REVIEW ARTICLE

SIGNIFICANCE OF HYDROGEL AND ITS APPLICATION IN AGRICULTURAL SECTOR

Rajni Yadav, Manu Rani*, Vikas Kumar, Sandip Kumar Gautam and Pankaj Singroha

Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana
Email: manusagwal@gmail.com

Received-01.03.2022, Revised-13.03.2022, Accepted-26.03.2022

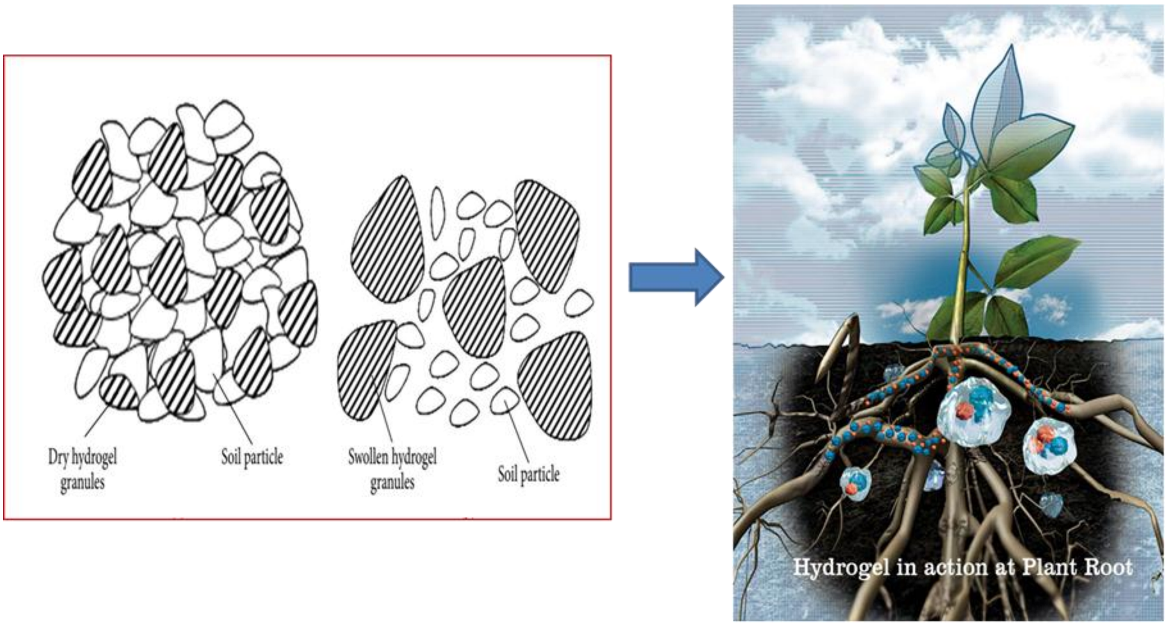
Abstract: The use of water-holding amendments such as hydrogel polymers for improving water and nutrient use efficiency will become more important over time, especially in arid and semiarid regions with limited water availability. The hydrogel is able to retain water and plant nutrients and release them to the plants when the surrounding soil near the root zone of the plants begins to dry up. Water management is currently regarded as one of the most significant challenges facing all countries in arid and semi-arid regions; in fact, global water demand is expected to be 50% higher by 2030 than it is today, resulting in water scarcity; at the same time, the agricultural sector consumes over 70% of freshwater in most parts of the world. According to research, when soil is treated with a water hydrogel composite, its water volumetric content increases dramatically, and when the surrounding soil dries, the stored water is gently released back into the soil. The hydrogel improves plant viability, ventilation, and root development, resulting in more efficient water consumption, lower irrigation costs, and longer irrigation intervals. It also improves soil's water holding capacity and porosity, providing plants with eventual moisture and nutrients, as well as improving plant viability, ventilation, and root development, resulting in a more conducive environment for better plant growth and, ultimately, increased crop yield. Hydrogels have a number of properties that support their usage as fertilizer release systems and soil conditioners in agricultural applications, such as high swelling and slow water retention. The agricultural sector benefits from hydrogel polymers because they can retain water and decrease soil erosion.

Keywords: Hydrogel, Soil conditioner, Water holding capacity, Crop yield, Nutrient efficiency

INTRODUCTION

Hydrogels are polymeric networks that can absorb and retain large amounts of water. The polymeric network contains hydrophilic groups that become hydrated in aqueous environments, generating a hydrogel structure (Akhtar *et al*., 2016). SAP (super absorbent polymers), also known as hydrogel, absorbent polymers, absorbent gels, super soakers, super slurpers, and water gel, is a novel form of macromolecular synthetic water absorption polymer material. SAPs are hygroscopic white sugar-like compounds that swell in water to produce a clear gel made up of discrete individual particles and can maintain moisture even under pressure without exploding or rupturing. Hydrogels used in agriculture are prepared from Acrylic acids plus a cross-linking agent such as potassium or sodium, which are made by solution or suspension polymerization. The resulting polymer is known as a polyacrylate, and its swelling capacity and gel modulus are highly dependent on the amount and type of cross-linker utilised. The hydrophilic functional groups connected to the polymer backbone provide water absorption, while cross-links between network chains provide resistance to dissolution. Polyacrylamide (C_3H_5NO) is a polymer made up of acrylamide subunits that is frequently utilised as a synthetic hydrogel. It can be made as a basic linear chain structure or as a cross-linked structure. Because linear linked polyacrylamide dissolves in water, it cannot be employed as a water absorption hydrogel. N, N'-methylene-bisacrylamide is used to make cross-linked polymers as hydrogels. Polyacrylamide cross-linked forms have proved to be more resistant to deterioration (10% – 15% per year), making them more stable for longer periods of time (2-5 years). Acrylamide is poisonous to the nervous system (neurotoxic), whereas polyacrylamide is not. When hydrated, it absorbs a lot of water and produces a soft gel. Polyacrylates are non-toxic, non-irritating, and non-corrosive, as well as biodegradable. They have a large water absorption capacity and can freely release 95 percent of that when suction pressure is applied by plant roots.

