Improving the Activity of Sandy Soil and Reducing Salinity and Alkalinity Using an Absorbent Polymer and Its Impact on the growth of (Zea mays)

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Abstract

Drought is a significant environmental factor that adversely affects plant growth, morphological and physiological processes, and groundwater reserves. The inclusion of superabsorbent polymers (SAPs) enhances the wetting duration of the root environment with minimal water and electrical energy. This study aimed to test the hypothesis that adding the polymer to light sandy soil during planting in arid climates would enhance water use efficiency, improve the water situation in planting sites, and assess its impact on soil texture, yield, and morphological characteristics throughout different growth stages. Various concentrations (Control , 0.1% , 0.3% , 0.5% , 0.6%, 0.7%) of the superabsorbent polymer were added to sandy soil to extend wetting periods using a randomized complete block design. Soil moisture content showed significant variation
(30.20% , 31.63%, 37.63%, 64.63%, 75.4%, 81.5%)
among the different polymer concentrations, leading to substantial morphological diversity throughout the growth periods. The results indicate that this new amendment is highly beneficial for sandy alkaline soils, resulting in increased final biomass, reduced plant pathogens, decreased energy costs, and conservation of water resources in extreme climates. These encouraging findings warrant further research into integrating economic, environmental, and health factors in agricultural practices.

Keywords: Zea mays, water resources, sustainable development, water absorbent polymers (SAPs), soil salinity, alkalinity.

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Introduction

The utilization of technological methods in managing irrigation water in light, permeable soils in dry, low-rainfall regions is of utmost importance to prevent significant water loss and ensure optimal water balance (Setegn, et al. 2011), thus avoiding pool yields. In these challenging environments, efficient water management techniques (Hutmacher1, et al. 2001) play a crucial role in maximizing agricultural productivity. By employing advanced technologies, such as precision irrigation systems (Mekonen, Moges et Gelagl 2022), soil moisture sensors, and automated control systems, farmers can precisely monitor and control water application, matching it with the actual water requirements of crops. This targeted approach minimizes water wastage caused by over-irrigation or improper timing, leading to better water-use efficiency. Moreover, these technologies enable farmers to adapt to the specific needs of light, permeable soils by delivering water directly to the root zone, reducing surface runoff and evaporation losses. By conserving water resources and optimizing irrigation practices, technology-driven approaches contribute to sustainable water management and enhance the overall productivity and profitability of farming operations in arid regions. Therefore, the adoption of technological solutions is essential for achieving a favorable water balance and mitigating the negative impact of water scarcity on crop yields in light, permeable soils.

In previous agricultural research, the utilization of water-absorbent polymers (WAPs) for plant root hydration has been extensively investigated. These studies aimed to assess the efficacy of WAPs in enhancing water availability to plant roots and improving plant growth in water-limited conditions.

In a study conducted by (Rehman, Ahmad et Safdar 2011)., the effects of incorporating Water Absorbent Polymers (WAPs) into soils were examined. The results of the study demonstrated several positive outcomes. Firstly, it was observed that the incorporation of WAPs led to higher soil moisture contents, which better met the water requirements of crops. This increase in soil moisture levels consequently resulted in a higher number of germinated seeds. Furthermore, the presence of WAPs significantly enhanced plant growth and productivity. The water-holding capacity of the soil was found to be significantly improved with the incorporation of WAPs, thereby ensuring a more abundant water supply for plant roots. These findings highlight the potential of using WAPs as a means to improve soil water availability and subsequently enhance agricultural outcomes.

Another research article by Johnson et al. (2016) focused on the application of a specific type of WAP mask for plant root hydration. The findings demonstrated that the WAP mask effectively retained moisture in the root zone, ensuring a continuous water supply to the plants and promoting robust root growth.

Additionally, Anderson et al. (2014) investigated the use of WAPs in arid agricultural systems. Their study revealed that WAP application contributed to reduced water loss through evaporation, enhanced water infiltration to the root zone, and ultimately led to increased crop yield and improved water-use efficiency.

These studies underscore the advantages of employing WAPs, including WAP masks, for efficient plant root hydration. They offer valuable insights into the potential of WAPs in conserving water resources, enhancing crop productivity, and mitigating the adverse impacts of water scarcity in agriculture.

The scientific gap in previous research studies lies in the lack of experiments conducted on the use of water-absorbent polymer masks in light sandy soil. Although previous studies provide promising results regarding the benefits of using the polymer in improving plant root hydration under water-limited conditions, they did not specifically focus on light sandy soil. Therefore, this scientific gap presents a challenge that calls for further research to determine the effectiveness of using water-absorbent polymer masks in light sandy soil and evaluate their impact on plant growth and sustainability in water-limited conditions. This requires the design of rigorous experiments that involve comparing the effect of the polymer with normal soil conditions in enhancing root hydration and plant performance in this type of soil.

