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Impact of hydrogel polymer in agricultural sector

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Abstract

The use of water holding amendments like hydrogel polymers material for enhancing water and nutrient use efficiency will become more important over time, especially in arid and semiarid regions with limiting water availability, the hydrogel able to retain water and plant nutrients and release it to the plants when surrounding soil near the root zone of plants start to dry up. Nowadays water management is considered one of the major challenges for all countries in arid and semi–arid regions, in fact, by 2030, global water demand is probable to be 50% higher than today, resulting in water scarcity, in the same time agricultural sector used over 70 percent of freshwater in most regions of the world.

Research evidence suggests that when the soil is treated with water hydrogel composite the water volumetric content of the soil increases significantly and when the surrounding soil dries, the stored water is released back slowly into the soil.

The hydrogel increase efficient water consumption, decreasing irrigation costs and increasing irrigation intervals, also, implement soil's water holding capacity and soil porosity, providing plants with eventual moisture and nutrients as well as enhancing plant viability and ventilation and root development which provides a conducive atmosphere for better growth of plants and finally increases crop yield.

Hydrogel has various characters like the high swelling and the slow water retention encourage their use as safer release systems for fertilizers and as a soil conditioner in agricultural applications. Hydrogel polymer is particularly valuable in agricultural sector since they can retain water and reduce land erosion.

There are various original publications, papers, reviews, and book chapter focused on the synthesis, properties, and applications of hydrogel polymer. The objectives of this work are to explain the role and applications of hydrogel polymer in agricultural sector i.e. improving soil characters, increasing nutrient use efficiency, and the management of irrigation to reduce water consumption and conservation.

Keywords: hydrogel polymer, soil conditioner, arid region, crop yield, nutrient efficiency

Introduction

Expanding world demand for water, combined with the impacts of climate change, is already micturition deficiency a reality in arid and semi–arid several regions, also, there's a contest of the limit amount of obtainable water from completely different sectors i.e. urban needs, industrial sector and agricultural sector that thought of one in all the most important consumption of water, within the same time irrigation water stress is one in all the most important limiting factors that have an effect on crop and fruit growth and productivity. Globally, over seventy percent of fresh water is used for agriculture; by 2050 feeding a planet of nine billion individuals would require associate degree calculable fifty percent increase in agricultural production and a fifteen percent increase in water withdrawals.[1]

Arid regions countries are intense a lot of and a lot of water from virtual water to supply daily needs, the usage of latest technologies for enhancing water and nutrient use potency can become a lot of necessary over time, particularly in arid regions with limiting water availability. Polymers play important role in agricultural sector and use as structural materials for creating a climate beneficial to plant growth and increasing irrigation water efficiency.[2]

During the last decade, hydrogels have been used broadly for improving water availability for plants, by increasing water holding properties of soil and growing media, application of hydrogel polymers may be a proper technique to enhance water and fertilizers use efficiencies,[3] it might absorb and store water many times of their weight and work as a tank to forestall water waste and increase irrigation potency, also, superabsorbent polymers improve some soil physical properties.[4]

The hydrogel polymer compound seems to be extremely effective to be used as a soil conditioner in agricultural sector, to boost crop tolerance and growth in a sandy or light–weight gravel substrate. Hydrogel polymer has been established as a soil conditioner to reduce soil water loss and increase crop yield.[5]

There are numerous papers, article, short communication, and monographs focused on the characters and applications of hydrogels polymer. This work focused on the role and application areas of the hydrogel in agriculture i.e. water usage and the management of irrigation to reduce water consumption and conservation. In this regard, this work provides a comprehensive literature on the role of the hydrogel in agricultural sector. More than two hundred references are cited in the whole text.

What's polymer hydrogel?

Polymer hydrogels is classified as a Super absorbent polymer, it's measure visco–elastic, loosely crosslink, and hydrophilic three–dimensional networks of versatile polymer chains with unconnected ionic purposeful group that may absorb an oversized quantity of water or alternative biological fluids in an exceedingly short time and retain them beneath sure conditions and considered as a soil conditioner which hold up to thousand times of their existing weight of water and increase crop yield.[6,7]

Hydrogel polymer have the ability to absorb water is quite a hundred times its original weight within short period of time and desorb the absorbed water under stress condition.[8]

There are three groups of a polymer as follow:

a) Starch–polyacrylonitrile graft polymers (starch co–polymers),

b) Vinyl alcohol–acrylic acid co–polymers (polyvinyl alcohols)

c) Acrylamide sodium acrylate co–polymers – cross–linked polyacrylamides[9]

Mode of action for polymer hydrogel

When the hydrogel is mixed with the soil, it forms an associate amorphous gelatin–like mass on hydration and is adept of absorption and desorption for an extended time, thus acts as a slow unharness supply of water within the soil.

