University of Thi-Qar Journal of agricultural research

Thi-Qar Journal of agricultural research

ISSN Onlin:2708-9347, ISSN Print: 2708-9339 Volume 13, Issue 2 (2024) PP 364-372

https://jam.utq.edu.iq/index.php/main *https://doi.org/10.54174/utjagr.v13i1.323*

Effect of Adding Different Concentrations of Hydrogel on the Water Properties of Clay Soil

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Abstract

A field experiment was conducted in Nasiriyah, Thi Qar Governorate, Utilizing clay soil to investigate the effects of various concentrations of hydrogel (0.0, 0.05, 0.1, 0.15, and 0.2) on water properties of the soil, including moisture content , field capacity, permanent wilting point , available water, and evaporation. The experiment was carried out during the 2023 growing season, following a systematic approach to soil preparation and plot division. Hydrogel was incorporated into the soil at a depth of 10 cm, based on the dry weight of the soil. The plots were planted with Zea mays. A randomized complete block design was utilized for data analysis, with a significance level established at 0.05. The results of the experiment indicated that hydrogel significantly improved soil moisture content, field capacity, permanent wilting point, and available water, while effectively reducing evaporation from the soil surface. Notably, treatment P4 demonstrated the most pronounced enhancement in water properties, especially when compared to the control treatment (P0).These findings highlight the potential advantages of hydrogel application in enhancing soil water retention and promoting agricultural productivity , which is particularly relevant in regions experiencing water scarcity.

Keywords : Water propreties, Hydrogel, Field Capacity, permanent Wilting point, Evaporation

I. Introduction

Worldwide, water is considered one of the most important natural resources needed for the success of agriculture and food production. Especially today, due to increasing climate change, population growth and increasing food demand, farmers face significant challenges in efficient and effective water management Arid and semi-arid regions , characterized by high temperatures, high humidity and low rainfall, covers nearly a third of the Earth's surface (Schmidt and Pearson., 2016) Although the ecosystems inhabiting these complex areas have adopted developmental strategies, these strategies were not sufficient for their persistence (Mwangi and Dohrn, 2008; Nassef, Anderson, and Hesse, 2009).As the global population continues to increase, particularly in recent years, there is an urgent need for more farmland to meet consumer demands and achieve higher crop yields (Tilman et al. , 2002, Qiao et al., 2016). Thus, serious commitment is needed to reclaim degraded lands (Li et al., 2014).

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Conservation agriculture is a crucial strategy for water conservation and is essential for promoting sustainable livelihoods in arid and semi-arid regions (Shahid et al., 2012; Zhang et al.,2017). In the recent years, hydrogels have been utilized in the formation of material that can enhance the quality of soil water. The polymer is a very water sensitive material which has the capability of absorbent large amount of water and nutrients for the plants. It works by absorbing water and nutrients and then releasing them to the plants slowly as needed, thus boosting plant growth where drought and water scarcity are concerns (Yazdani el al., 2007 ; Rezashateri el al.,2016 ; Dahri el al., 2019). The addition of 60 to 90 kilograms per hectare of superabsorbent polymers has been seen to increase the water retention capacity of the soil and crop production (Hou el al.,2017).

The addition of SAP (Super Absorbent Polymer) into the soil enhances the water storage at field capacity and permanent wilting point thus enhancing the water availability to the plants (Karimi el al., 2009 ; Agaba el al .,2010 ; Banedjschafie el al., 2015 ; Montesano el al 2016). Increase in water availability for plants can help in reducing water stress, high temperature , and salt stress which are the effects of climate change. Therefore, between successive irrigations, it can enable the soil to sustain longer periods, improving plant growth and performance (Viero el al 2002 ; Han el al 2005 ; Beniwal el al 2010). Aso, adding a small amount (5 grams per kilograms of soil) of Super Absorbent Polymer significantly increased the water retention capacity and prolonged the initial stage of evaporation, which is influenced by both external conditions and surface soil conditions, in comparison to the water retention in the soil alone (Yu el al., 2012).Super Absorbent Polymers can also increase the percentage of stable aggregates in the soil with particle sizes of 0.25-0.125 mm (Alkhasha el al., 2018).

