Hydrogel-assisted application of 2-amino-6-oxopurine for improving cotton cultivation in saline soils

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Abstract. Soil salinization constrains cotton cultivation in arid and semi-arid regions by reducing water availability, disrupting nutrient uptake, and impairing plant development. This paper examines a proposed guanine (2-amino-6-oxopurine)-loaded hydrogel system for cotton cultivation under saline conditions. The discussion integrates hydrogel chemistry, water retention, guanine immobilization, release kinetics, and plant stress physiology. A factorial experimental design is proposed to compare saline and non-saline soils, unloaded hydrogel, guanine-loaded hydrogel, and free guanine.
Keywords: 2-amino-6-oxopurine; guanine; hydrogel; cotton; saline soil; water retention; salt stress; controlled release.

1. Introduction

Cotton (Gossypium hirsutum L.) is a major agricultural crop in Uzbekistan and other arid regions. Soil salinity restricts crop establishment and growth through osmotic stress, sodium and chloride toxicity, nutrient imbalance, and oxidative injury. Although cotton tolerates moderate salinity, high salt loads can reduce germination, root elongation, photosynthesis, and yield. Hydrogels are three-dimensional hydrophilic polymer networks capable of absorbing water and releasing part of it as the surrounding soil dries. Their agronomic performance depends on polymer chemistry, crosslinking, soil texture, and salinity.

2-Amino-6-oxopurine, commonly called guanine, has amino, carbonyl, and ring nitrogen functionalities capable of hydrogen bonding. These characteristics make it an interesting candidate for incorporation into hydrophilic polymer matrices. Nevertheless, free guanine should not be equated with cytokinin plant growth regulators such as 6-benzylaminopurine. Its biological effect after soil application has not been established. This study proposes a scientific framework to examine whether guanine-loaded hydrogels can influence soil water retention, release characteristics, and cotton performance under salinity.

2. Materials and methods

2.1. Hydrogel preparation. A proposed hydrogel consists of acrylic acid, starch, bentonite, potassium persulfate initiator, and N,N′-methylenebisacrylamide crosslinker. An initial acrylic acid-to-starch ratio of 2:1 may be evaluated, followed by optimization. Guanine can be dispersed within

the polymer matrix; because it has limited water solubility, its loading and homogeneity must be confirmed. Washing is required to reduce residual monomer and other extractables.

2.2. Experimental design. Cotton cultivar Bukhara-102 is proposed for greenhouse experiments. Treatments comprise T0 non-saline soil without hydrogel, T1 saline soil without hydrogel, T2 saline soil with unloaded hydrogel, T3 saline soil with guanine-loaded hydrogel, and T4 saline soil with free guanine. Preliminary hydrogel doses of 0, 2, and 3 g kg−1 dry soil can be tested with at least four independent replicates. Soil salinity should be described using saturated-paste extract electrical conductivity (ECe), pH, and soluble ion concentrations.