The hydrogel particles are also taken as "miniature water reservoir" in the soil and water will be detached from these reservoirs upon the root mandate through osmotic pressure difference.[10] Due to the respectable volume reduction of the hydrogel as water is released to the plant, hydrogel creates at intervals the soil, free pore volume providing further space for air and water infiltration, storage and root growth.[11]

Hence hydrogel polymer deed as a slow–release basis of water and dissolved fertilizers in the soil (Figure 1).

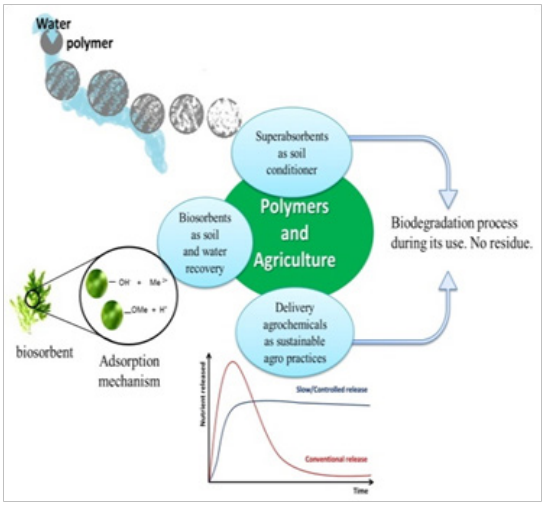

Figure 1 Polymer mechanism in agriculture.[11]

Water conservation by hydrogel creates a buffered setting being effectiveness in short–run drought tension and losses reduction in institution phase. Ability in water consumption and dry matter production square measure positive crop reactions to hydrogel, once polymers are mixed into soil, they preserved vast quantities of water and nutrients reach up to hundred times of its original weight and conserve regarding ninety–five percent of keep water out there for plant absorption,[12] which are released as required by the plant, therefore, plant growth was enhanced with limited water supply, however, in rainfall region adding hydrogel polymer to soil implement soil infiltration rates.[13]

Hydrogel usage in agriculture

The existence of water in the soil is vital to various plant kinds and vegetation, the use of hydrogel in the agricultural sector is gaining acceptance from scientist, hydrogel provided solutions for the shortage in fresh water for agriculture which is to increase soil and water productivity without destroying the environment and the natural resources. Polymers hydrogel actually influence soil permeability, density, structure, texture, and evaporation and infiltration rates of water through the soils.[14] Hydrogel releases water and nutrient to the plants when surrounding soil around root zone of plants starts to dry up, plant growth is mainly a utility of fertilizer and water for prolonging the survival of plants under drought conditions,[15] scientists targeted at develop new tools for increase the efficacy of nutrient relief to the plants, slow release fertilizers considered an actual method to decrease fertilizer loss by the effect of rain or irrigation water, supply nutrition for a long time, and to minimize amount of fertilizers used[16] Granulated nutrients encapsulated by various materials like carboxymethyl chitosan hydrogels have been developed,[17] application of hydrogel polymer to the soil improving the availability of water in the substrate, enhancement seed germination, increase leaf water content and leaf chlorophyll content under arid region conditions.[18] Improving root development, plant growth, minimize nutrient losses by leaching and contribute to improving soil penetration, decreased the adverse effects of water stress after plant transplantation and implement development of seedling's parameters.[19]

Polymer hydrogel slow release acts as carriers of nutrients in the soil and considered as a key approach for improving fertilizers efficiency through reducing the nutrient losses by leaching, reducing the cost, and decrease pollution for the environment, hydrogels are very useful in agriculture as they can retain water and avoid soil erosion.