The study aims to evaluate the effect of adding different levels of hydrogel (0.0%, 0.05%, 0.1%, 0.15%, and 0.2%) on the water properties of clay soil, including moisture content, field capacity, permanent wilting point, available water, and evaporation. The study is expected to provide new insights into improving water management in agriculture, particularly in regions suffering from water scarcity due to rising temperatures, high evaporation, low rainfall, and decreased organic matter, as observed in central and southern Iraq.

II. Material and Method

Hydrogels:

Hydrogel is a type of polymer that has excellent adsorption capacity due to the presence of carboxyl, hydroxyl, amino, and other absorbable groups in its molecular chain, with a certain degree of cross-linking, This contributes greatly to its ability to adsorb and store water in amounts that can be hundreds or thousands of times its own weight (Omidian el al.,2005).

Experiment Location:

An agricultural experiment was conducted in a field in Nsssiriyah, Thi Qar District during the 2023 growing season to study the effect of adding different amounts of (SAP) hydrogels on soil and water properties.

Implementation of the Experiment

After the land soil field was prepared, it was divided into three sectors, each of which was further divided into 15 experimental units. SAP Hydrogel was applied to the soil surface at a depth of 10 cm, after which maize seed were sown in the plots. Table 1 presents some physical properties of soil.

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Table 1: Some physical properties of the soil in the experimental field.

Soil Texture			Organic Matter (%)	Bulk Density (mg m^{-3})	Water Content %
Silt %	**Sand %**	**Clay %**			
345	71	584	%1.05	1.28	14.65
Water	**EC (ds m^{-1})**	**pH**	**CEC meq $100g^{-1}$**	**EC (ds m^{-1})**	**pH**
	2.79	7.66	31.42	2.83	7.28

Experimental treatments

Different amounts of (SAP) hydrogel were used in the experiment as follows: Control group: no hydrogel (P0), 0.05% hydrogel (P1), 0.1% hydrogel (P2), 0.15% hydrogel (P3), 0.2% hydrogel (P4) .

Studied Traits

1- **Moisture Content**: measured using the gravimetric method.
2- **Field Capacity**: determined using the pressure plate extractors.
3- **Permanent Wilting Point**: measured using the pressure plate extractors.
4- **Available Water Capacity (AWC):**determined by calculating the difference between the moisture content at field capacity and the permanents wiling point.
5- **Evaporation**: determined by using evaporation pans.

Statistical Analysis:

The data were analyzed using a randomized complete block design, and the means were compared using the least significant difference at 0.05% level.

III. Results

1- Moisture Content (%)

The results indicated that soil moisture content increased significantly with hydrogel concentration. Figure 1 shows that treatment P4 exhibited the highest moisture content, reaching 29.84%, while the other treatments recorded moisture contents of 21.13%, 23.38%, and 27.99% for P0,P1, P2, and P3, respectively. The increase in moisture content reflects the water holding capacity of the hydrogel, thereby enhancing water availability to the plants. The percentages are summarized in Figure 1. These results are consistent with Al Khanfous,2024, who observed an increase in soil moisture content with the addition of superabsorbent polymer, noting that the magnitude of the increase positively correlates with the concentration of the added polymer.