*Corresponding Author



Water absorption mechanism of hydrogel

Water absorption in hydrogels is caused by the hydrophilic groups (acrylamide, acrylic acid, acrylate, carboxylic acid, etc.) of the polymer chain. The acid groups are connected to the polymer's main chain. When these polymers are mixed with water, the water osmosisally enters the hydrogel system, where hydrogen atoms react and emerge as positive ions. Negative ions are left along the length of the polymer chain. As a result, the hydrogel now contains multiple negative charges along the length of it. These negative charges repel each other. The polymer chain is forced to unwind and open up as a result of this. They also attract water molecules and use hydrogen bonds to bind them (Li *et al*., 2009). This method allows the hydrogel to absorb more than 400 times its weight in water. When the hydrogel's surrounds begin to dry out, it gradually releases up to 95 percent of the water it has held. When exposed to water again, it will rehydrate and begin the water storage process over again. This process takes 2–5 years to complete, during which time the biodegradable hydrogel decomposes.

The functional features of an ideal hydrogel material are as follows:

In saline, it has the largest absorption capacity (maximum equilibrium swelling). Depending on the application, desired absorption rate (preferred particle size and porosity). The highest absorbency under load (AUL). The monomer with the least soluble content and the most residual monomer. The cheapest option.In the swelling environment and during storage, the maximum durability and stability.The maximum biodegradability possible without the creation of hazardous species as a result of the decomposition. After swelling in water, pH neutrality is achieved. Rewetting capabilities (if required): Depending on the use, the hydrogel must be able to return or sustain the absorbed solution (e.g., in agricultural or hygienic applications). (Pande *et al*., 2017).

Importance of hydrogel

Hydrogels were developed to alter the physical qualities of soil in order to improve the soil's water-holding capacity. As water that would have otherwise leached beyond the root zone is collected when hydrogels are used, water use efficiency improves. Increase permeability and infiltration rates in the soil.

Reduce the soil's tendency to compaction. Reduce water run-off and soil erosion. Hydrogels aid in the reduction of plant water stress, resulting in increased plant growth and performance (especially in structure-less soils in areas subject to drought). Insecticides, fungicides, and herbicides are all being explored as potential carriers in cross-linked polyacrylamide hydrogels.

Advantages

Hydrogel is more elastic and durable and having have excellent transparency. They have a degree of flexibility that is equivalent to natural tissue due to their high water content. They're biodegradable, biocompatible, and injectable. Hydrogels can detect changes in pH, temperature, or metabolite concentration and release their load as a result of these changes. The use of hydrogel beads to entrap microbial cells offers the advantage of low toxicity. Growth factors and other nutrients are released at specific times to guarantee optimal tissue growth. The transport properties of hydrogels are excellent. (Helalia*et al*., 1988; Reddy *et al*., 2017)

Disadvantages They are expensive and have poor mechanical strength. They are non-adherent and may require a secondary dressing to keep them in place. They may produce a sensation similar to that produced by maggot movement. They can be difficult to manage. It's possible to have trouble loading of drugs/nutrients (Mohite*et al*., 2017).

Application methods

Prepare a 1:10 admixture of hydrogel and fine dry soil for field crops and apply it along with the seeds/fertilizers or in the furrows before sowing. Hydrogel should be placed near seeds for optimal effects. In a transplant nursery bed: Apply 2 gm of hydrogel and mix uniformly in the top 2 inches of the nursery bed (or according to the recommended rate). Before planting, mix 3-5 g/kg of soil in pot culture.

While transplanting, make a free-flowing solution by thoroughly mixing 2g (or according to the suggested rate) of hydrogel per litre of water and let it to settle for half an hour. Dip the plant's roots in the solution before transplanting it to the field.

Purpose	**Application rate**
Arid & Semi-arid Regions	4-6 g/kg soil
To improve relative water content and leaf water use efficiency	0.5-2.0 g/pot
To delay permanent wilting point in sandy soils	0.2-0.4 g/kg or 0.8% of soil
To reduce drought stress	0.2-0.4 % of soil
For all level of water stress treatment and improved irrigation period	2.25-3 g/kg soil

The results of a wheat field experiment in several wheat-growing zones of India (specifically, the north-eastern plain zone, the central and peninsular zone) reveal that applying 5 kgha-1 of hydrogel increased grain yield significantly at all irrigation levels (viz. no irrigation, two and four irrigations). When 5 kgha-1 of hydrogel was applied, the equivalent yield of four irrigations with no hydrogel was attained with only two irrigations. In all types of lands (flatbed sowing, ridge sowing, and raised bed sowing), 2.5 kgha-1 of hydrogel produced significantly greater growth, contributing characteristics, and yield in aerobic rice compared to control [Rehman*et al*., 2011]. In comparison to the control and water soaking treatments, coating pearl millet seed with 10 and 20 g of hydrogelkg-1 of seed resulted in considerably greater effective tillers, ear length, test weight, grain, and stover yield [Singh, 2012].

Properties of Hydrogel

Swelling Properties: A slight change in the environment can cause rapid and reversible changes in the hydrogel. A change in the physical texture of the hydrogel can be caused by changes in environmental parameters such as electric signal, pH, temperature, and the presence of enzymes or other ionic species. (Das 2013)

Mechanical qualities: Depending on the material's intended use, mechanical properties can vary and be fine-tuned. By raising the crosslinking degree or decreasing it by heating the material, a gel with higher stiffness can be obtained. Mechanical property changes are linked to a wide range of variables and causes, requiring different analyses depending on the material. (Chirani*et al*., 2016)

Hydrogels are made from a variety of polymers, both natural and manufactured. Chitosan, gelatin, alginates, and fibrin are examples of natural polymers. Vinyl acetate, acryolic acid, and methacrylate-vinyl 2 pyrrolidine are examples of synthetic polymers.

Properties that make it biocompatible: The capacity of a material to perform with an adequate host reaction in a certain application is known as biocompatibility. Biocompatibility is made up of two components: (a) bio-functionality, which refers to a material's ability to perform the task for which it was designed. (b) bio-safety, which includes a proper host response, both systemic and local (in the surrounding tissue), the lack of mutagenesis, and cytotoxicity (Garg*et al*., 2016).