Effect of the hydrogel in retaining the water

Due to water resource crisis, water–saving agriculture is essential for sustainable development, Hydrogel polymer improve water penetration rate, hydrogel polymer have been used as water retaining material in arid and semiarid region under limitation of supplementary irrigation sources and salinity conditions which affect negatively on gradual growth and productivity of crops, hydrogel used to increase a water reservoir near the root system, increased the field capacity of different soils, also, increased both water available for plants and the period of its availability.[4]

Moreover, previous studies point to good ability of hydrogel polymer for increasing water retention, water uptake and water use efficiency which help reduce water stress of plants and implement plant performance resulting in increased growth.[20]

Hydrogels are also claimed to reduce fertilizer leaching, which seems to occur through interaction of the fertilizer with the polymer, polymer is also being considered as a potential carrier for protected agent like pesticides and herbicides.[21]

The use of hydrogels is particularly useful in dry and semi–dry regions where irrigation water is limited.[22]

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Effect of hydrogel on plant growth

Seed germination and seedling establishing considered the most important phases in the initial growth of any plant kinds; the successful establishment depends on available water and is regularly restricted by low level of soil moisture mainly in arid and semi–arid regions.[23]

Hydrogel polymers enhancement plant growth by swelling water holding capacity in soil and prolonged the time till reaching wilting point which increasing plants survival under water stress,[24] decreasing fruit drop ratio, and may lead to expanded total yield and fruit weight under various severity conditions.[25]

Furthermore, added hydrogel to the soil increased the plant circumference; this may be due to increasing the amount of available water in the root zone, which inferring longer irrigation intervals.[12]

Moreover, application of hydrogel polymer used to create a water reservoir near the root zone of plants, decrease osmotic moisture of soil, improve the capacity of plant available water, enhancement plant growth and increase whole yield and decrease production costs of crop (Figure 2), uses of hydrogels improving plant viability, seed germination, ventilation and root development mainly under arid environments,[26] additionally, with respect to the growth of the plant, it's been noticed that there's a significant increase in the growth of the plants when usage of the hydrogel.[27]

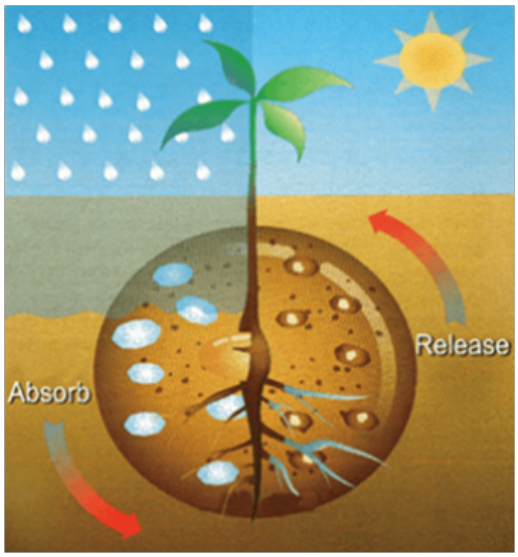

Figure 2. Hydrogel swelling water for plants.[48]

Hydrogel application in agriculture

Hydrogel polymers play a vital role in agricultural uses as structural materials for creating a climate beneficial to plant growth in arid and semi–arid regions; it could use as retaining ingredients in different forms as follow:

1) Seed additives to support seed germination or seed coatings.[28]
2) Dipping of seedling roots before establishment.[29]
3) Immobilizing plant growth substances.[9]
4) Coating protecting agents (herbicides and pesticides) for slow release.[30]
5) Polymeric Biocides and Herbicides.
6) Water – insoluble polymers.
7) Polymers for soil remediation.

In particular, hydrogel absorbs soluble fertilizer, water and then releases it in proper time for plants.

The effects of hydrogel on soil

Soil moister considered as a restricting factor for crop production in arid and semi–arid regions.[31] The polymer as soil conditioners was recognized since the 1950s.[32]

Agricultural hydrogels can change the different soil properties through various mechanisms like:

a) Implement water–holding capacity of the soil.[31]
b) Increasing soil permeability.[33]
c) Improving water retention on different soil types.[34]
d) Increase the water use efficiency.[35]
e) Increase irrigation intervals due to increasing the time to reach a permanent wilting point.[25]
f) Minimizing soil erosion and water run–off.[36]
g) Implement soil penetration and infiltration.[37]
h) Decrease soil compaction tendency.[14]
i) Improving soil drainage.[38]
j) Support crop growth performance under reduced irrigation conditions.[39]
k) Enhance nutrient retention as a result of solute release from hydrogel polymer particles and delay the dissolution of fertilizers.[40]

Also, hydrogel application expected to have wide potential applications in light soil, and actually influence soil penetration, texture, and evaporation, also, increased infiltration rates of water through the soils.[14]

In specific, hydrogel absorbs soluble fertilizer and releases it in time

Application of hydrogel polymer improving aeration and soil drainage, and minimize nutrient losses by leaching, therefore, appropriate usage of the hydrogel in arid and semiarid regions is helpful and has different positive effects on soil like:

