Large areas of arid and semi-arid lands are experiencing progressive soil degradation, loss of vegetation cover, and reduced water availability. These phenomena are particularly severe in Central Asian regions, including Uzbekistan, where the expansion of desert landscapes such as the Kyzylkum and Karakum deserts and the ecological crisis in the Aral Sea region have led to dramatic ecological and socio-economic consequences. The urgent need to rehabilitate and restore these degraded lands has led to increased interest in phytomelioration — the use of plants to stabilize soils, improve fertility, and restore the natural ecological balance. However, plant establishment and growth in such extreme conditions remain challenging due to high temperatures, poor soil structure, and water scarcity. Therefore, innovative approaches combining plant physiology, chemistry, and materials science are required to enhance plant survival and growth in arid environments. In recent years, the development of smart polymeric materials, such as hydrogels, has offered new opportunities for addressing water scarcity in agriculture and land reclamation. Hydrogels are threedimensional polymeric networks capable of absorbing and retaining large amounts of water while maintaining structural integrity. They can slowly release water and nutrients to plant roots, thereby improving the water-use efficiency and enhancing soil moisture retention. By integrating bioactive compounds with hydrogels, it is possible to create multifunctional systems that not only provide moisture but also stimulate physiological and biochemical processes in plants. One promising approach involves the incorporation of biologically active nitrogen-containing heterocyclic compounds such as 6-aminopurine, commonly known as adenine, which plays a crucial role in plant metabolism as a precursor of cytokinins. 6-Aminopurine is a purine derivative that acts as a plant growth regulator by influencing cell division, differentiation, and morphogenesis. It has been widely studied for its ability to stimulate chlorophyll synthesis, delay senescence, and enhance the growth of roots and shoots. However, the direct application of 6-aminopurine to plants often faces limitations such as rapid degradation, poor solubility, and uncontrolled release, which reduces its long-term effectiveness under field conditions. To overcome these drawbacks, chemical modification and encapsulation of 6-aminopurine into polymeric hydrogels have emerged as promising strategies. The development of hydrogels modified with 6-aminopurine can ensure sustained release of this bioactive compound, provide localized delivery near the root zone, and improve the overall resilience of plants under drought and salinity stress[1-5]. The creation of 6-aminopurine-modified hydrogels involves combining organic synthesis techniques with advanced polymer chemistry. These hydrogels can be synthesized using natural or synthetic polymers such as polyacrylamide, polyvinyl alcohol, or chitosan, which are crosslinked in the presence of 6-aminopurine molecules. The resulting materials exhibit high water-absorption capacity, biocompatibility, and chemical stability, making them suitable for long-term soil application. Moreover, through controlled release mechanisms, the hydrogels can gradually deliver both water and biologically active molecules to plant roots, creating a microenvironment favorable for seed germination and plant establishment. Phytomelioration of desert areas using drought-resistant species such as Haloxylon aphyllum (saxaul) has gained particular attention due to its ecological significance in stabilizing sand dunes, preventing wind erosion, and maintaining soil fertility. Saxaul is a keystone species in Central Asian deserts, playing a vital role in maintaining the ecological equilibrium of these fragile ecosystems. The combination of 6-aminopurine-modified hydrogels with phytomelioration technology introduces a new generation of eco-friendly soil conditioners that simultaneously act as water reservoirs and plant growth stimulators. Such materials can absorb rainfall or irrigation water during wet periods and release it during dry spells, thus reducing the frequency of watering and improving plant water availability. Furthermore, the gradual release of 6-aminopurine enhances cytokinin activity within plant tissues, promoting photosynthesis, nutrient uptake, and cell division. This integrated approach can drastically improve the survival rate of seedlings in desert reclamation projects, making it a sustainable and cost-effective solution for arid land restoration.

Another essential aspect of this technology lies in the environmental safety and biodegradability of the materials used. Hydrogels developed from biocompatible polymers degrade gradually under natural conditions, preventing soil contamination and supporting the long-term health of the ecosystem. Additionally, the use of 6-aminopurine, a naturally occurring purine base, ensures non-toxicity to soil microorganisms and plants, aligning with modern principles of green chemistry and sustainable agriculture.

The development of 6-aminopurine-modified hydrogels as a soil-conditioning and plant-growth-promoting system represents a promising step toward achieving sustainable land management in arid regions. This innovative technology not only addresses the immediate challenges of water scarcity and low plant survival but also sets a foundation for future research in green chemistry, biomaterials, and plant–soil interaction. The integration of chemical synthesis, material engineering, and ecological restoration provides a comprehensive framework for advancing desert agriculture and environmental rehabilitation.

In conclusion, this study seeks to design, synthesize, and evaluate the performance of 6-aminopurine-modified hydrogels for enhancing plant growth and soil improvement in desert areas. By merging biological activity with water-retention capability, the proposed materials are expected to revolutionize phytomelioration practices, enabling efficient, eco-friendly, and resilient land restoration in the world's most challenging ecosystems.

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