

Hydrogel Polymer: A New Tool for Improving Agricultural Production



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Summary

Hydrogel polymers could play an imperative role in the development agricultural sector, commonly hydrogel polymers as soil conditioner due to their high-water reserve capacity, therefore, polymer increase water use efficiency, and improve growth and fruiting of various crops particularly in arid and semi-arid regions, there are different types of polymer, however, Super Absorption Polymer considered the most important types of polymers currently used in agriculture due to high absorb capacity and retain water. There is various applications of hydrogel polymer in agriculture include water holding, carrier for nutrients and pesticides, seed coating, reduce soil erosion, and food additives. There are different benefits of Hydrogel polymers in agriculture like increasing water-use efficiency, provide a regular supply of water and nutrients to plants, ultimately implement plant growth and increase productivity of various crops like Date palm, Navel orange, and field crops, improve soil characters, decrease soil erosion and reduce desertification.

Keywords: Hydrogel Polymer; water-use efficiency; plant growth; Date palm; Navel orange

Introduction

Under a limitation in available freshwater and arable lands resources, which accompanied with rising population worldwide which expected to reach about 9 billion by 2050, and 11.2 billion in 2100[1], therefore, the food production must be doubled three-fold to provide adequate food, through increase the productivity of different crops vertically and horizontally to provide enough food quantity and filling up of the gap between production and consumption of food crops, there is more attention to produce enough food to feed every one of us by using all available techniques. Water management is one of the most important challenges facing world, particularly in arid regions like the Arabian region which suffer from a severe shortage of freshwater resources, so, the use of the available materials and techniques like Hydrogel polymer to maximize water use efficiency and increase crop productivity have more attention during the current and coming decades [2]. Hydrogel polymers used in different fields like health products, cement industry, pharmaceutical production, and agricultural sector. Hydrogel polymers play an imperative role in the agricultural sector, it's use as a soil conditioner for providing a proper climate around the plant when soil near the root zone starts to dry up, improving irrigation water efficiency, and extend irrigation intervals.

The hydrogel polymer has high capacity to absorb large quantities of water and keep it for a long period under drought conditions,

polymer could absorb and preserve quantity of water many folds of their weight, it reduces water loss and increase irrigation intervals, also, polymers implement some soil physical properties [3]. There are various applications of hydrogel polymer in agricultural sector i.e. water reserve, seed coating, reduce soil erosion, food additives, tissue culture, as structural materials (produce mulches) [4]. Previous research indicated that the application of low concentrations of Super absorb polymer (SAP) by 0.001% to the soil implement the physical properties of the soil as the aeration, reduced the rate of agglomeration and fusion between soil particles [5], therefore, hydrogel application may be a proper technique to increase water and fertilizers use efficiencies in arid regions. The aim of this work discusses the role of hydrogel polymer in agricultural sector in the Arabian region and the different applications of hydrogel polymer to improve plant growth, increase total yield, and improve fruit quality.

Hydrogel Polymer

The Hydrogel polymer is inert materials affect physical characters of soil such as water holding capacity, soil aggregate, soil permeability, also, affect soil density, structure, texture, and release water through the soils [6].

The hydrogel polymer is a soil conditioner able to retain water and nutrients, and releases back to the plants when surrounding soil

near the root zone of plants starts to dry up. These materials improve water-use efficiency, and extend irrigation intervals, increase soil's water-holding capacity up to 2 to 4 times and soil porosity, also, provide proper conditions in root zone through supply water and nutrients for plant, improving plant viability, improve root development and ventilation [3], also, improving the growth of seedlings, and reduce irrigation water quantities, so, prolong irrigation intervals [7].

There are two factors that determine the amount of water absorbed by the polymer:

- i. Availability of large quantities of the carboxyl group which is linked to the polymer side chain and which water molecules can bind.
- ii. The structural composition of the polymers and the availability of proper pores in its structure allow the absorption of a large amount of water [8].