Classification of hydrogel products

Hydrogel can be classified on different bases as described:

1. Classification based on source

Hydrogels are divided into two classes based on whether they are natural or manufactured (Zhao *et al*., 2013); Silva *et al*., 2009).

a) Natural hydrogels are biodegradable, biocompatible, and have excellent cell adhesion qualities. Proteins such as collagen, gelatin, and lysozyme (LYZ) and polysaccharides such as hyaluronic acid (HA), alginate, and Chitosan are the two main forms of natural polymers utilised to make natural hydrogels (Cts).

b) Synthetic hydrogels: Synthetic hydrogels are more valuable than natural hydrogels because they can be made to have a considerably larger variety of mechanical and chemical properties. Because of its non-toxicity and compatibility, polyethylene glycol (PEG) based hydrogels are one of the most commonly utilised materials.

c) Hybrid hydrogels: These are hydrogels made up of both natural and synthetic polymers. Many naturally occurring biopolymers, such as dextran, collagen, and Chitosan, have been mixed with synthetic polymers, such as poly (Nisopropylacrylamide) and polyvinyl alcohol, to combine the advantages of both synthetic and natural hydrogels (Zaman*et al*., 2015).

2. Classification according to polymeric composition

The procedure of preparation leads to formations of principal classes ofhydrogels. These can be represented as following:

a) Homopolymeric hydrogels: These are polymer networks made up of a single species of monomer, which is the fundamental structural unit of any polymer network (Takashi *et al*., 2007). Depending on the monomer and polymerization process, homopolymers may have a cross-linked skeletal structure.

b) Copolymeric hydrogels: These are made up of many monomer species, each with at least one hydrophilic component, arranged in a random, block, or alternating pattern along the polymer network's chain (Yang *et al*., 2002)

c) Multi polymer: Also known as interpenetrating polymeric hydrogels (IPN), these are a type of hydrogel that is made up of two independent cross-linked synthetic and/or natural polymer components that are contained in a network structure. One component of a semi-IPN hydrogel is a cross-linked polymer, while the other is a non-cross-linked polymer (Maolin*et al*., 2000)

Classification based on configuration

This classification of hydrogels based on their physical structure andchemical composition are as follows **(**Faheem*et al*., 2015):

a) Amorphous (non-crystalline).

b) Semicrystalline: A complex mixture of amorphous and crystallinephases

c) Crystalline

Classification based on type of cross-linking

On the basis of the chemical or physical behaviour of the cross-link junctions, hydrogels can be categorised into two types. Physical networks have temporary junctions that come from polymer chain entanglements or physical interactions such as ionic contacts, hydrogen bonds, or hydrophobic interactions, whereas chemically cross-linked networks have stable junctions. **Classification based on physical appearance**

The appearance of hydrogels as matrix, film, or microsphere is determined by the polymerization technique used in the formulation process. On the basis of the presence or lack of electrical charge on the cross-linked chains, hydrogels can be divided into four types

a) Non-ionic (neutral)

b) Ionic-(including anionic or cationic)

c) Amphoteric electrolyte (ampholytic) comprising both acidic andbasic groups

d) Zwitterionic (polybutenes) consisting of both anionic and cationicgroups in their structural repeating unit

Classification based on solubility

There are two broad classes of hydrogels

a) Soluble (linear)

b) Insoluble (cross linked)

Linear polyacrylamide (PAM) dissolves in water and has been effectively utilised in agricultural fields to reduce irrigation-induced erosion. When water is added to cross linked PAM, it forms a gel and is commonly utilised in agriculture and landscaping, with goods branded as "superabsorbent gels" or "hydrating crystals." These gels collect water instead of dissolving and grow to many times their original size. Water is progressively discharged into the soil as they dry.

According to the biodegradability

1. Biodegradable hydrogels: Many polymers found in nature, such as Chitosan, fibrin, and agar, are biodegradable hydrogels. Synthetic biodegradable polymers include poly (aldehyde guluronate), polyanhydrides, and poly (N-isopropyl acrylamide).

2. Non-biodegradable hydrogels: Non-biodegradable hydrogels are commonly made with vinylated monomers or macromers such as 2-hydroxyl ethyl methacrylate, methoxyl poly (ethylene glycol), 2-hydroxyl propyl methacrylate, and acrylamide.

Hydrogel preparation methods

Polymer networks with hydrophilic qualities are known as hydrogels. Hydrophilic and hydrophobic monomers are both employed in the creation of hydrogels to control their characteristics for specific applications. Hydrogels can be made by copolymerizing/ cross-linking free-radical polymerizations of hydrophilic monomers with multifunctional cross-linkers. Water-soluble linear polymers of natural and synthetic origin are cross-linked in a variety of ways to generate hydrogels:

a. Bulk polymerization

Bulk hydrogels can be made using one or more types of monomers, the most common of which being vinyl monomers for hydrogel formation. In most hydrogel formulations, a tiny amount of crosslinking agent is included. The polymerization reaction is started by radiation, ultraviolet light, or chemical catalysts. The initiator is chosen based on the monomers and solvents that will be utilised. Rods, particles, films and membranes, as well as emulsions, are all possible forms of the polymerized hydrogel (Enas, 2015).

b. Free radical polymerization

A variety of monomers, such as acrylates, vinyl lactams, and amides, are employed to make hydrogels in this approach. These polymers are functionalized with radically polymerizable groups or have appropriate functional groups. This method comprises propagation, chain transfer, initiation, and termination processes, as well as the chemistry of normal free radical polymerizations. A wide variety of thermal, ultraviolet, visible, and redox initiators can be used to generate radicals in the initiation stage, and the radicals react with the monomers to convert them into active forms (Shuanhong*et al*., 2016).

