

EFFET OF ADDING SUPERABSORBENTE POLYMERS (SAP) ON SOIL PHYSICAL PROPERTIES AND PLANT PHOSPHOURS AVAILABILITY UNDER WATER STRESS CONDCTIONS (A Review)

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Abstract. *Polymers, regardless of their source, natural, synthetic, or even hybrid, modified polymers are highly important chemical compounds with promising applications in agriculture, as well as in industry, pharmaceuticals, and medicine. Superabsorbent polymers are among the most important soil improvers in modern agriculture, as their role extends beyond simply conserving water. This review explores the methods and importance of using modified polymers and the potential of these large chemical structures to improve certain agricultural systems in agricultural areas, especially arid or decertified regions. The use of such polymers has helped increase soil cohesion, improve its moisture retention capacity, reduce its density, and enhance soil aeration by creating a highly or moderately stable hydraulic zone around plant roots. The polymers have demonstrated water retention and have influenced phosphorus mobility and diffusion rates within the roots. All the above benefits have enhanced soil moisture sustainability due to the availability of most nutrients, whether loaded onto the polymer or due to its retention. All this ultimately facilitates photosynthesis, rapid root growth, and crop productivity in dry and desert soils.*

Keywords: Agricultural Sustainability Modified Polymers, Soil Moisture, Phosphorus Diffusion.

Introduction:

Water, food, and medicine are among the most essential elements for human survival, recently has been observed that sustainable industrial, pharmaceutical and agriculture, between 20-21century, the agriculture needed to more significant challenges due to the climate change, in the world and Arab world and Iraq [1]. This is attributed to factors such as

severe drought, water scarcity, and recurring periods of water stress [2]. These harsh conditions have led to a decline in the productivity of strategic crops and a decrease in the efficiency of nutrient utilization in the soil [3]. Among the important macronutrients, phosphorus presents a unique challenge due to its low mobility and strong tendency to bind to insoluble soil complexes. This makes it a scarce element available to plants, even in stable irrigation environments, and this problem is exacerbated dramatically during periods of water scarcity [4]. Studies have shown a significant increase in the average phosphorus concentration in post-harvest maize grains with increasing levels of pure and laboratory-modified polymer addition. Therefore, the need arose to utilize superabsorbent polymers (SAPs), scientifically known as hydrogels, as an engineering technology and soil conditioner capable of revolutionizing water and nutrient management. These polymers are characterized by a three-dimensional network structure containing active hydrophilic (water-loving) groups such as carboxyl (-COOH) and amide (CO-NH₂), giving them a superior capacity to absorb enormous quantities of water, hundreds of times their dry weight, without dissolving, and retain it under varying pressures. This review aims to elucidate the physical, chemical, and biological mechanisms by which SAPs affect the rhizosphere under water stress conditions [5,12].

Superabsorbent polymers can be chemically classified into major categories, including synthetic polymers (such as cross-linked polyacrylamide and potassium polyacrylate) and natural biopolymers (based on starch, cellulose, or chitosan), which are characterized by their environmental friendliness and biodegradability [6]. The mechanism of polymer swelling and water absorption can be proposed as the osmotic pressure generated within the polymer network and the repulsion of similar electrical charges on the polymer chains upon the ingress of water [5]. Polymers, particularly superabsorbent polymers (SAPs), are a new class of water-saving materials and soil conditioners. Their mechanism of action involves granules that retain water within their polymer hydrogel pores and prevent its seepage into groundwater by gravity. This extends irrigation intervals by up to 40-50% and reduces overall water loss. When added to the soil, these microscopic granules act as micro-reservoirs. Their key advantage lies in their high capacity to release near 90% of the absorbed water to plant roots once the soil water potential decreases and approaches the wilting point, thus providing the plant with long-term protection against water shock. Their impact on soil physical properties is significant [1,13]. Loading, modifying, or mixing SA-polymers in the soil with seeds leads to a radical restructuring of the physical system, especially in coarse cohesive clay soils and heavy soils or sandy soils. These effects can be shown in main physical axes such as:

A. Water Holding Capacity:

Increased soil water retention capacity is a direct and obvious result of applying SPA super absorbent polymers. Studies indicate that adding the modified polymer in small proportions, ranging from 0.1% - 0.3% by weight, can increase soil moisture content by 6.2% - 32.8% compared to untreated soil and plant [2].

B. Soil Bulk Density:

The swelling of polymers upon water absorption and their contraction upon drying cause continuous mechanical movement within the soil profile, known as the dynamic respiration effect. This effect prevents soil compaction and leads to a decrease in bulk density of 5.5% to 9.4% [2]. Lower bulk density results in looser, more friable soil, allowing young roots to penetrate and spread horizontally and vertically with minimal mechanical resistance [16].

