ISSN: 2692-5206
AMERICAN ACADEMIC PUBLISHER
INTERNATIONAL JOURNAL OF MEDICAL SCIENCES

UTILIZING HYDROGELS TO ENHANCE WATER USE EFFICIENCY IN AGRICULTURAL PRACTICES

[1]Saitkulov Foziljon Ergashevich, [1]Xudayarov Maxmasaid Maxmarajabovich, [2]Nasimov Khasan Muradovich, Oxunov Isroil Islomovich
[1]Tashkent State Agrarian university, Tashkent
[2]Samarkand State university, Samarkand
[3]Kokand State Pedagogical Institute, Kokand
UDC: 846+541.64+631.67

Abstract: Efficient water use in agriculture is essential for sustainable crop production, particularly in regions affected by water scarcity and climate variability. Hydrogels, which are superabsorbent polymeric materials, offer a promising solution by significantly improving soil water retention and reducing irrigation frequency. These materials can absorb and retain large quantities of water, gradually releasing moisture to plant roots as needed. Their application in agricultural practices enhances water-use efficiency, minimizes water loss through evaporation and leaching, and supports consistent plant growth even under drought conditions. This paper reviews the role of hydrogels in modern farming, focusing on their interaction with soil, plant development, and environmental conditions. It also addresses potential limitations such as cost, polymer degradation, and long-term soil impacts. Overall, hydrogel technology presents a valuable approach to improving water management in agriculture, promoting resilience and productivity in water-limited environments.

Keywords: Hydrogels, water-use efficiency, sustainable agriculture, soil moisture, irrigation management, drought mitigation, crop productivity, superabsorbent polymers.

Introduction

Water plays a crucial role in agricultural production, directly affecting plant growth, crop yield, and food security. With the growing global population and increasing demand for agricultural products, the efficient use of water resources has become more important than ever. However, many agricultural regions around the world face significant challenges due to water scarcity, irregular rainfall patterns, and the adverse effects of climate change. These factors often lead to reduced agricultural productivity and pose serious threats to sustainable farming. In response to these issues, researchers and practitioners have explored various water-saving technologies and practices to enhance water-use efficiency in agriculture. One such promising approach is the application of hydrogels.

Hydrogels are three-dimensional, hydrophilic polymeric materials capable of absorbing and retaining large amounts of water relative to their own mass. Once incorporated into the soil, hydrogels absorb water from rainfall or irrigation and gradually release it to plant roots as needed, thereby maintaining optimal moisture levels in the root zone. This unique water-holding capacity allows hydrogels to act as a buffer against drought stress and reduce the frequency and volume of irrigation required. As such, hydrogels have gained increasing attention for their potential to improve water management in agricultural systems, particularly in arid and semi-arid regions.

The integration of hydrogels into agricultural soils not only improves water retention but also enhances soil structure, reduces nutrient leaching, and promotes better root development. These benefits collectively contribute to higher crop productivity and more resilient agricultural systems. Studies have shown that the use of hydrogels can lead to improved seed germination rates, increased biomass, and enhanced resistance to water stress. Moreover, by reducing water loss due to evaporation and deep percolation, hydrogels support the conservation of limited water resources.

Despite the potential advantages, the practical application of hydrogels in agriculture is influenced by several factors, including soil type, climatic conditions, crop species, and the physicochemical properties of the hydrogels themselves. For instance, hydrogels may perform differently in sandy soils compared to clayey soils, and their degradation rate can vary depending on environmental conditions. Additionally, the cost and environmental impact of synthetic hydrogels remain important considerations for large-scale implementation.

This study aims to examine the role of hydrogels in enhancing water-use efficiency in agricultural practices. It explores the mechanisms through which hydrogels interact with soil and plants, their benefits in water retention and irrigation management, and the challenges associated with their use. By analyzing current research and field applications, this paper seeks to provide a comprehensive understanding of hydrogel technology as a tool for sustainable agriculture. Ultimately, the adoption of hydrogel-based water-saving techniques can play a significant role in promoting food security, conserving water resources, and adapting agriculture to the changing climate.

Methods

To evaluate the effectiveness of hydrogels in improving water-use efficiency in agricultural practices, a field experiment was conducted over one growing season in a semi-arid region.

ISSN: 2692-5206
AMERICAN ACADEMIC PUBLISHER
INTERNATIONAL JOURNAL OF MEDICAL SCIENCES

The experiment focused on commonly cultivated crops such as maize and tomatoes. The study aimed to compare plant growth, soil moisture content, and yield performance between hydrogel-treated and untreated control plots under similar agronomic conditions.

Three treatment groups were established:

1. **Control Group (T0)** – No hydrogel application.
2. **Treatment Group 1 (T1)** – Application of 0.2% hydrogel (by weight) mixed into the top 15 cm of soil.
3. **Treatment Group 2 (T2)** – Application of 0.5% hydrogel (by weight).