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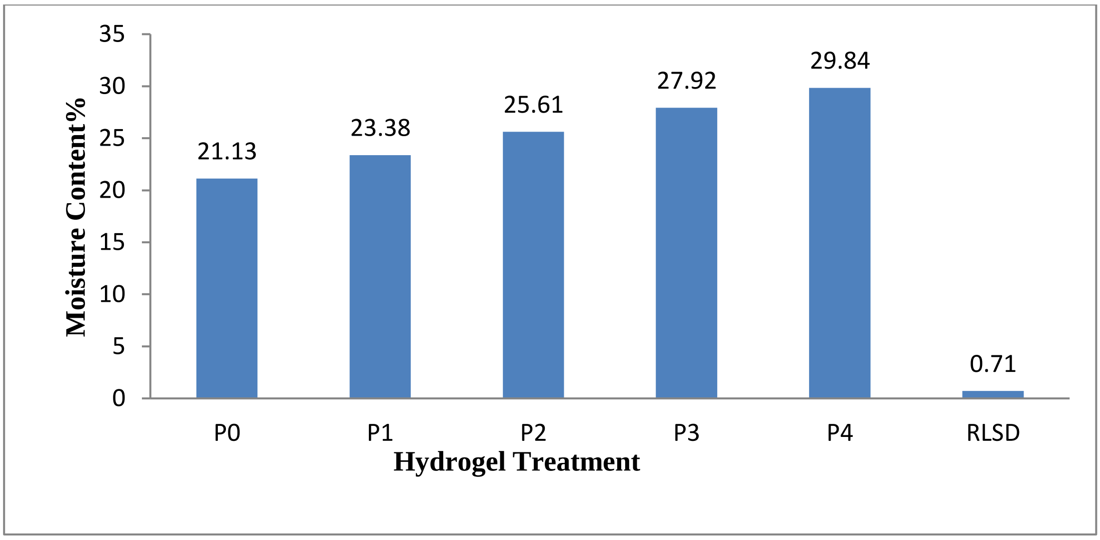

Figure 1: Effect of Hydrogel Concentrations on Soil Moisture Content (%).

2- Field capacity (%)

From figure 2, it can be observed that hydrogel significantly contributed to increasing field capacity of soil. Treatment P4 exhibited the highest field capacity value, recording impressive 42,07%. In contrast, the treatment without any addition (P0) recorded the lowest field capacity value of 32.93%, while the other treatments recorded values of 37.07%, 38.35%, and 40.19% for P1,P2,and P3, respectively. The increase in filed capacity associated with the hydrogel is attributed to its effectiveness in improving the physical properties of soil, which positively impacts the water retention characteristics of the soil.

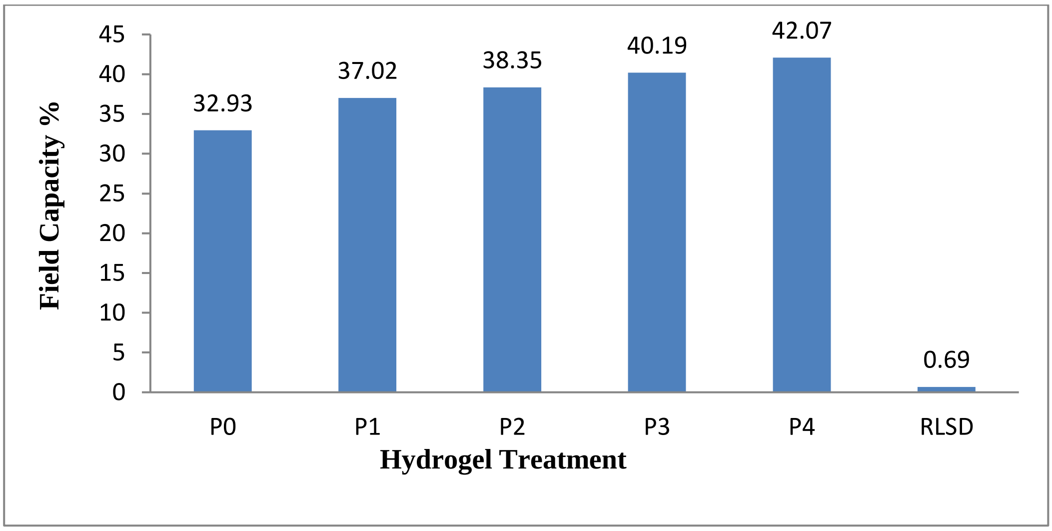

Figure 2: Effect of Hydrogel Concentrations on field capacity (%).

3- Permanent Wilting Point (%)

Figure 3 demonstrates that hydrogel significantly outperformed the control treatment in increasing moisture content at permanent wilting point, thereby ensuring necessary moisture

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availability for plants during dry periods. Additionally, Figure 3 indicates that treatment P4 achieved the highest moisture content at the permanent wilting point, recording a value of 21%, while the control treatment exhibited the lowest rate at 16.15%.