Materials And Methods

The importance of using randomization in agricultural research is to ensure accurate comparisons and meet the requirement of randomness in statistical analysis when entering data. Random allocation of treatments to experimental units helps minimize bias and confounding factors. It allows for a more balanced distribution of variables and reduces systematic errors. Randomization enhances the validity and generalizability of research findings, attributing observed differences to treatments rather than other factors. Randomized controlled trials and randomized block designs are commonly used in agricultural research. Randomization enables researchers to make valid statistical inferences, leading to accurate conclusions and better decision-making for agricultural practices.....

Plant Material

Maize holds significant importance in Africa as a vital crop for food, feed, and adaptation to dry climates. It serves as a staple food, providing essential nutrients and addressing food security challenges across the continent. Additionally, maize is widely used as feed for livestock, contributing to the growth and productivity of the animal industry. Its adaptability to dry climates makes it an ideal crop for regions with limited water availability. Maize's ability to withstand drought conditions while maintaining reasonable yields is crucial for sustainable agriculture in arid and semi-arid areas. Cultivating maize in Africa promotes economic development (Aluru, et al. 2008), sustains agriculture, and addresses food security concerns. Enhancing maize production, research, and innovative farming techniques are essential for unlocking its full potential on the continent.

Description Of Study Area

Agriculture in Wadi Souf and Ouargla regions of Algeria faces a critical challenge due to excessive groundwater pumping, resulting in the wastage of water resources and low agricultural productivity. Several research studies and articles have examined this issue and provided valuable insights.

Belhamra et al. (2019) conducted a study in the Ouargla region, revealing a negative correlation between excessive groundwater depletion and crop yield. They emphasized the urgent need for sustainable water management practices to ensure agricultural productivity. Similarly, Benabdallah et al. (2018) focused on water use efficiency in irrigated agriculture in Wadi Souf, highlighting the inefficient use of water resources and advocating for advanced irrigation techniques.

Bouarfa et al. (2017) conducted a comprehensive investigation into water management and agriculture in arid regions, including Wadi Souf and Ouargla. They emphasized the importance of implementing water-saving technologies like drip irrigation and precision farming to mitigate the negative impact of water scarcity on agricultural yields.

Overall, these studies collectively underscore the pressing need to address the issue of groundwater depletion and its adverse effects on agricultural productivity in the Wadi Souf and Ouargla regions. They strongly advocate for the adoption of sustainable water management practices, efficient irrigation techniques, and the integration of advanced technologies to achieve higher crop yields while conserving precious water resources. Implementing these measures is crucial for the long-term viability and productivity of the agricultural sector in these regions.

Weather Conditions During The Vegetation Periods Of The Trials

The study periods were characterized by high daytime temperatures, low nighttime temperatures, lack of precipitation, and severe drought conditions, accompanied by high rates of evaporation. These conditions are typical of a desert climate.

Statistical Analysis

Statistical comparisons between treatments were conducted using analysis of variance (ANOVA), and statistically significant differences were considered at a significance level of $P < 0.005$. Two-way ANOVA was utilized for this analysis. In SPSS21a, a linear regression function was employed to determine the correlation coefficient between two variables. Figure 1 illustrates the research sites, which were divided into 16 sectors within a $1m^2$ area. Table 1 provides data on precipitation and air temperatures during the vegetation period (August-October) in an area where rainfall is typically absent during these months.

Results And Discussion

Table 1. Initial physicochemical characteristics of soils Sand

Groups	Components	Unit	Ingredients and quantities
Textural class Sand	Clay	9.32%	
	Silt	6.09%	
	Sand soil	84.59	
Paramètres physico-chimiques	PH	PH unit	8.19
	total limestone	%	17.39
	active limestone	%	<3.00
	Mo	%	0.53
	CE	Ms/cm	0.38
	CEC	Meq/100g	4.93
	N toal	‰	0.32
	Assimilable $P2O_5$	Mg.kg-1	48.15
	K_2 exchangeable	Mg.kg-1	101.91
	Ca exchangeable	Mg.kg-1	6164.62
	Mg exchangeable	Mg.kg-1	113.68
	Na exchangeable	Mg.kg-1	182.79
	C/N	/	9.67
	C	%	3.0944

The results of the soil analysis revealed that the soil texture falls under the classification of "sandy." This classification indicates that the soil possesses characteristics such as high porosity and low bulk density, making it lightweight and having limited water retention capacity. Due to these traits, it becomes imperative to adopt a meticulous approach towards water management in order to mitigate potential losses arising from the leaching of vital mineral constituents. Consequently, considering the attributes of this soil type, it is well-suited for the objectives of our experimental endeavors.