c. Solution polymerization/cross-linking

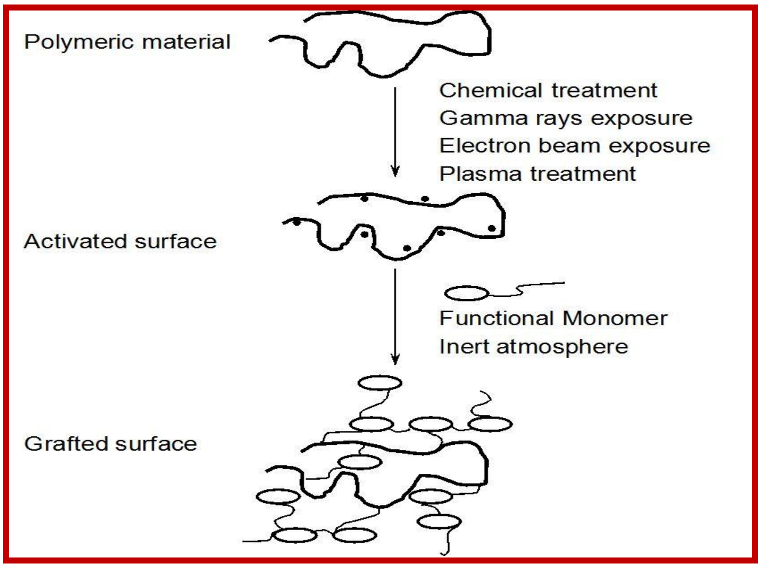
The multifunctional crosslinking agent is combined with ionic or neutral monomers in these. UV irradiation or a redox initiator system is used to start the polymerization process. The major advantage of the solution polymerization over the bulk polymerization is the presence of solvent serving as a heat sink. The initiator, soluble monomers, oligomers, cross-linking agent, extractable polymer, and other contaminants are rinsed out of the produced hydrogels using distilled water. Water-ethanol combinations, water, ethanol, and benzyl alcohol were utilised as solvents.

d. Suspension polymerization or inverse-suspension polymerization

The benefit of this process is that the goods are obtained as powder or microspheres (beads), which eliminate the need for grinding. The polymerization is referred to as "inverse suspension" because the water-in-oil (W/O) technique is used instead of the more typical oil-in-water (O/W). The monomers and initiator are disseminated as a homogeneous mixture in the hydrocarbon phase in this approach. The viscosity of the monomer solution, rotor design, agitation speed, and dispersant type are all influenced by the resin particle size and shape. Because the dispersion is thermodynamically unstable, it requires constant agitation as well as the inclusion of a low hydrophilic–lipophilic balance (HLB) suspending agent.

e. Grafting to a support

As hydrogels created by bulk polymerization have a weak structure, it is required to increase their mechanical properties so that they can be grafted onto a stronger support. This involves generating free radicals on a more durable support surface, then polymerizing monomers directly onto it to generate a chain of monomers that are covalently bound to the support (Das, 2013).



f. Polymerization by irradiation

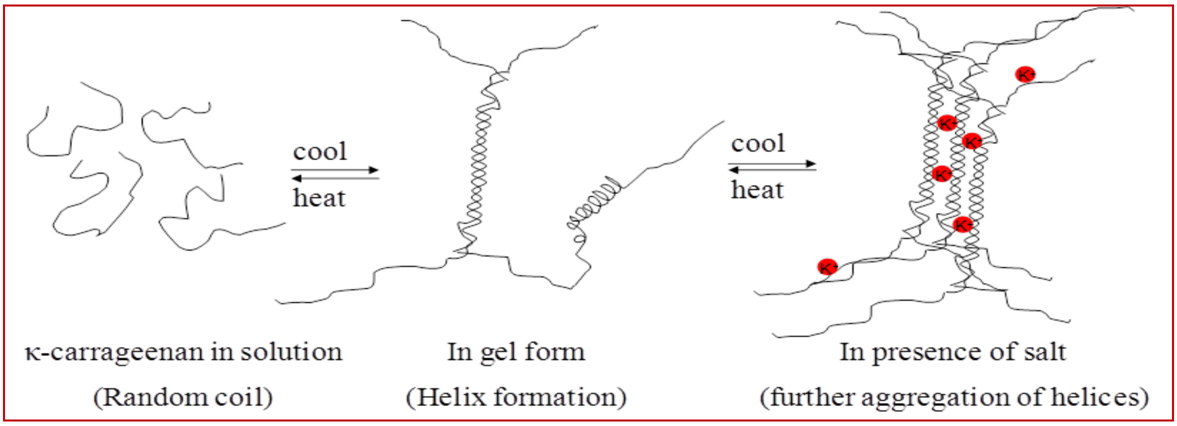
Initiators such as ionising high energy radiation, like gamma rays and electron beams, have been employed to create hydrogels of unsaturated molecules. The production of radicals on the polymer chains occurs when an aqueous polymer solution is irradiated. The production of covalent bonds arises from the recombination of macro-radicals on distinct chains, resulting in the formation of a cross-linked structure. Polymerization by irradiation is done with poly (vinyl alcohol), poly (ethylene glycol), and poly (acrylic acid). This approach produces hydrogels that are quite pure and free of initiators (Das, 2013).

g. Physical cross-linking

It is the most popular and straightforward method for forming hydrogels by crosslinking polymers through physical interactions. Hydrogen bonding, polyelectrolyte complexation, and hydrophobic association are examples of ion interactions in physical cross linking. The following procedures are utilised to make physically cross-linked hydrogels:

Heating/cooling a polymer solution

It's made by cooling hot gelatin or carrageenan solutions to generate physically cross-linked gels. The gel is formed by the helices joining together, producing helixes, and forming junction zones. Polyethylene glycol-polylactic acid hydrogel and polyethylene oxide polypropylene oxide are examples.