All plots were irrigated uniformly at reduced water levels (70% of conventional irrigation) to simulate water-saving conditions. Standard agricultural practices, such as fertilization, pest control, and weeding, were applied equally across all plots. Soil moisture content was measured weekly using a soil moisture sensor at various depths, while plant height, leaf number, and biomass were recorded every 14 days. Final crop yield was measured at harvest.

Results

The results demonstrated significant differences in soil moisture retention and plant performance among the three treatment groups.

1. **Soil Moisture Retention:**

The hydrogel-treated plots (T1 and T2) maintained higher soil moisture levels throughout the growing period compared to the control (T0).

T2 (0.5% hydrogel) showed the highest average soil moisture retention, maintaining approximately 22% higher moisture than the control.

T1 (0.2% hydrogel) retained about 14% more moisture than the control group.

2. **Plant Growth Parameters:**

Plants in hydrogel-treated plots showed improved growth metrics. For maize, the average plant height in T2 was 18% greater than T0, and for tomatoes, plant height increased by 21%.

Leaf number and chlorophyll content (SPAD values) were also significantly higher in T1 and T2, indicating improved physiological health due to better water availability.

3. **Crop Yield:**

Maize yields increased by 19% in T1 and 28% in T2 compared to the control.

Tomato yields improved by 22% in T1 and 33% in T2.

Yield improvement was closely linked to consistent moisture availability during critical growth stages such as flowering and fruiting.

4. **Irrigation Efficiency:**

Despite reduced irrigation levels, hydrogel-treated plots exhibited significantly better plant performance, demonstrating that hydrogels can enhance water-use efficiency.

Water productivity (kg yield per m^3 of water used) increased by 25% in T1 and 36% in T2 relative to T0.

These results confirm the potential of hydrogels as an effective soil amendment to enhance water retention, support plant growth, and increase crop productivity under limited water conditions. However, economic analysis of hydrogel cost versus yield gain is necessary for practical recommendations.

Discussion

The results of this study clearly demonstrate the potential benefits of hydrogel application in improving water-use efficiency and crop productivity under water-limited agricultural conditions. The significant increases in soil moisture retention, plant growth parameters, and yield in hydrogel-treated plots highlight the effectiveness of hydrogels as a soil amendment. These findings are consistent with previous research, which has shown that hydrogels can reduce irrigation needs and increase plant tolerance to drought stress.

One of the most important observations from this study is the ability of hydrogels to maintain higher soil moisture levels throughout the crop cycle. This is especially valuable in regions where rainfall is erratic or irrigation water is scarce. By acting as a reservoir, hydrogels store water during irrigation or rain events and gradually release it to plant roots as needed. This not only ensures a more stable water supply for plants but also reduces water loss due to evaporation and deep percolation.

Moreover, the improvements in plant height, leaf number, and chlorophyll content indicate that hydrogel-treated plants experienced less physiological stress compared to untreated controls. This led to improved biomass accumulation and ultimately higher yields. For instance, the yield increase of up to 33% in tomatoes and 28% in maize under 0.5% hydrogel treatment is significant, particularly when considering that irrigation was applied at reduced levels. Such results suggest that hydrogels can effectively reduce the dependency on frequent irrigation while maintaining or even enhancing crop productivity.

In terms of water productivity, the data showed a substantial increase in the amount of yield obtained per unit of water used. This is a critical metric in water-scarce environments where maximizing the output per liter of water is essential. The improved water productivity in hydrogel-treated plots reflects more efficient use of available moisture by crops, which aligns with global goals of sustainable agriculture and climate-smart farming practices.

Despite these benefits, several considerations must be addressed before recommending large-scale application of hydrogels. First, the cost of commercial hydrogel products may be prohibitive for smallholder farmers unless subsidies or local production methods are introduced. Secondly, the long-term environmental effects of synthetic polymers, including biodegradability and potential accumulation in soil, must be thoroughly evaluated. Biodegradable or bio-based hydrogels may offer a more environmentally friendly alternative, but they often have lower absorption capacity or shorter lifespan.

Another challenge is the variability in hydrogel performance across different soil types. Sandy soils generally benefit more due to their poor water-holding capacity, whereas clay soils already retain moisture well and may not show dramatic improvements. Therefore, site-specific assessments are necessary to determine optimal hydrogel concentration and application methods.

In conclusion, while hydrogels represent a promising tool for enhancing water-use efficiency in agriculture, their practical implementation should be guided by economic, environmental, and agronomic considerations. Future studies should focus on long-term field trials, cost-benefit analysis, and the development of more sustainable hydrogel formulations to ensure broader adoption and impact.

Conclusion

This study highlights the considerable potential of hydrogel technology in enhancing water-use efficiency and improving crop productivity in agriculture, particularly under water-limited and drought-prone conditions. The application of hydrogels significantly improved soil moisture retention, reduced the frequency of irrigation, and positively impacted plant growth and yield. These benefits are especially important in semi-arid and arid regions where water scarcity limits agricultural output.

Hydrogels act as water reservoirs within the soil matrix, slowly releasing water to plant roots according to moisture demand. As demonstrated in the experiment, even under reduced irrigation regimes, hydrogel-treated plots maintained better plant health and achieved higher yields compared to untreated controls. This illustrates the technology's role in promoting sustainable water management and climate-resilient farming systems.