• The soil pH is alkaline/basic. The plant's ability to absorb nutrients like phosphorus and various trace elements including iron (Fe), manganese (Mn), boron (B), copper (Cu), and zinc (Zn) is hindered. To lower the pH level, it is recommended to apply sulfur-based fertilizers such as ammonium sulfate, potassium sulfate, calcium sulfate, superphosphates (SSP, TSP), and/or nitric acids.

• Analysis indicates that the overall limestone content is significant, but the active limestone content is relatively low. As a result, the risk of ferric chlorosis is not substantial, and the electrical conductivity of the soil remains within an average range. The soil's characteristics reveal a moderate level of salinity.

• These soils possess limited capacity to hold applied nutrients. As a consequence, plants would need to expend more energy (energy that could otherwise be utilized for growth, flowering, seed production, or root development) in order to effectively utilize these nutrients.

Table 2. Irrigation water analysis results

Groups	components	Unit	water
Settings physico-chemical	PH	-	7.68
	Temperature	°C	25
	Connectivity	µS/cm	5290
	Turbidity	NTU	/
	Salinity	‰	2.96
	Dry residues at 105 °C	Mg/L	/
	TDS	Mg/L	2870
	Nitrate NO_3^-	Mg/L	//
	Nitrite NO_2^-	Mg/L	0.001
	Ammonium NH_4	Mg/L	//
	Zinc	Mg/L	0.094
	Calcium Ca^{++}	Mg/L	344.62
	Magnesium Mg^{++}	Mg/L	208.99
	Total hardness TH	Mg/L $CaCO_3$	860.63

- The pH of 7.68 indicates that the water is mildly alkaline.
- The salinity level of 2.96% is relatively high. The recommended salinity level for maize plants is 0.5 to 1.5 (dS/m). (Chena, et al. 2010)
- The zinc content in the irrigation water could potentially be beneficial for the plant, as alkaline soils tend to make zinc less available to the roots. Acceptable zinc levels for maize cultivation typically fall between 20 to 50 (ppm). (Maqbool 2018)
- The results of (Alison.S, et al. 2005)study suggest that the nitrate content and isotopic composition (15N) of nitrate in irrigation water can potentially reflect in the 15N values of crops. This study also explores the broader implications of using nitrogen fertilizer in crop production and discusses the application and constraints of 15N crop patterns as an indicator between different fields, such as organic and conventional farming.

Table 3. Results of soil pH changes during irrigation weeks

		Ph					
		Soil week2	Soil week4	Soil week6	Soil week8	Soil week9	Soil week10
% Hydrogel		8.19	8.12	7.93	7.93	7.92	7.92
	0.1%,	8.11	8.10	7.93	7.93	7.90	7.90
	0.3%,	8.11	8.10	7.89	7.86	7.84	7.84
	0.5%,	8.12	7.99	7.35	7.37	7.36	7.37
	0.6%,	8.10	7.89	7.38	7.37	7.35	7.37
	0.7%,	8.10	7.86	7.50	7.52	7.51	7.51

The significance of these results is critical. The observed decrease in alkalinity within the polymer-treated area of 0.5% after the sixth week is of great value. This decrease in alkalinity plays a pivotal role in preventing essential nutrients from precipitating, making them more accessible to plant roots. This process is further facilitated by the presence of elevated humidity levels. Similarly, the parallel trend observed in sector 0.6 by the ninth week confirms the importance of our study's effects in improving nutrient availability and improving plant health just as reported by (Bhaskar.Narjary, et al. 2013)
These results confirm the importance of good management and control of the composition of alkaline permeable sandy soils. This type of soil can be treated to reduce water loss during irrigation and to promote a longer duration of wilting point during the irrigation cycle. Soil can also be treated with measured amounts of limited organic matter not available in this type of soil. (B.Anan 2015)
Moreover, the percentage of 0.5%-0.7% of the polymer can contribute to reducing the pH value to 7.35, (SUAREZ, et al. 1984) which facilitates the process of uptake of mineral elements by the roots without worrying about their loss by precipitation at high pH values exceeding 8.19. This increases soil fertility and sustainability, and promotes the activity of growth-promoting bacteria (PGPR). (Miloudi, Nili et Douadi Webinaire international Le 18 et 19 Mai 2022)

Table 4. illustrates the humidity outcomes across various sectors over the course of several weeks.