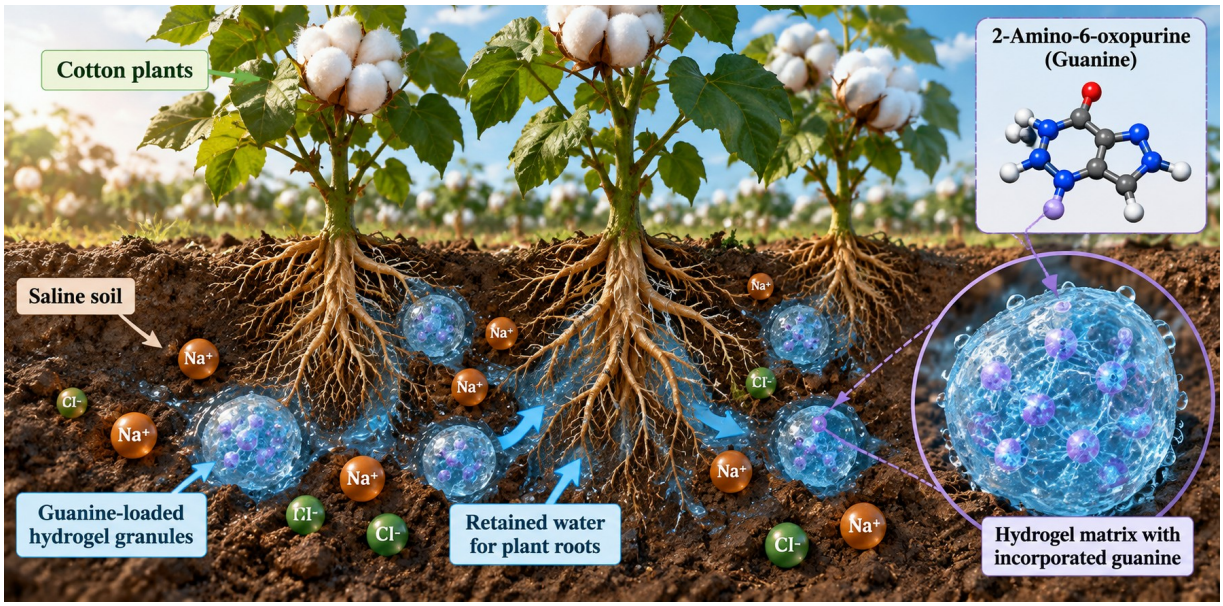


Figure 1. Conceptual illustration of guanine-loaded hydrogel granules in the saline cotton root zone.

2.3. Swelling and release. Equilibrium swelling is Q = (Ws − Wd)/Wd, where Ws and Wd are the swollen and dry masses. Tests should compare distilled water and saline media. Guanine release is Rt = (Mt/M0) × 100%, where Mt is the cumulative released mass and M0 is the initial loaded mass. A validated chromatographic method is recommended for guanine quantification.

2.4. Plant measurements. Germination, root length, shoot height, leaf area, dry biomass, relative leaf water content, chlorophyll, proline, malondialdehyde, and tissue Na^+, K^+, and Ca^{2+} should be measured. Factorial ANOVA and appropriate post-hoc tests can identify treatment effects and interactions.

3. Results and discussion

3.1. Matrix interactions. Guanine may interact with starch hydroxyl groups and polyacrylate carboxyl groups through hydrogen bonding. FTIR can suggest changes in functional-group environments, while microscopy and swelling tests assess matrix morphology and performance. Spectral shifts alone cannot prove covalent bonding.

3.2. Water retention under salinity. Hydrogel granules may act as local water reservoirs, improving moisture continuity around roots. However, ionic screening usually decreases swelling in saline water. Calcium and magnesium ions may further affect anionic hydrogel networks. Performance must therefore be evaluated in representative irrigation water and soils.

3.3. Soil salt balance. Hydrogels do not inherently remove NaCl from agricultural soil. Their influence on soil conductivity depends on water movement, drainage, leaching, and salt redistribution. A measured reduction in plant stress must not be misrepresented as soil desalination without ion mass-balance evidence.

3.4. Germination and roots. Stable moisture during seed imbibition may support cotton establishment, although excessive polymer doses could impair aeration or seed–soil contact. Comparisons with unloaded hydrogel and free guanine are essential to distinguish physical hydrogel effects from possible chemical effects of guanine.

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3.5. Physiology. Salinity can lower leaf hydration, disrupt K+/Na+ homeostasis, and stimulate oxidative injury. Improved water availability might indirectly support stomatal function and photosynthesis, but these responses require direct measurement. Tissue ion ratios, chlorophyll, and stress biomarkers provide complementary evidence.

3.6. Release and environmental performance. Guanine release may depend on diffusion, swelling, erosion, pH, and ionic strength. Laboratory release curves should be linked to actual rhizosphere concentrations. Polymer persistence, residual monomers, repeated wetting–drying cycles, and cost-effectiveness should be assessed before field deployment.

3.7. Interpretation. The most defensible expected benefit is water management from the hydrogel network. Any added biological benefit of guanine is a hypothesis rather than a demonstrated outcome. Replicated greenhouse and field experiments are needed to evaluate yield, salinity responses, and safety.

4. Conclusions

A guanine-loaded hydrogel is a plausible experimental material for improving root-zone water management during cotton cultivation in saline soils. The hydrophilic network may buffer fluctuations in water availability, although salinity can substantially reduce swelling. Guanine may form noncovalent interactions with the polymer matrix and exhibit controlled release, but its growth-promoting activity in cotton remains unverified. The proposed design separates hydrogel effects from guanine effects and emphasizes quantitative soil, polymer, and plant measurements. Claims concerning higher yields, reduced sodium toxicity, or soil desalination should be made only after experimental validation.

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Note: This manuscript is a conceptual research article; no original measurements or yield increases are claimed.