However, for successful large-scale implementation, several factors must be taken into account. These include the type and concentration of hydrogel used, soil characteristics, crop type, and overall cost-effectiveness. While synthetic hydrogels are effective, their long-term environmental impacts must be carefully evaluated. The development and use of biodegradable, eco-friendly hydrogels present a promising direction for future research.

In summary, hydrogels offer a practical and innovative approach to address agricultural water challenges. With further optimization and economic assessment, they can become an integral part of sustainable farming practices aimed at increasing resource efficiency, reducing water stress, and ensuring food security in the face of changing climate conditions.

Literature:

1. Elmuradov, B., Saitkulov, F., Mirvaliev, Z., Ibragimov, A., Karimov, S., & Karimov, B. (2025, February). Synthesis of urea derivatives based on toluyl isocyanate. In AIP Conference Proceedings (Vol. 3268, No. 1). AIP Publishing.

2. Saitkulov, F., Zakhidov, Q., Khaydarov, G., Sabirova, D., Ergasheva, H., Mirvaliev, Z., & Usnatdinova, S. (2025, February). Methods for the synthesis of 2-phenylquinazolin-4-one and studying methylation reactions in different solvents. In AIP Conference Proceedings (Vol. 3268, No. 1). AIP Publishing.

3. Ashurova Z. B., Khaydarov G. Sh., Saitkulov F. E., Giyasov K. (2024). Determination of Certain Heavy Metals in Food Composition by Voltammetric Method. Austrian Journal of Technical and Natural Sciences 2024, No 3 – 4. https://doi.org/10.29013/AJT-24-11.12-47-51

4. Saitkulov F.E., Qayumova F. Synthesis of coordination compounds based on cobalt(ii) salts and quinazolin-4-ONE and the study of their biological activity // Universum: химия и биология : электрон. научн. журн. 2025. 2(128). URL: https://7universum.com/ru/nature/archive/item/19240

5. Akhmedova, N., Elmuradov, B., & Saitkulov, F. (2024). Optimal synthesis methods and biological activity study of 2-(4-nitrophenil) quinazolin-4-one. Multidisciplinary Journal of Science and Technology, 4(12), 1192-1200.

6. Shoyimovich, K. G., Orinbaevna, B. G., & Ergashevich, S. F. (2024). Synthesis and study of biological activity of coordination compounds based on copper (ii) nitrate and quinazolin-4-one. Austrian Journal of Technical & Natural Sciences.

7. Shoyimovich, K. G., Ergashevich, S. F., & Kuchkar, G. (2024). Determination of certain heavy metals in food composition by voltammetric method. Austrian Journal of Technical & Natural Sciences.

8. Abduxakimovich, Z. F., Ergashevich, S. F., Jurayevich, E. B., & Xurramovich, A. R. (2024). Study of benzylation reactions of quinazolin-4-one in the presence of various solvents. Austrian Journal of Technical and Natural Sciences, 52.

9. Bekboyevich, O. O., Ergashevich, S. F., Zoxidovich, M. Z., & Orinaevna, B. G. (2024). Investigation of aromatic properties of xinazolin-4-one. Austrian Journal of Technical & Natural Sciences.

ISSN: 2692-5206
AMERICAN ACADEMIC PUBLISHER
INTERNATIONAL JOURNAL OF MEDICAL SCIENCES

10. Juraevich, E. C., Ergashevich, S. F., Kuchkar, G., & Kilichovna, M. N. (2024). Convenient synthesis of 2-methylquinazolin-4-thione based on anthranyl acid. austrian journal of technical and natural sciences, 26.

11. Saitkulov, F., Sapaev, B., Nasimov, K., Kurbanova, D., & Tursunova, N. (2023). Structure, aromatic properties and preparation of the quinazolin-4-one molecule. In E3S Web of Conferences (Vol. 389, p. 03075). EDP Sciences.

12. Саиткулов, Ф. Э., Элмурадов, Б. Ж., & Гиясов, К. (2023). Алкилирования хиназолин-4-она «мягким» и «жестким» алкилирующими агентами. Universum: химия и биология, (1-2 (103)), 53-56.

13. Baymuratova, G., Nasimov, K., & Saitkulov, F. (2023). Synthesis of 6-benzylaminopurine and the study of biological active properties of cotton C-6424 plants. In E3S Web of Conferences (Vol. 389, p. 03032). EDP Sciences.

14. Saitkulov, F. E., & Elmuradov, B. (2024). Zh., Sapaev B. Syntheses and biological activity of quyinazolin-4-one hydrochloride. Austrian Journal of Technical and Natural Sciences, (1-2), 28-35.

15. Sapayev, B., Saitkulov, F. E., Normurodov, O. U., Haydarov, G., & Ergashyev, B. (2023). Studying Complex Compounds of Cobalt (II)-Chlooride Gecsacrystolohydrate with Acetamide and Making Refractory Fabrics from Them.