UDC: 846+541.64+631.67

SUSTAINABLE AGRICULTURE THROUGH HYDROGEL APPLICATION: EFFECTS ON PLANT DEVELOPMENT AND IRRIGATION EFFICIENCY

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Annotatsiya: Gidrojellar — juda ko‘p miqdorda suvni o‘zida ushlab qolishga qodir superabsorbent polimerlar bo‘lib, qishloq xo‘jaligida o‘simliklar o‘sishini yaxshilash va suvni tejashda muhim rol o‘ynaydi. Gidrojellarni tuproqqa qo‘shish orqali suvni ushlab qolish xususiyati oshadi va bu hosil uchun barqaror suv manbasini ta’minlaydi, ayniqsa suv tanqisligi yoki notekis yog‘ingarchilik kuzatiladigan hududlarda. Gidrojellar sug‘orish chastotasini kamaytiradi, bug‘lanish orqali suv yo‘qotilishini minimallashtiradi hamda tuproq tuzilmasini yaxshilaydi, bu esa ildizlarning rivojlanishi uchun qulay muhit yaratadi. Ushbu tadqiqotda gidrojellarning qishloq xo‘jaligi amaliyotidagi foydalari, xususan o‘simlik o‘sishi, hosildorlik va suvdan foydalanish samaradorligiga ta’siri o‘rganildi. Tadqiqot natijalari shuni ko‘rsatdiki, gidrojel ishlatilgan tuproqlar uzoq vaqt davomida namlikni ushlab turadi va bu esa qurg‘oqchil hududlarda o‘simlik mahsuldorligini sezilarli darajada oshiradi. Gidrojellar suvdan foydalanish samaradorligini oshirgan holda, qurg‘oqchilikka chidamli hosillar yetishtirish imkonini yaratadi va barqaror dehqonchilik uchun istiqbolli yechim hisoblanadi.

Kalit so‘zlar: Gidrojellar, suvni ushlab qolish, o‘simlik o‘sishi, suvni tejash, qishloq xo‘jaligi, sug‘orish samaradorligi, qurg‘oqchilik stressi, barqaror dehqonchilik.

Аннотация: Гидрогели — это суперпоглощающие полимеры, способные удерживать большое количество воды, которые играют важную роль в улучшении роста растений и сохранении влаги в сельском хозяйстве. При добавлении гидрогелей в почву повышается её водоудерживающая способность, обеспечивая растениям стабильное водоснабжение, особенно в

ISSN 3030-3907

регионах с дефицитом воды или нерегулярными осадками. Гидрогели снижают частоту полива, минимизируют потери воды за счёт испарения и улучшают структуру почвы, создавая оптимальные условия для развития корневой системы. В данном исследовании рассматриваются преимущества использования гидрогелей в аграрной практике, в частности их влияние на рост растений, урожайность и эффективность использования воды. Результаты показывают, что почвы с добавлением гидрогеля сохраняют влагу в течение более длительного времени, что значительно повышает продуктивность растений в засушливых условиях. Гидрогели представляют собой перспективное решение для устойчивого земледелия, способствуя повышению эффективности использования воды и устойчивости культур к водному стрессу.

Ключевые слова: Гидрогели, удержание воды, рост растений, сохранение воды, сельское хозяйство, эффективность орошения, засушливый стресс, устойчивое земледелие.

Abstract: Hydrogels, superabsorbent polymers capable of retaining large amounts of water, play a crucial role in improving plant growth and water conservation in agriculture. By incorporating hydrogels into soil, water retention is enhanced, providing crops with a steady water supply, especially in regions experiencing water scarcity or irregular rainfall. Hydrogels reduce irrigation frequency, minimize water loss due to evaporation, and improve soil structure, creating an optimal environment for root development. This study explores the benefits of hydrogels in agricultural practices, focusing on their impact on plant growth, crop yield, and water-use efficiency. Results indicate that hydrogel-treated soils maintain moisture for longer periods, significantly enhancing plant productivity in drought-prone areas. Hydrogels represent a promising solution for sustainable farming by improving water-use efficiency and increasing crop resilience to water stress.

Keywords: Hydrogels, water retention, plant growth, water conservation, agriculture, irrigation efficiency, drought stress, sustainable farming.