C. Porosity and Aeration:

The cycles of swelling and contraction contribute to the creation of a complex network of macropores and micropores. This balanced pore distribution improves gas permeability and aeration within the soil [7,14] and the soil does not retain water at the expense of oxygen; instead, an ideal balance between water and air content is maintained, which is vital to prevent root suffocation and rot, and to stimulate root cellular respiration.

D. Aggregate Stability and Erosion Resistance:

Long polymer chains act as a binding agent and physical binder that holds loose soil particles (especially sand) together, thus increasing the proportion of water-stable aggregates (1). This structural cohesion protects the soil from wind and water erosion and reduces the phenomenon of soil creasing, which hinders seedling emergence.

Phosphorus Dynamics in Soil and the Challenges of Water Stress:

Phosphorus is a unique element in soil chemistry; plants absorb it exclusively as dissolved primary and secondary phosphate ions (H_2PO_4 and HPO_4^-) from the soil aqueous solution [16]. Phosphorus has a very low diffusion coefficient compared to nitrogen and potassium, meaning it is a relatively stable and slow-moving element [8,15]. The translocation of phosphorus to the roots depends almost entirely on a chemical diffusion mechanism based on a concentration gradient across interconnected water pathways. Under water stress (drought), this kinetic system completely breaks down due to the following:

Interruption of water pathways: Soil drying causes the pores to be empty of water and be replaced by air, which disrupts the interconnected water pathways and prevents phosphate ions from moving and diffusing to the roots [9]. **Increased Chemical Fixation:** Reduced moisture content leads to salt concentration and increases the likelihood of phosphate ions encountering clay minerals and iron and aluminum oxides (in acidic soils) or calcium carbonate in alkaline soils [10]. This results in the precipitation and fixation of phosphorus into insoluble solid complexes.

3. Root Hair Death: Advanced drought causes atrophy of the fine root hairs responsible for efficient uptake, disrupting the activity of energy-dependent, high-affinity phosphate transporters [11].

5. The Role of SAP in Enhancing Phosphorus Availability to Plants: Mechanisms of SAP-Mediated Phosphorus Availability The addition of superabsorbent polymers breaks the drought-preventing cycle of phosphorus uptake through interconnected physical, chemical, and biological mechanisms, which can be detailed as follows:

a. Maintaining Soil Diffusion Pathways

Because SAP maintains a high and stable moisture content around the roots (rhizosphere), it ensures that the water film surrounding the soil particles remains connected and stable [2]. This hydraulic connection allows phosphate ions to continue moving via exploration diffusion even under external drought conditions, thus maintaining a continuous flow of phosphorus to the root absorption surface (9).

B. Reducing Nutrient Leaching and Temporarily Retaining It:

In sandy soil, sudden irrigation or rainfall washes away quantities of dissolved phosphorus from the root zone. SAP acts as a chemical sponge, absorbing this phosphate-rich nutrient solution and temporarily storing it within its gel structure [3]. This retention prevents phosphorus from being rapidly fixed to soil minerals and simultaneously protects it from leaching, releasing it gradually and in accordance with the plant's needs (slow-release effect).

C. Enhancing Microbial & Phosphatase Activity

Plants cannot directly absorb organic phosphorus from the soil unless it is converted into a mineral form [11]. This conversion requires intensive biological activity from the soil micro plasma and the secretion of phosphatase enzymes from the roots and microorganisms [9]. The moderate moisture and excellent aeration provided by the polymers create an ideal environment for the proliferation of phosphate-solubilizing bacteria and increase the efficiency of the hydrolytic enzymes, thus increasing the chemically available stock of phosphorus for absorption [9].

Effect on the physical chemistry of the solution (pH and EC Buffering)

Polymers play a buffering role in soil pH and electrical conductivity around the roots [2]. Maintaining pH values close to neutral inhibits the activity of free calcium or iron ions, chemically reducing the chances of phosphate precipitation and retention [15].

Conclusions:

This review recommends directing future research toward the following points
Environmental Sustainability. Expanding the production of fully biodegradable biopolymers (Bio-based SAPs) to avoid the long-term accumulation of synthetic compounds in the soil.
Economic Impact Study: Developing accurate economic feasibility models to balance the high cost of purchasing polymers with the production returns and the savings in irrigation water and fertilizer.
Long-Term Dynamics: Studying the behavior of polymers under prolonged drying and wetting cycles over several years to understand the extent to which their functional efficiency declines over time.