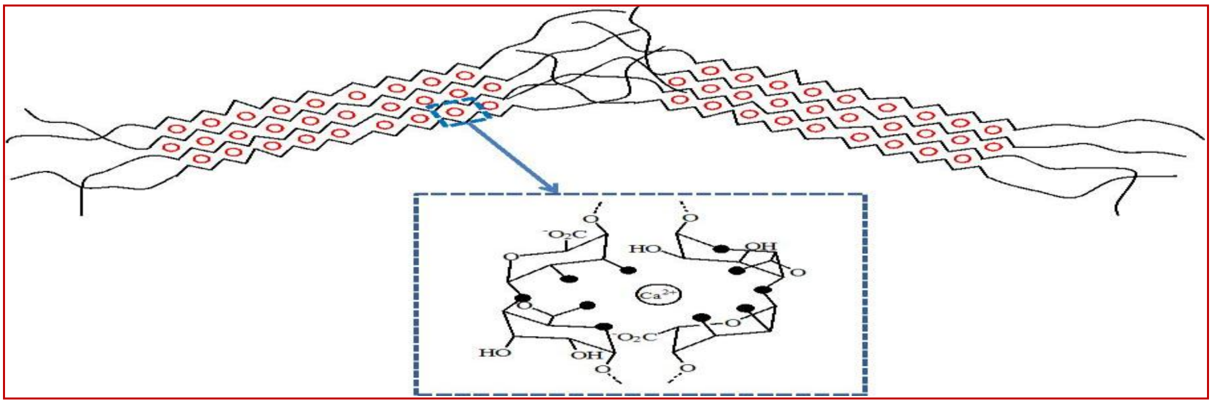


Complex coacervation

Polyanions and polycations are mixed to form complicated coacervate gels. Polymers with opposite charges stick together and create soluble and insoluble complexes depending on the concentration and pH of the corresponding solutions, according to the basic concept of this approach. Coacervation of polyanionic xanthan with polycationic chitosan is one such example (Madolia and Sheo, 2013).

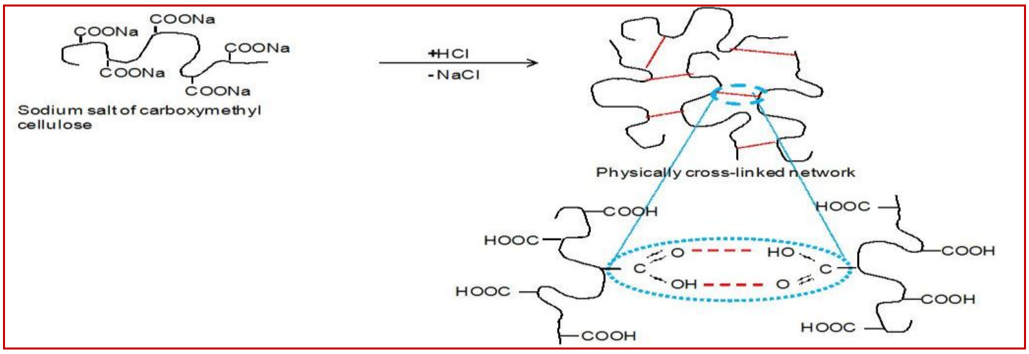
Ionic interaction

Cross linking between polymers occurs when divalent or trivalent counter ions are added to an ionic polymer. The principle of gelling a polyelectrolyte solution (e.g. Na alginate) with a multivalent ion of opposing charges (e.g. Ca2+ + 2Cl-) is based on this approach. Chitosan-polylysine, chitosan-glycerol phosphate salt, and chitosan dextran hydrogels are some other examples.



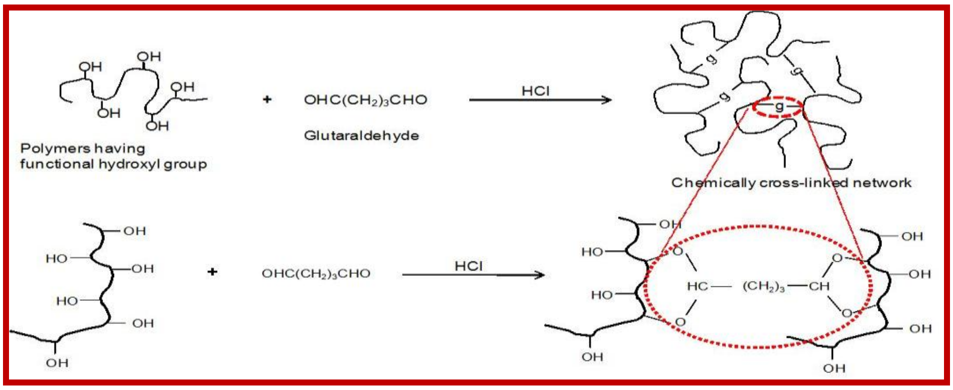
Hydrogen bonding

A hydrogen bond is created when an electron-deficient hydrogen atom is combined with a functional group with a high electron density. The development of hydrogen bonds between PA and PNVP, for example, can result in the production of a hydrogel. The molar ratio of each polymer, polymer concentration, solvent type, solution temperature, and polymer structure are all elements that affect hydrogels.



Chemical cross-linking

In this procedure, a crosslinking agent is used to join two polymer chains, and monomers are grafted onto the polymers' backbones. Cross-linking of natural and synthetic polymers is accomplished by combining their functional groups (such as OH, COOH, and NH_2) with cross-linkers like aldehyde (e.g. glutaraldehyde, adipic acid dihydrazide). IPN is a polymerized monomer that forms an interpenetrating network structure within another solid polymer (Chauhan *et al*., 2012).



Hydrogel application in agriculture

Hydrogel polymers are important in agriculture because they may be used as structural materials to create an environment that is conducive to plant growth in arid and semi-arid regions. They can also be used as retaining elements in various forms, such as:

1) Seed coats or seed additives to aid seed germination. (Woodhouse *et al*., 1991)
2) Roots of seedlings are dipped before they are planted. (Viero*et al*., 2002)
3) Plant growth chemicals are immobilised. (Woodhouse *et al*., 1991)
4) Slow-release coating protective agents (herbicides and insecticides). (Abd EI-Rehirn*et al*., 2004)
5) Herbicides and polymeric biocides.
6) Polymers that is insoluble in water.
7) Soil remediation polymers.