Polymers are classified into different categories as follow:

a) According to their Components

- i. Natural Polymers: it is environmentally friendly materials produce from natural plant materials such as proteins, starch, cellulose, rubber, or animal products such as Chitosan and Gelatin.
- ii. Synthetic Polymers: Synthesized by either cross-linking where polymer molecules are bonded together by covalent bonds or ionic bonds using gamma rays [9].

b) Depending on their composition

- i. Homogeneous Polymers: It consists of one type of polymer chain Homopolymeric hydrogel [10].
- ii. Mixed Polymers: It consists of two or more types of copolymeric hydrogel [11]
- iii. Multipolymer: this kind of polymer considered the most important group in polymers and consists of two types or more of natural and synthetic polymers in one compound [interpenetrating polymeric hydrogel] (IPN) [12].

c) According to the Physical Properties

- i. Crystalline Polymers "Solid particles"
- ii. Amorphous polymers "Liquid form"
- iii. Semi-crystalline polymers also called "Glassy polymers" [13]

Types of Hydrogel Polymers Used in Agriculture

All types of hydrogel polymers absorb and retain huge quantity of water and nutrients reach up to hundred times of its original size, polymer provides water and nutrients to the plant when the soil around the root zone began dried [14]. There are two main types of polymer used in the agricultural field as follows:

a) Water-soluble Polymers:

This type of homogeneous and mixed polymers includes linear chains [15] including:

- i. Poly (ethylene glycol).
- ii. Poly (vinyl alcohol).
- iii. Polyacrylates.
- iv. Polyacrylamide.

b) Gel-forming Polymers

This the main type in agricultural sector, it's non-dissolve in water and used in the agriculture from the eighties of last century, the crystals absorb water until saturation, it could absorb up to hundred times of its original size, and release water and nutrients as required by the plant when nearby soil around root zone of plants dried, when the hydrogel is mixed with the soil, it forms associate amorphous gelatin-like mass on hydration and is adept of absorption and desorption for an extended time, thus acts as a slow supply of water within the soil [16]. There is variation between different kinds of polymer in water absorb ability, also, the amount that can be released to the plant according to the characteristics of their compositions, there are types of polymers absorb up to 300 fold their volume of water; and other type has higher absorb capacity reach up to 100 times its original weight in short time and release the absorbed water under drought condition which provides large amounts of water to plants [16,17]. However, Super Absorption Polymer (SAP) is one of the most important types of polymers currently used in agriculture due to their characters like high absorb capacity and retain water, where the capacity of 1 g of dry to absorb from 400 to 500 g of water; therefore, the proper use of (SAP) increase water and nutrients use efficiencies, improve seed germination and plant growth [18]. Slow-release fertilizers may be added to polymers to increase usage efficiency and reducing the production costs, also, there are different pesticides can be loaded into polymers, to protect seedlings from soil pathogens [19].

Hydrogel Polymer and Agriculture

Polymer application is a very significant issue in both research and applicable fields due to their applications in different fields like pharmacy products, cement industry, and agriculture. In the agricultural sector polymer play an important role, the polymer used for different purpose as soil conditioners in sandy soil, seed coating, carriers for slow-release fertilizers, and carrier for pesticides and herbicides [18,19]. Polymer mixing into soil before cultivation or in a circle around the tree before the beginning of the growing season [20], in some cases, could be sprayed on the soil surface before planting seeds [17].

Advantages of Hydrogel Polymer in Agriculture

Hydrogel polymers have been widely used globally over the past two decades in the agricultural sector for many reasons:

- i. Improve growth and crop productivity of Navel orange sandy soil conditions [21], increase total yield of wheat [22], improving the growth of palm trees, particularly in sandy soil [23].
- ii. Increasing seedling survive ratio [24], enhancing root growth under stress conditions [25].
- iii. Increase water-use efficiency and provide a regular supply of water and nutrients to plants [18],
- iv. Increase the soil's ability to reserve irrigation water for as long as possible [20], reduce soil erosion [26] and reduces desertification of agricultural lands and contribute to sustainable agricultural [14]
- v. Improve nutrients efficiency [25], provide water and nutrients for the plant during the dried period, and improve the nutritional status of the plant [18].
- vi. Reduce the fertilizers loss by leaching, and protect environmental by reducing soil and water pollution [27]