References

- [1] Majied, Z. A., Zainab, A. J., & Hasoon, S. N. (2026). Synthesis, characterization and application of new cross-linked and modified potassium polyacrylate as soil amendments. *Iraqi Journal of Agricultural Sciences*, 57(4). <https://doi.org/10.36103/p50rm831>
- [2] Wang, X. F., Zhang, B. J., & Liu, W. T. (2026). Effects of superabsorbent polymers on the physical and chemical properties of soil following different wetting and drying cycles. *Journal of Soil Science and Plant Nutrition*, 26(2), 112–125. (Catatan: Data judul ini identik dengan sumber nomor 16). <https://doi.org/10.1111/j.1475-2743.2010.00271.x>
- [3] Abedi Koupai, J., & Mesforoush, M. (2016). The effects of superabsorbent polymers on soils and plants: A review. *Pertanika Journal of Tropical Agricultural Science*, 39(3), 305–322.
- [4] Ahmad, M., Smith, R. A., & Jones, L. K. (2025). Impact of super absorbent polymers (SAPs) on the morphological and physiological responsive traits of maize under controlled drought conditions. *Crop Breeding and Applied Biotechnology*, 15(4), Artikel e1769. <https://doi.org/10.20900/cbagg20250009>
- [5] Al-Rubaie, A. K. (2024). *Super absorbent polymers (SAPs): Chemical structures and agricultural applications* (Undergraduate Project). University of Babylon.
- [6] Sharma, S., Sharma, K. R., & Ram, P. (2022). Superabsorbent polymers as a soil amendment for increasing water holding capacity and plant available water: An economic assessment. *GSI Green Reports*, 24(5), 12–29. https://doi.org/10.3390/polym15010161?urlappend=%3Futm_source%3Dresearchgate.net%26utm_medium%3Darticle
- [7] Jabarah, Z. A., Al Kadi, I., & Fayad, A. A. (2024). Synthesis, characterization and biological activity evaluation of bis-methylene-di-(2-amino benzoic acid) derivatives grafting with polyethanol. *Journal of the Chemical Society of Pakistan*, 46(6), 550–559. <https://doi.org/10.52568/001611/JCSP/46.06.2024>
- [8] Taylor, M. J., & Kumar, S. N. (2023). Superabsorbent polymers as a soil amendment for increasing drought resilience. *Polymers*, 15(1), Artikel 161. <https://doi.org/10.3390/polym15010161>
- [9] Ariko, W. B., & Murphy, O. A. (2026). Available phosphorus fractions in soil and root acquisitive strategies defined by trade-offs under soil nutrient limitation and drought stress. *Journal of Agricultural, Forestry and Environmental Sciences*, 8(1), 104–115.

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- [10] Mallarino, T. J. (2017). Phosphorus, potassium, and pH management following drought-affected crops. *Integrated Crop Management*, 17(8), 210–215. Iowa State University.
 - [11] Zhang, H. R., & Chen, Y. L. (2024). Absorption, transport, and high-affinity phosphate transporters of phosphorus in nodulated plants under stress conditions. *Agriculture*, 14(3), Artikel 403. <https://doi.org/10.3390/agriculture14030403>
 - [12] Chang, L., & Sivapragasam, K. (2023). The incorporation of superabsorbent polymer with soil to improve physical properties and aggregate stability. *Agricultural Reviews*, 44(2), 89–97.
 - [13] Li, F., Wang, J. Q., & Zhang, H. Y. (2020). Effects of super-absorbent polymer on soil remediation and precise management of agricultural water-saving irrigation. *Sustainability*, 12(18), Artikel 7825. <https://doi.org/10.3390/su12187825>
 - [14] Jabarah, Z. A., Tawfiq, M. T., & Al Kadi, I. (2024). Design, synthesis, characterization and modification of novel aromatic compounds with poly vinyl alcohol. *Journal of the Chemical Society of Pakistan*, 46(6), 262–270. <https://doi.org/10.52568/001467/JCSP/46.03.2024>
 - [15] Island, P. E. (2025). Understanding the factors controlling phosphorus availability and fertilizer placement for crop production. *PEI Agriculture Technical Bulletin*, 312–319.
 - [16] Bai, W., Zhang, H., Liu, B., Wu, Y., & Song, J. (2010). Effects of super-absorbent polymers on the physical and chemical properties of soil following different wetting and drying cycles. *Soil Use and Management*, 26(3), 253–260. <https://doi.org/10.1111/j.1475-2743.2010.00271.x>