The presence of water in the soil is essential for the survival of various plant species and vegetation. Scientists are beginning to accept the use of hydrogel in the agricultural sector. Hydrogel has provided solutions for the shortage of fresh water in agriculture, allowing farmers to increase soil and water productivity while preserving the environment and natural resources. The permeability, density, structure, texture, and evaporation and infiltration rates of water through soils are all influenced by polymers hydrogel (Ekebafe *et al*., 2011). Plant growth is mostly utilize fertilizer and water for prolonging the survival of plants under drought circumstances, and hydrogel provides water and nutrients to the plants when the surrounding soil around the root zone of the plants begins to dry up (Huttermann *et al*., 1999).Scientists targeted to develop new tools for increase the efficiency of nutrient relief to the plants, Slow release fertilisers were considered an actual method to decrease fertiliser loss due to the effect of rain or irrigation water, supply nutrition for a long time, and minimise the amount of fertilizers used (Tomaszewska *et al*., 2002). Under arid region conditions, granulated nutrients encapsulated by various materials such as carboxy methyl chitosan hydrogels have been developed, and the application of hydrogel polymer to the soil has improved the availability of water in the substrate, enhanced seed germination, increased leaf water content, and leaf chlorophyll content (Wang *et al*., 2014; Khadem *et al*., 2010). Improving root development, plant growth, reducing nutrient losses through leaching, improving soil penetration, reducing the negative impacts of water stress during plant transplantation, and implementing seedling parameter development (El-Asmar *et al*., 2017).

Polymer hydrogel slow release acts as nutrient carriers in the soil and is regarded as a key approach for improving fertilizer efficiency by reducing nutrient losses through leaching, lowering costs, and lowering pollution for the environment. Hydrogels are particularly useful in agriculture because they can retain water and prevent soil erosion. Hydrogel polymers can be employed as soil conditioners, transporters for slow release fertilizers, and protective agents in the agricultural industry. Hydrogels can be applied by mixing them with the soil or spraying them on the soil surface.

Drug delivery, water storage, soil erosion reduction, food additives, tissue culture, and structural materials (producing mulches and building green houses) are just a few of the applications for hydrogels in agriculture.

Effect of the hydrogel in retaining the water

Due to the scarcity of water, water–saving agriculture is critical for long-term development. Hydrogel polymer has been used as a water-retaining material in arid and semiarid regions where supplementary irrigation sources are limited and salinity conditions have a negative impact on crop growth and productivity. Hydrogel was used to increase a water reservoir near the root system, increasing field capacity. (Montesano *et al*., 2015). Furthermore, prior research has shown that hydrogel polymers have a good ability to boost water retention, water uptake, and water use efficiency, which helps plants avoid water stress and implement plant performance, resulting in increased growth (Belen-Hinojosa *et al*., 2004). Hydrogels are also reported to prevent fertiliser leaching, which appears to occur as a result of the fertilizer's interaction with the polymer. Polymers are also being studied as a potential carrier for pesticides and herbicides. Hydrogels are especially effective in dry and semi-arid locations where irrigation water is scarce. (Bakass *et al*., 2002).

Effect of hydrogel on plant growth

Seed germination and seedling establishment are regarded the most critical phases in any plant's initial growth; effective establishment is dependent on available water and is frequently limited by low soil moisture, especially in dry and semi-arid locations. (Abdel-Raouf*et al*., 2003). Hydrogel polymers promote plant growth by increasing soil water holding capacity and lengthening the time it takes for plants to wilt, increasing plant survival under water stress (Orikiriza *et al*., 2009). Decreasing fruit drop ratio, and possibly increasing total yield and fruit weight under various severity conditions (Barakat *et al*., 2015). Additionally, adding hydrogel to the soil increased plant circumference; this could be attributed to an increase in accessible water in the root zone, implying longer irrigation intervals (Johnson, 1984).

Furthermore, hydrogel polymer is used to create a water reservoir near the root zone of plants, reduce osmotic moisture in the soil, improve the capacity of plant available water, improve plant growth and increase whole yield while lowering crop production costs, and hydrogels are used to improve plant viability, seed germination, ventilation, and root development, primarily in arid environments (Helalia *et al*., 1989). Furthermore, when it comes to plant growth, it's been shown that when the hydrogel is used, the plants' growth is much increased. (Yazdani *et al*., 2007).

Effect of hydrogel on nutrients

Hydrogel treatment reduces the amount of fertilisation needed by preventing micronutrients from washing into water tables and increasing water consumption efficiency. It also reduces the amount of fertilisation needed since nutrient leaching is prevented by lowering runoff. Alternatively, fertilizer-containing hydrogels with controlled water release can be used to modify the fertiliser dose over time (Ni *et al*., 2009). The nutrient is available to the plant for a longer duration of time than ammonium nitrate, ammonium phosphate, or potassium chloride, which are available to the plant rapidly (Rahman *et al*., 2001).