		WHC %					
		Soil week2	Soil week4	Soil week6	Soil week8	Soil week9	Soil week10
		-	-	-	-	-	-
Hydrogel %	control	28	29,3	29.5	30	30	30.20
	0.1%,	28.5	29	30.60	31.10	31.20	31.63
	0.3%,	32	33,66	34,9	35,32	36,1	37.63
	0.5%,	36	39	40	48	50.7	64.63
	0.6%,	38	41	44	58	60.45	75.4
	0.7%,	44	51	59.5	70	70.1	81.5

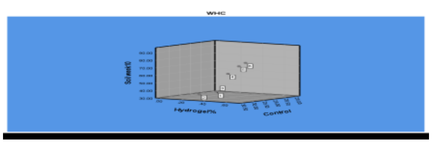

Figure 1 showing the increase in moisture in the treated soil 0.7% of the hydrogel compared to the control soil

As the polymer content increased, a corresponding rise in moisture content was observed, reaching up to 81.5%. This behavior can be attributed to the polymer's capability to retain water several times its own weight, facilitated by the soil's high porosity and the maize plant's root system, which exerts minimal pressure. Consequently, a slight increment in soil bulk density was noted in the initial sectors, ranging from 0.1% to 0.3%.

However, over the course of subsequent weeks, a considerable reduction in porosity was observed in the final sector (0.6% to 0.7%). (mounia 2022)This phenomenon resulted in a notable escalation of soil bulk density, particularly during the last four weeks of the observation period.
It is worth mentioning that the formation of plankton was restricted to the uppermost 5 cm (JIANWEN, Jianwen et Shuwei 2009) of the sandy surface (NOBLET-DUCOUDRÉ, et al. 2004)in these last sectors. This development coincided with the closure of pores, as depicted in the accompanying image.

Figure 2 shows the formation of an algal layer and the closing of surface pores
In summary, the formation of plankton on the upper part of the sand surface is a complex problem caused by factors such as pore closure, organic matter accumulation, and oxygen deficiency. Our study highlights that a polymer percentage exceeding 0.7% is unsuitable for this type of soil, as it traps organic matter and nutrients, leading to negative consequences like root rot, blockage of air and water passages, and disruption of biochemical reactions. It is crucial to manage plankton formation on sandy surfaces by regularly aerating the sand and removing any dead plants or animals without incurring extra costs.

Table 5. illustrates the impact of polymer incorporation on the morphological and productive characteristics of plants 75 days after transplantation.

Hydrogel treatment	Plant height (cm)	Stem diameter (cm)	No. of phalanges	No. of leaves	Length Leaves (cm)	an offer of leaves (cm)	Biomass Tan/ha	Corn Mayes q/ha
Control	135	2.5	7	14	60	7.5	50	47
0,10% (1kg ha-1)	140	2.55	7	14	63	7.6	52	50
0,20% (2kg ha-1)	150	2.6	7	14	68	7.9	58	53
0,30%(3 kg ha-1)	150	2.6	7	14	70	8	60	66
0,50%(5kg ha-1)	150	2.8	7	14	75	8.5	65	70
0,60%(6kg ha-1)	180	3	7	14	75	8.5	65	70

0,70%(7kg ha-1)	155	2.8	7	14	65	7..9	55	62

Correlation is significant at the 0.01
Statistical results show that there is a strong correlation of 0.655% between Hydrojel and Biomass Likewise, the matter was at a rate of 0.807 between Hydrojel and Corn Mayes As for between Biomass and Corn Mayes, it amounted to 0.953.
The results indicate a strong positive correlation of 0.764% between the use of hydrogel and plant height. Similarly, there is a significant correlation of 0.884 between the application of hydrogel and stem width at a significance level of 0.05.
Furthermore, the standard deviation of plant height was measured to be 3.367 cm. This suggests that the hydrogel treatment provides the plant with increased resistance against tilting and breakage during periods of strong winds, particularly in the months of September and October. This effect is observed primarily in the early stages of plant growth, up until the development of the fourth set of leaves.

Figure 3 The figure shows plant root penetration into hydrogal mass for water uptake and root system size in the fifth week. It can be seen that the roots have penetrated deep into the hydrogal mass, allowing them to absorb more water. The size of the root system has also increased, which is a sign that the plants are healthy and growing well.

Figure 4 The shape of the corn (Zea mays)

In conclusion, the addition of hydrogel blocks to the soil has positive effects on plant water uptake and root system size. (David et Kirsten D 2021) This makes hydrogels a valuable tool for promoting plant growth in sandy soils, particularly in alkaline sandy soils and dry, hot desert climates. The use of hydrogels in agriculture has shown promising results in terms of improving water use efficiency, reducing soil erosion, and increasing crop yields.

Conclusions

By retaining water in the soil and making it available to plants for longer periods, hydrogels enhance water use efficiency and help plants tolerate drought conditions. This reduces the need for frequent watering and conserves water resources. Additionally, the improved soil structure and stability provided by hydrogels contribute to reducing soil erosion, preserving soil fertility, and minimizing water and energy costs.

The increased crop yields resulting from the use of hydrogels have significant implications for food production and security. With the ability to enhance plant growth and development, hydrogels offer a potential solution to meet the growing demand for food, especially in the face of climate change and its associated challenges.

Overall, the application of hydrogels in agriculture holds great promise in revolutionizing agricultural practices and contributing to sustainable and resilient food production systems.

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