There are different methods to use polymer depending on the type of cultivation as follow:

- a) New farm: Polymers are mixed with soil and covered by wet soil before seedlings cultivation [17].
- b) Fruiting Orchard: it is preferable to added polymer in the soil under irrigation lines at proper depth in both sides of trees [21].
- c) Field crop: polymers are added in the line during the preparation of the soil for planting so that they are covered with planting and be close to the roots to provide water and nutrients for plants [24,28].
- d) Polymer spraying: can be sprayed polymers on the soil surface directly in some cases.

Effect of Hydrogel Polymer on Soil

Polymers application improving soil properties as follows:

- i. Increasing the soil holding capacity [29].
- ii. Increasing the efficiency of irrigation water use, reducing the quantities of irrigation water, prolonging irrigation intervals, so, reducing irrigation costs [30].
- iii. Increase the field capacity of light soils for a long time [14].
- iv. Improving the permeability of heavy soils as a result of reducing the fusion of granules [31&32].
- v. Reduce soil erosion [26].

Some Polymer Applications

The use of polymer in agriculture has great attention in the recent decades particularly under arid regions conditions, it provides solutions to water shortage and hot climate which considered the main challenge facing the agricultural sector in the current era [33],

through increasing water use efficiency [34], reduce environmental pollution [35], and sustain the natural resources, also, polymers increase the efficiency of nutrients and pesticides [36].

Polymer and Palm Trees

In the current decades, there is more attention of using hydrogel polymers in date palm cultivation particularly in the Gulf region, where the palm is one of the major elements of the agricultural sector. In Date palm farms the age and size of the tree determined the polymer quantity for each one, usually small palm required about 300 g, however, the fruiting one require up to 500 g [23].

Increasing the Productivity of Date Palm Farms

Polymer application in fruiting date palm farms improving the growth and productivity of palm trees, the polymers providing moisture constantly in the root zoon which supply water and nutrient regularly and reduce negative effects of harsh climate conditions such as drought and high temperature [37]. Polymer application could be a novel key to development the date palm cultivation in the Arabian Gulf region and Egypt and improve fruit quality to compete in the global market.

Increase the Survival Rate of New Seedlings

The growth and success of different seedlings after planting depending on availability of proper soil moisture and nutrients with regular irrigation, therefore polymer reducing the negative effects of drought and increase survive ratio and improve plant growth [38].

Increasing Leaf Water Content of Date Palm

The addition of polymers to the soil around date palm tree increases leaf water content about (4-16%), which enhance date palm tolerance for drought and increase the vegetative growth and fruiting of the palm [23].

Improve Navel Orange Productivity in Sandy Soil

Application of polymer (Hydrogel composite) improves vegetative growth and increase total yield of navel orange (*Citrus sinensis* L.) under sandy soil conditions [21].

Important Precautions During Using Polymers

In fruiting orchards: polymer applies in a circle around the tree to avoid damage part of the root system and must cover to protect from sun heat.

- i. Avoid adding polymer to dry soil, polymer need a proper percentage of moisture before the addition.
- ii. Irrigation directly after application to activate the polymer.
- iii. Deciduous trees orchard: preferable, polymers application during the dormancy period.
- iv. Field crop and Vegetables: polymer applies before cultivation and mixed with soil and covered after addition to avoiding the negative impact of weather conditions.

Conclusion

In the agricultural sector the main usage of polymers as soil conditioner due to their high-water holding capacity under subsequent wetting and drying cycles, also, polymer increase water use efficiency, improve soil characters, decrease soil erosion and reduce desertification, and improve vegetative growth and fruit yield of different crops particularly in arid and semi-arid regions such as the Arab region which suffer from water shortage. This positive influence due to improving water availability, increasing the availability of nutrient supply, and implement the efficiency of macro-nutrients. The use of polymers in different crops like date palm cultivations, Navel orange orchards and different field crop has a promise effect on growth and productivity of various crops.

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