Improving crop productivity

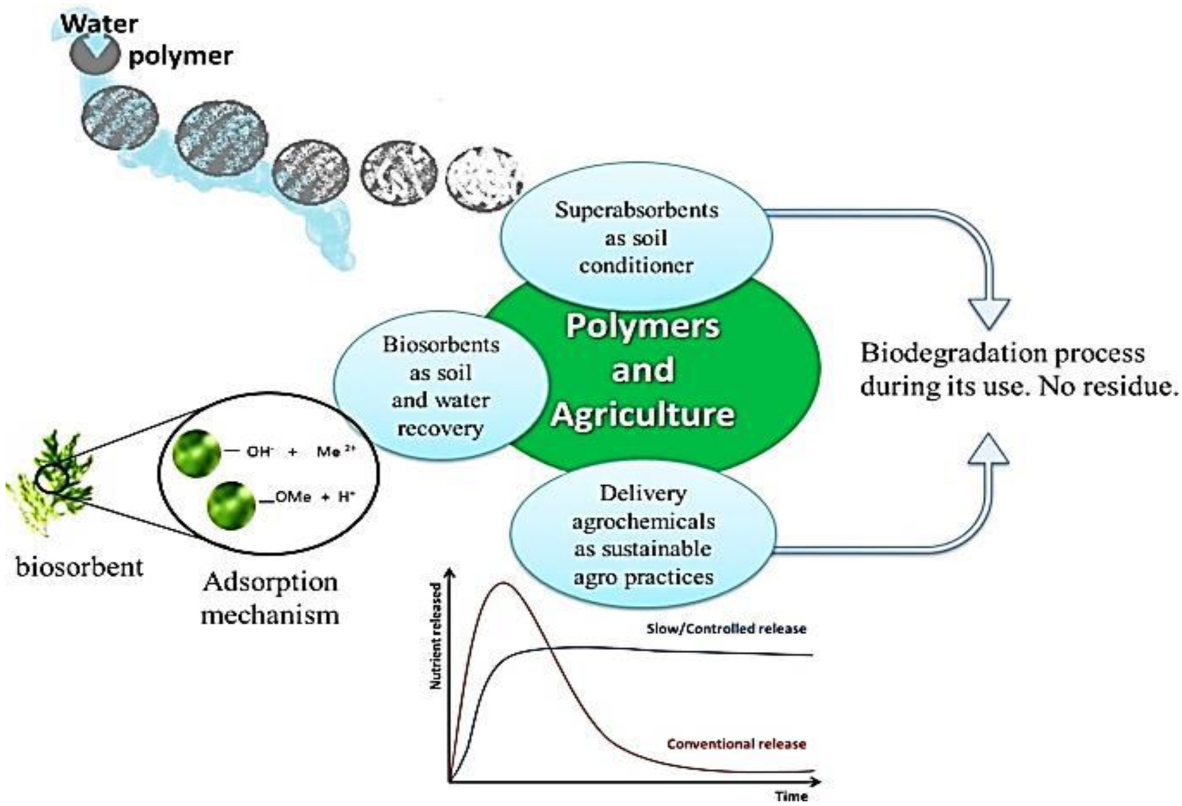
Elbarbary and Ghobashy (2017) observed that addition of hydrogel to the soil of Valencia orange trees boosted total yield and implemented fruit characters, while mixing soil with hydrogel-loaded nutrients improved Zea maize plant growth. Under drought stress, the quantity of flowers, root/shoot proportion, and covering area of Chrysanthemum plants are also improved by employing hydrophilic hydrogel. Khushkhui and Ghasemi,(2008).

Seed coating

Nowadays, seed growers utilise hydrogel polymers as seed coating polymers alone or in combination with active substances such as insecticides and fungicides to improve seed growth and resistance to pathogens and pests during the juvenility stage, as well as to facilitate seedling growth. Seed coating with a combination of pesticide and polymer also results in a higher total yield and higher quality seeds. Miyamoto and Dexter, 1995 recorded that hydrogel surface coating of sugar beet seeds boosted the emergence ratio.

Hydrogel polymer as plant protector

During establishment, the hydrogel polymer coat protects against the stress caused by accelerated age, such as pathogen invasion and pest attack. 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 allows for the automatic release of the ingredients to the target at controlled limits, and to reserve their concentration in the optimum limits over a specified time.



Future trends for hydrogel polymer

Recently, the use of hydrogel polymer has shown remarkable potential and growth in the agricultural sector; additionally, there is increasing interest in using hydrogel polymer to boost soil water retention and improve crop yield in arid and semiarid environments (Dar *et al*., 2017). On the other hand, natural materials are now being used to obtain the majority of these materials for multifunctional applications, particularly in the field of slow release nutrients.

CONCLUSION

The application of hydrogel in arid and semi-arid locations improves soil characteristics, enhances soil water holding capacity, improves soil water retention, improves irrigation efficiency, boosts crop growth, and increases agricultural water production. It also creates a favourable environment for root growth in well–drained soils, resulting in increased production. Hydrogels can be utilised as an absorbent in the agricultural sector as water retention, soil conditioners, and nutrient carriers because of their chemical and physical structures.

REFERENCES

Abd El-Rehirn, HA, Hegazy, ESA and Abd El-Mohdy, HL. (2004). Radiation synthesis of hydrogels to enhance sandy soils water retention and increase performance. *J ApplPolym Sci*. 93(3):1360–1371.
Google Scholar

Abdel-Raouf, AM and Samira, RM (2003). Improving soil physical properties and its effect on acacia tortilis seedlings growth under field conditions. *Asian Journal of Plant Sciences*. 2(11):861–868.
Google Scholar

Akhtar, MF, Hanif, M. and Ranjha NM. (2016). Methods of Synthesis of hydrogels: A review. Saudi Pharmaceutical Journal; 24: 554-559.
Google Scholar

Bakass, M, Mokhlisse, A. and Lallemant, M. (2002). Absorption and desorption of liquid water by a superabsorbent polymer: effect of polymer in the drying of the soil and the quality of certain plants. *Journal of Applied Polymer Science*. 83(2):234–243.
Google Scholar

Barakat, MR, El-Kosary, S. and Borham, TI. et al. (2015). Effect of hydrogel soil addition under different irrigation levels on Grand Nain banana plants. *J HortSci&Ornamen*.Plants. 7(1):19–28.
Google Scholar

Belen-Hinojosa, M, Carreira, JA and Garcia-Ruiz, R, et al. (2004). Soil moisture pretreatment effects on enzyme activities as indicators of heavy metal-contaminated and reclaimed soils. *Soil Biology and Biochemistry*. 36(10):559–1568.
Google Scholar

Chauhan, S., Harikumar and SL, Kanupriya (2012). Hydrogels, a Smart Drug Delivery System, Int. J Res Pharm Chem. 2(3):604-615.
Google Scholar

Chirani, N., Yahia, L.H. and Gritsch, L. et al. (2016). History and Applications of Hydrogels.Journal of Biomedical Science. 4:2.
Google Scholar

Dar, S.B., Mishra, D. and Zahida, R., et al. (2017). Hydrogel: To enhance crop productivity per unit available water under moisture stress agriculture. *Bull EnvPharmacol. Life Sci*. 6(10):129–135.
Google Scholar