These results indicate that the inclusion of hydrogel in agriculture, especially in arid and semi-arid areas, is very important to avoid a great reduction in productivity due to water stress. Therefore, hydrogel can serve to improve plant health through better retention of water, thus increasing yields, mainly in critical periods of drought. The study presents benefits that can be achieved by adding hydrogel to the soil management program to optimize the water availability for crops.

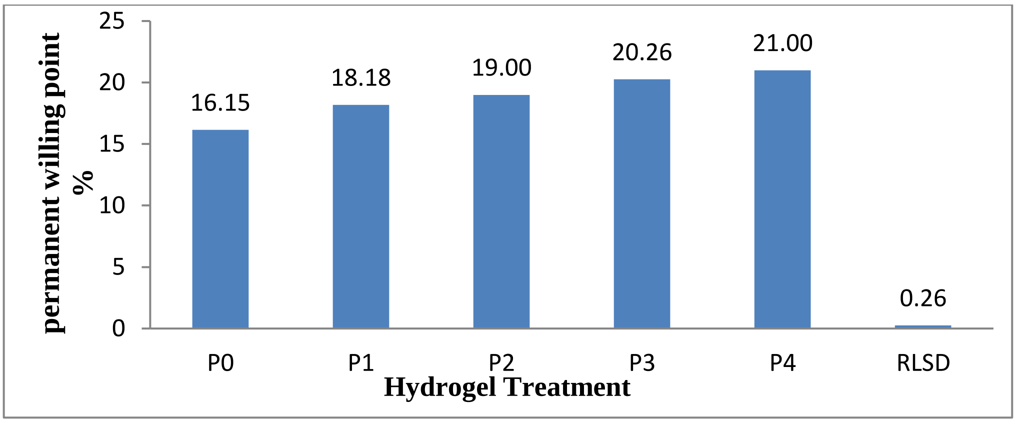

Figure 3: Effect of Hydrogel Concentrations on permanent willing point (%)

4- Available Water (%)

The results indicate that treatment P4 recorded the highest value of water availability , reaching 21.07%, while the control treatment exhibited the lowest value of available water at 16.78%. Additionally, the other treatments recorded values of available water at 18.85%, 19.35%, and 19.93% for P1, P2, and P3, repetitively.

The observed increase in available water for plants upon the addition of hydrogel can be attributed to its ability to enhance water retention capacity of soil. Hydrogel acts as a moisture reservoir, allowing the soil to hold more water and thereby reducing the frequency and volume of irrigation required. The improvement in water availability is particularly beneficial in agricultural practices, especially in regions prone to drought or water scarcity. The Figure 4 shows the effect of hydrogel on available water.

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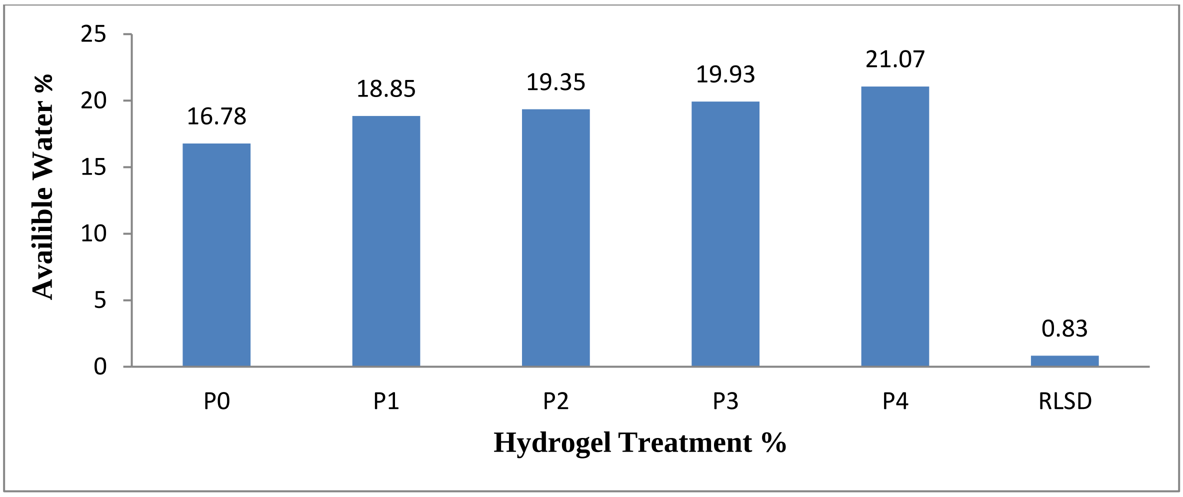

