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Sustainable Management of Deficit Irrigation Using Superabsorbent Hydrogel: Crop Growth Characteristics and Soil Salinity under Different Soil Types

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Abstract: Deficit irrigation is a crucial agricultural practice as irrigated agriculture becomes increasingly common in areas with limited water supplies. Deficit irrigation in arid regions can be effectively managed with the use of hydrogels. This study aimed at studying the effect of the hydrogel application rate on crop growth characteristics and soil properties under different irrigation levels and soil texture classes. Lettuce was used in this study, as a crop highly sensitive to water stress. Pot experiments were conducted using four irrigation levels (100%, 85%, 70%, and 60% of full irrigation requirements), four hydrogel application rates (0%, 0.1%, 0.2%, and 0.3%, expressed as a weight-by-weight percentage relative to soil dry mass) and three soil textures (clay, loamy sand, and sandy-clay soil). The crop growth parameters were significantly improved due to hydrogel application. Hydrogel significantly increased lettuce marketable yield, root fresh and dry weights, root diameter, and plant height. The hydrogel application of 0.3% and 85% of irrigation requirements did not result in significant yield reductions. The data also revealed that hydrogel application reduced soil salinity; the decrease was significant at high levels of hydrogel application (0.2% and 0.3% w/w). Under severe water deficit (60% of irrigation requirements), a hydrogel application rate of 0.3% significantly reduced soil salinity by 9.1% as compared to the control. These findings point out that hydrogel could be recommended to enhance crop growth and productivity under deficit irrigation and mitigate soil salinity risks associated with limited water conditions. **DOI: 10.1061/JIDEDH.IRENG-10640**.

Practical Applications: Water scarcity makes it difficult for farmers to maintain high productivity, especially in arid and semiarid regions. Hydrogel or polymer is a substance that can absorb and retain large amounts of water. This study shows that adding small amounts of hydrogel to soil can help crops sustain growth and productivity under drought conditions. Lettuce was used as a test crop because it is very sensitive to drought. Results showed that hydrogel improved plant size, root growth, and yield under water stress. Using 0.3% hydrogel with 85% of crop water requirements gave nearly the same yield as full irrigation. This indicates that farmers can save water without significant yield reduction. The results also showed that hydrogel reduces soil salinity, which is often a problem when water supply is limited. Under severe drought, hydrogel lowered soil salinity levels by more than 9% compared with untreated soil. These results suggest that hydrogel can be a practical solution to save water, protect soil, and maintain crop productivity in water-limited areas.

Author keywords: Water-saving strategies; Soil amendments; Crop growth; Crop productivity; Arid agriculture; Water stress mitigation.

Introduction

Climate change has a significant impact on water scarcity around the world. Changes in precipitation patterns, rising temperatures, and extreme weather events change water availability in different regions. Droughts are becoming more frequent and severe in many parts of the world, leading to water shortages that impact agriculture, ecosystems, and communities. In addition to climate change, the increasing demand for food due to population growth has led to higher freshwater demands for irrigation. Agriculture is the main consumer of water in many parts of the world, including Egypt, accounting for about 80% of freshwater withdrawal (Gabr 2023; Jungudo 2023; Khedr 2019; Sedhom et al. 2023).

Egypt faces major challenges related to water scarcity, as the water deficit in Egypt exceeds 30 BCM/year. Between 1989 and 2018, Egypt's population increased annually by 2.1%, reaching 109 million people in 2021. The per capita water share has been less than 560 m^3 since the 1990s, which is far below the water poverty line (1,000 m^3 annually per capita). This value is expected to decrease to 500 m^3/capita by 2030 (Abdelkader et al. 2018; Alotaibi et al. 2023; Selim et al. 2023). To address water scarcity challenges, water-saving strategies have been proposed to enhance sustainable water management. These strategies may include deficit irrigation practices and enhancing soil properties using super absorbent hydrogels.

Deficit irrigation (DI) can be defined as a water management strategy that involves deliberately applying less water than the full/optimum irrigation requirements. In DI a controlled level of water stress is created to achieve specific objectives such as conserving water resources, reducing irrigation costs, or managing crop growth and yield. In terms of water use, DI involves a strategic approach that balances the optimization of water resources while maintaining acceptable crop yields through controlled application

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