Effect of hydrogel on nutrients

Hydrogel application minimizes micronutrients from washing out to water tables and increase water consumption efficiency; also, it's reducing the quantity of fertilization, since the nutrient leaching is prohibited by decreasing runoff. Alternatively, hydrogels which contain fertilizers and have controlled water release so that the dose of the fertilizer is adjustable in time.[41] The nutrient is available for the plant over a longer period of time rather than a rapid availability that ammonium nitrate, ammonium phosphate or potassium chloride.[42]

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Recent applications for hydrogel polymer

Hydrogel polymer continues being a very significant issue in both academic and applicable fields due to their applications in numerous technologies. In agricultural sector hydrogel polymer can be used as soil conditioners and carriers for slow release fertilizers and protecting agent, hydrogels may be applied by being mixed with the soil or by spraying on the soil surface.

Hydrogels have various applications in agricultural sector i.e. drug delivery, water reserve, reduce soil erosion, food additives, tissue culture, as structural materials (produce mulches and creating green–houses).

Improving crop productivity

Soil addition of hydrogel to Valencia orange trees increased total yield and implement fruit characters, also, mixing soil with hydrogel loaded fertilizers improving the growth of Zea maize plant (Figure 3).[43] Also, using hydrophilic hydrogel improve the number of flowers, root/shoot, proportion and coverage area of Chrysanthemum plant under drought stress.[44]

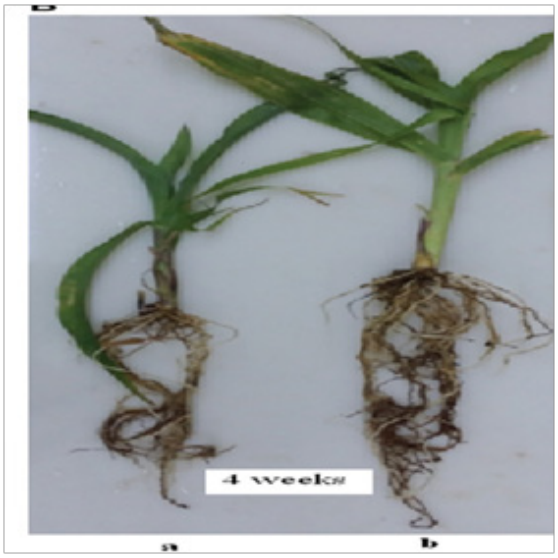

Figure 3. Zea maize plants roots in soil (a) treated fertilizers without hydrogel (b) hydrogels loaded fertilizers.[43]

Seed coating

Nowadays hydrogel polymer used as seed coating polymers by seed producers alone or combination with active substances like insecticides and fungicides to improving seed growth and resistance against pathogen and pests in juvenility stage, moreover implement the seedling growth. Also, seed coating with combination of insecticide and polymer produce greater total yield and good quality seeds.[5] Moreover, surface coating of sugar beet seeds with hydrogel increased emergence ratio.[45]

Hydrogel polymer as plant protector

The hydrogel polymer coat provides protection from the stress imposed by accelerated age, which includes pathogen invasion and pest attack during establishment. Plant substances (Pesticides and Herbicides) as a new system has newly arisen for the controlled issue creations used to escape or decreased the possible side effects associated the use of biologically active ingredients, this technique permits the automatic release of the ingredients to the target at controlled limits, and to reserve its concentration in the optimum limits over a specified time.[5]

Effect of hydrogel on nutrients

Hydrogel application minimizes micronutrients from washing out to water tables and increase water consumption efficiency; also, they reduce the quantity of fertilization, since the nutrient leaching is prohibited by decreasing runoff.[2]

Future trends for hydrogel polymer

Recently the use of hydrogel polymer has shown a great potential and growth in the agricultural sector, also, in arid and semiarid regions there is attracting considerable interest for usage of hydrogel polymer to increase soil water retention and improve crop productivity.[46] From other side most of these materials for multi–functional applications especially in the field of slow release nutrients are now being acquired using natural materials.[47,48]

Conclusion

The application of hydrogel in arid and semi–arid regions improve soil properties, increases the water holding capacity of the soil, enhance of the soil water retention, improving irrigation efficiency, increasing the growth of various crops, and enhancement water productivity of the crop. It also provides a conducive atmosphere for the better growth of roots in well–drained soils and ultimately increases yield.

According to chemical and physical structures of hydrogels, it can be used as an absorbent in environment preservation in the agricultural sector as water retention, soil conditioners, and nutrient carriers.

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