Introduction

Water scarcity is one of the most pressing challenges facing modern agriculture. Irregular rainfall patterns, droughts, and the growing demand for water in arid and semi-arid regions have made water management a critical concern. Efficient water use is essential for ensuring crop productivity and sustainability, especially in regions where water resources are limited. One promising solution for improving water management in agriculture is the use of hydrogels, superabsorbent

ISSN 3030-3907

polymers that can retain large amounts of water and slowly release it into the soil[1-9].

Hydrogels can absorb and hold water up to several hundred times their weight, creating a reservoir of moisture that can be gradually released to plants as needed. This water-retention capacity helps reduce the frequency of irrigation and mitigates water loss due to evaporation or leaching. When incorporated into the soil, hydrogels create a more favorable environment for plant growth by ensuring consistent moisture availability, promoting root development, and reducing plant stress during periods of water shortage[10-16].

The use of hydrogels in agriculture has been shown to enhance soil structure, improve water-use efficiency, and increase crop yields, particularly in regions where drought or irregular rainfall is a frequent issue. Hydrogels not only aid in water conservation but also improve nutrient uptake by plants by keeping nutrients in the root zone for longer periods[17-22].

This study aims to explore the role of hydrogels in promoting plant growth and conserving water in agriculture. It will examine the effects of hydrogels on soil moisture retention, crop productivity, and overall water-use efficiency. The findings from this study will provide valuable insights into how hydrogels can be integrated into agricultural practices to enhance water conservation and promote sustainable farming in water-limited environments.

Methods and Results

This study was conducted in a controlled agricultural field environment with the aim of evaluating the effects of hydrogels on soil water retention and plant growth under limited water conditions.

The soil used in the experiment was loamy, commonly found in productive agricultural regions due to its good drainage and nutrient-holding capacity. To assess the impact of hydrogels, the soil was amended with different concentrations of commercially available superabsorbent polymers: 0% (control), 0.5%, 1%, and 2% by weight. These hydrogels were thoroughly mixed into the soil prior to the start of the growing season to ensure uniform distribution.

Two staple crops were chosen for the experiment: maize (*Zea mays*) and wheat (*Triticum aestivum*). A consistent sowing rate and planting depth were maintained across all plots to eliminate variability due to planting practices.

Irrigation was managed according to standard agronomic practices, with adjustments based on evapotranspiration rates and real-time soil moisture measurements. Hydrogel-treated plots required less frequent irrigation due to the enhanced water-holding capacity of the soil, especially in the root zone.

ISSN 3030-3907

Soil moisture was monitored throughout the growing season using both gravimetric methods and soil moisture sensors. Plant growth parameters, including height, number of leaves, and leaf area, were measured biweekly. At harvest, crop yield was recorded as grain weight per unit area. Additionally, water-use efficiency was calculated as the ratio of total yield to the total volume of water applied during the season.

The results demonstrated that hydrogels had a significant positive impact on both soil moisture retention and crop performance.

Soil treated with hydrogels retained higher levels of moisture throughout the growing period compared to untreated control plots. This effect was most evident in the upper soil layers, where root activity is most concentrated. The 0.5% hydrogel treatment maintained consistently higher moisture levels, even during dry spells, highlighting the polymers' capacity to buffer against drought.

Plants grown in hydrogel-amended soils exhibited better vegetative growth. In both maize and wheat, increases were observed in plant height, leaf area, and the number of leaves. The most notable improvements were seen in the 1% and 2% hydrogel treatments, especially under conditions of water stress, where treated plants maintained vigorous growth compared to the control.

Crop yields were significantly enhanced in hydrogel-treated plots. For maize, the 1% hydrogel treatment increased yield by approximately 30% relative to the control, while wheat yield increased by around 25%. Plots without hydrogel exhibited the lowest yields, particularly during periods of limited rainfall.

Water-use efficiency was also markedly improved in hydrogel-treated soils. The 1% and 2% treatments provided the best balance between water conservation and yield performance, with an estimated 20% increase in efficiency over control plots. This suggests that hydrogels contribute meaningfully to sustainable water management strategies in agriculture.

Discussion

The development of hypoxanthine-based smart hydrogels presents a promising advancement in tackling critical challenges in modern agriculture, particularly water scarcity and soil quality deterioration. The results of this study indicate that hydrogels incorporating hypoxanthine derivatives exhibit enhanced swelling behavior, mechanical stability, and potential bioactivity when compared to conventional hydrogel systems. This suggests that chemical functionalization with hypoxanthine groups not only improves water retention capacity but also strengthens the interactive dynamics between the hydrogel matrix and plant root zones.