Figure 4: Effect of Hydrogel Concentrations on available water (%).

5- Evaporation (mm)

The results presented in Figure 5 indicate that treatments incorporating hydrogel significantly outperformed the control treatment in reducing evaporation from the soil surface. Specifically, Figure 5 illustrates that treatment P4 recorded the lowest evaporation value at 28.43mm, compared to the other hydrogel treatments. In contrast, the control treatment (P0) exhibited the highest rate of evaporation, measuring 40.83mm.

These findings align with the research conducted by Yu el al.(2012), who noted that the presence of hydrogel in the soil effectively reduces evaporation by enhancing moisture retention. Hydrogel achieves this by forming a particularly beneficial in agricultural settings, where moisture conservation is crucial for maintaining optimal soil conditions and supporting plant growth.

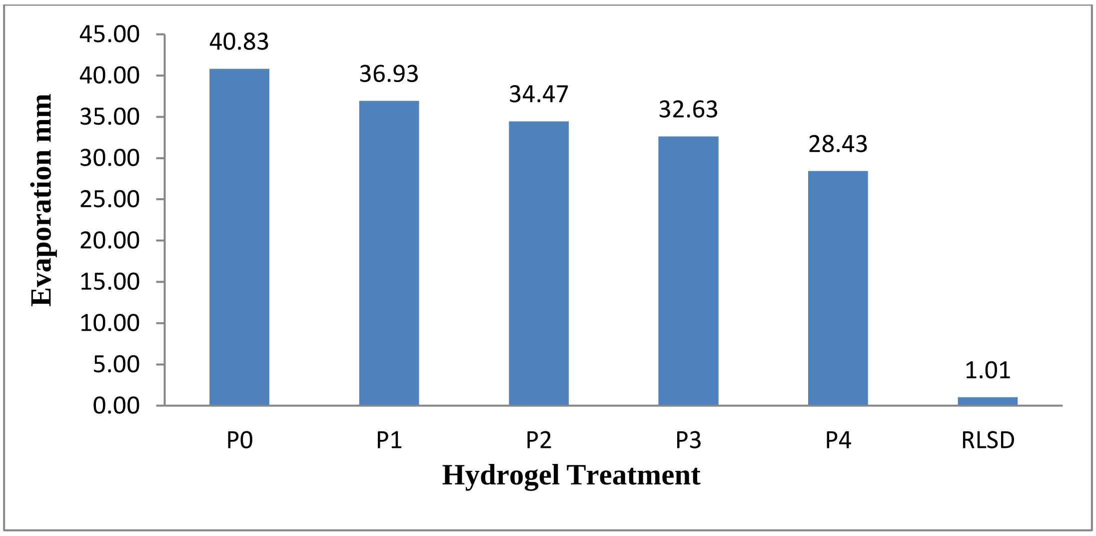

Figure 5: Effect of Hydrogel Concentrations on evaporation (mm).

Discussion

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The results of study have shown that different levels of hydrogel supplementation in soil had a positively significant effect on improving the water characteristics of clay soil. The findings agrees with previous research reports regarding the role of hydrogels in improving soil water management in agricultural productivity. Despite clay soils holding more water than sandy soils, face a lot of challenges, including poor drainage, resulting in the inadequacy of oxygen supply and the reduced supply of nutrients within the soil. The results also indicate that the introduction of hydrogels as a soil moisture management system has a pronounced improvement effect on the soil.