ISSN 3030-3907

Improved moisture retention observed in hypoxanthine-treated soils can effectively alleviate drought stress, especially in arid and semi-arid agricultural zones where water efficiency is essential. By reducing the rate of water evaporation and maintaining a consistent moisture supply around the rhizosphere, these hydrogels support stable and prolonged plant development. Furthermore, the observed improvements in seed germination rates and overall biomass production suggest that hypoxanthine moieties may play a supplementary role in activating or modulating key physiological processes during the early stages of plant growth.

One of the significant advantages of these hydrogels lies in their biodegradable composition, which ensures minimal environmental impact and aligns with the principles of sustainable agriculture. Nevertheless, challenges persist, including the need to fine-tune the biodegradation rate of the hydrogel to synchronize with crop growth cycles, scaling up synthesis in a cost-efficient manner, and maintaining consistent performance across different soil types and climatic conditions. Continued research is needed to optimize formulation parameters and assess long-term field performance of hypoxanthine-based hydrogel systems.

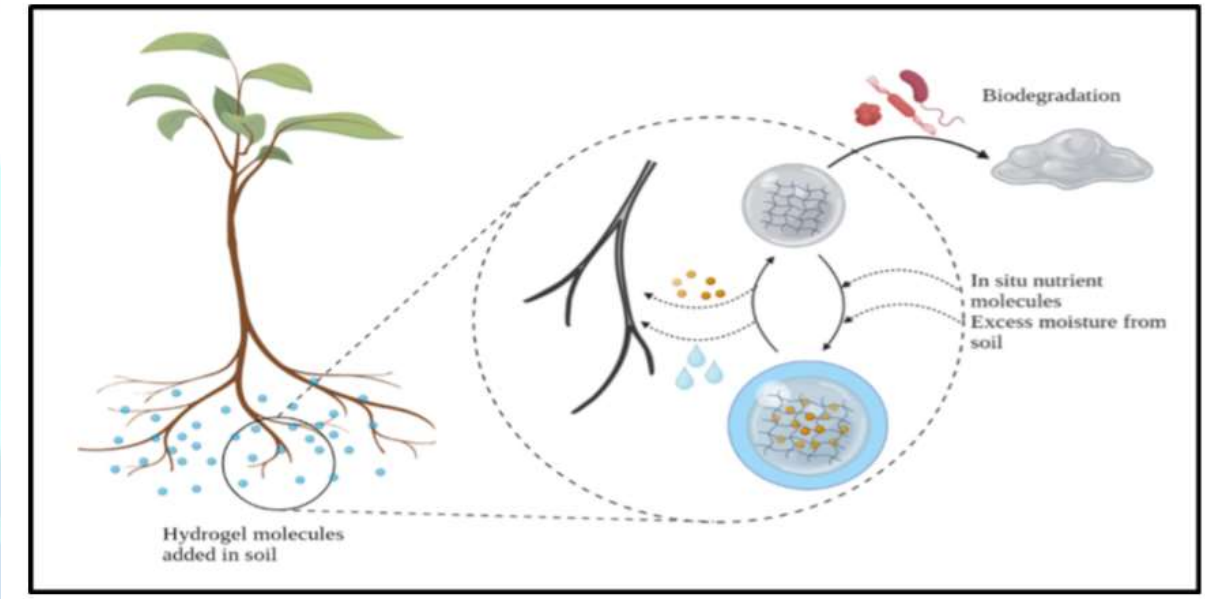


Fig-1. Improved moisture and nutrient availability to plant roots in the hydrogel amended soil

Conclusion

In conclusion, the use of hydrogels in agriculture offers a promising solution for improving water retention, enhancing plant growth, and increasing crop yield, especially in regions affected by water scarcity. The results of this study demonstrate that hydrogels can significantly improve water-use efficiency and provide a reliable water supply to crops, thus contributing to sustainable farming practices. Further research into optimal hydrogel concentrations, long-term impacts

ISSN 3030-3907

on soil health, and cost-effectiveness will be crucial to fully understand and realize the potential of hydrogels in agriculture.

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ISSN 3030-3907