They also, showed that the use of high concentrations of hydrogel (P3 and P4) resulted to increase in soil moisture content more than the control treatment. This suggests that hydrogel improved the ability of the soil to hold moisture because of its net structure and function of soil particle binding. Thus, it enhances the water holding potential of soil by several hundred to thousands fold in hydrogel as oppose to the untreated soils and this improves its physical characteristics. The results can be supported by finding other researches such as those presented by (Rezashateri el al., 2016 and Dahri el al., 2019).

In terms of the effect of hydrogel on field capacity moisture content as well as its value at the permanent wilting point, it is clear that hydrogel indeed raises moisture content at both field capacity and the permanent wilting point in comparison to the control treatment. The improvement was due to hydrogel's effect on the soils as well as the increase in the available soil moisture content that can be provided to plants at the appropriate times, thus creating conditions favorable for the development of roots (Karimi et al. 2009; Agaba et al. 2010; Banedjschafie et al. 2015; Montesano et al. 2016). The moisture content at field capacity and permanent wilting point, along with the corresponding increase in moisture content and the ability to provide permanence of such saturation ,is highly regarded especially for areas prone to drought. It also provide a sources of moisture to the plants druing drought seasons or when irrigation intervals are long. Their production period is increased as they can survive for a very long time without additional water, meaning that drought in agriculture won't be a significant problem anymore. The advantage lowers requirement for irrigation water, thus supporting the sustainability of water resources management (Viero el al .,2002; Han el al., 2005; Beniwal el al., 2010).

The findings further suggest that the incorporation of hydrogel polymers contributed to alleviating the problem of moisture loss through evaporation. The treatments that had high application rates of hydrogel recorded the lowest rates of evaporation, which implies that more water would remain available for the plants. This improves water use efficiency in agricultural contexts, which is particularly important particularly in regions with hot and arid weather. These results are consistent with (Yu et al 2012), who emphasized the function of hydrogel in controlling soil moisture evaporation. This effect is attributed to the network structure of the hydrogel, which forms a barrier that prevents evaporation, thereby minimizing moisture loss.

Moreover, it became clearly evident from the results that hydrogel made a significant and critical contribution to increasing water productivity at higher concentrations. This obvious impact can be explained by the crucial role of the polymer in increasing moisture at field capacity and the permanent wilting point, as well as its high water retention capacity. For all these reasons, the amount of irrigation water applied, as well as the number of times irrigation had to be carried out, were significantly reduced, hence increased water productivity for all. These findings are in line with the previous studies by (Alkhasha et al., 2018; Banedjschafie et al., 2015; Montesano et al., 2016).

The assessment of the results should also address the environmental impacts of using hydrogels. While most hydrogels are safe to apply, more studies are needed to fully assess their possible adverse effects on soil microbial life and its balance. It thus becomes imperative to choose the hydrogels that are compatible with environmental norms and do not pose a threat to the fragile ecosystem in which these are applied.

Finally, the findings from the study have the potential to significantly contribute to sustainable agriculture by focusing on the critical need for effectively managing water resources in farming practices in an economical manner. Hydrogels innovative materials can play a vital role in reducing irrigation rates , the frequency of irrigation, and even the spacing between irrigation applications, thereby contributing greatly to overall water conservation efforts. This is of great value to regions classified as arid and semi-arid, where water is actually a very scarce commodity. Moreover, these observed effects call for a serious rethinking of traditional agricultural methods and urge transformative approaches that will not only adapt but also encourage new and innovative ways of improve agricultural practices and enhance seed production processes.

IV. Conclusions

In conclusion, the research clearly shows that the use of hydrogels serves as a highly effective means of enhancing various properties of soil, with special emphasis on its water-related characteristics. This major improvement results in higher crop productivity, which is beneficial for agricultural produce and also reduces the need for irrigation, thereby conserving water resources. However, these finding must be followed by furthers scientific research to determine the long-term effects of using hydrogel under different agricultural conditions and to better understand possible interactions between hydrogel, soil, and plants. Through, the study, substantial improvements can be made to the sustainability of agricultural lands and an increase in their productivity, leading to enhanced global food security.

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