Das, N. (2013). Preparation Methods and Properties of Hydrogel: A Review, Int. J Pharmacy Pharmaceuti Sci. 5(3):1-2.
Google Scholar

Dexter, ST and Miyamoto, T. (1995). Acceleration of water uptake and germination of sugar beet seed balls by surface coatings of hydrophilic colloids.*Agronomy Journal*. 51(7):388–389.
Google Scholar

Ekebafe, LO, Ogbeifun, DE and Okieimen, FE (2011). Polymer applications in agriculture. *Biokemistri*. 23(2):81–89.
Google Scholar

El-Asmar, J., Jaafar, H., Bashour, I., et al. (2017). Hydrogel banding improves plant growth, survival, and water use efficiency in two calcareous soils. *CLEAN Soil Air Water*. 47(7):1700251.
Google Scholar

Elbarbary, AM and Ghobashy, MM. (2017). Controlled release fertilizers using superabsorbent hydrogel prepared by gamma radiation. *Radiochim Acta*.
Google Scholar

Enas MA. (2015). Hydrogel: Preparation, characterization, and applications: A review. J Adv Res. 6:105-121.
Google Scholar

FaheemUllah, Muhammad BisyrulHafi Othman, Fatima Javed, Zulkifli Ahmad and Hazizan Md. Akil, (2015). Classification, Processing and Application of Hydrogels: A Rev Material Sci Eng. C.
Google Scholar

Garg, S. and Garg, A. (2016). Hydrogel: classification, Properties, Preparation and Technical Features. Asian Journal of Biomaterial Research. 2(6):163-170.
Google Scholar

Ghasemi, M. and Khushkhui, M. (2008). Effects of super absorbent polymer on irrigation interval and growth and development of chrysanthemum (Dendranthema×grandiflorumKitam). *J. SciTechnol Iran*. 8(2):65– 82.
Google Scholar

Helalia, A. and Letey, J. (1988). Cationic polymer effects on infiltration rates with a rainfall simulator. Soil Sci Soc. Am J. 52(1):247-250.
Google Scholar

Helalia, AM and Letey, J. (1989). Effects of different polymer on seedling emergence, aggregate stability and crust hardiness. *Soil Science*. 148(3):199– 203.
Google Scholar

Huttermann, A., Zommorodi, M. and Reise, K. (1999). Addition of hydrogels to soil for prolonging the survival of Pinushalepensis seedlings subjected to drought. *Soil and Tillage Research*. 50(3-4):295–304.
Google Scholar

Johnson, MS. (1984). Effect of soluble salts on water absorption by gel forming soil conditioners. *Journal of Science and Food Agriculture*. 35(10):1063– 1066.
Google Scholar

Khadem, SA, Galavi, M. and Ramrodi, M., et al. (2010). Effect of animal manure and super absorbent polymer on corn leaf relative water content, cell membrane stability and leaf chlorophyll content under dry condition. *Australian J of Crop Sci*. 4(8):642–647.
Google Scholar

Li, YK, Xu, TW and Ouyang, ZY, et al. (2009). Micromorphology of macromolecular superabsorbent polymer and its fractal characteristics. J Appl. Polym.Sci. 113(6):3510-3519.
Google Scholar

Madolia, H. and Sheo, D.M. (2013). Preparation and Evaluation of Stomach Specific IPN Hydrogels for Oral Drug Delivery: A Review. J Drug Delivery Therapeutics. 3(2):131-140.
Google Scholar

Maolin, Z, Jun, L., Min, Y. and Hongfei, H. (2000). The swelling behaviour of radiation prepared semi- interpenetrating polymer networks composed of poly NIPAAm and hydrophilic polymers. Radiation Phy Chem. 58:397-400.
Google Scholar

Mohite, P.B. and Adhav, S.S. (2017). A hydrogels: Method of Preparation and applications. International Journal of Advances in Pharmaceutics 06(03):79-85.
Google Scholar

Montesano, F.F., Parente, A. and Santamaria, P., et al. (2015). Biodegradable superabsorbent hydrogel increases water retention properties of growing media and plant growth. *Agriculture and Agricultural Science Procedia*.4:451– 458.
Google Scholar

Ni, B., Liu, M. and Lü, S. (2009). Multifunctional slow-release urea fertilizer from ethylcellulose and superabsorbent coated formulations. *ChemEng J*. 155(3):892–898.
Google Scholar

Orikiriza, LJB, Agaba, H. and Tweheyo, M., et al. (2009). Amending soils with hydrogels increases the biomass of nine tree species under non-water stress conditions. *Clean-Soil Air Water*. 37(8):615–620.
Google Scholar

Pande, PP and Anamica (2017). Polymer Hydrogels and Their Applications. International journal of materials science. 12(1): 0973-4589.

Google Scholar

Rahman, M.S., Sarker, A.M. and Islam, M.S., et al. (2001). Effect of soil moisture on grain yield of wheat (Triticumaestivum L) cultivars. *Environment and Ecology*. 19(2):304–308.
Google Scholar

Reddy, VRK, Nagabhushanam, MV and Naik, ER. (2017). Swallable hydrogels and cross linking Agents- Their role in drug delivery system. Research Journal of Pharmacy and technology 10(3): 0974-3618.
Google Scholar

Rehman, A., Ahmad, R. and Safdar, M. (2011). Effect of hydrogel on the performance of aerobic rice sown under different techniques. Plant Soil Environ. 57(7):321-325.
Google Scholar

Shuanhong, M., Bo, Y., Xiaowei, P. and Feng, Z. (2016). Structural hydrogels, Polymer. 98:516-535.
Google Scholar

Silva, AKA, Richard, C., Bessodes, M., Scherman, D. and Merten, OW. (2009). Growth Factor Delivery Approaches in Hydrogels, Biomacromolecules. 10(1):9-18.
Google Scholar

Singh, H. (2012). Effect of hydrogel on growth, yield and water use efficiency pearl millet (*Pennisetumglaucum*) production. Forage Res. 38(1):27-28.
Google Scholar

Takashi, L., Hatsumi, T., Makoto, M., Takashi, I., Takehiko, G. and Shuji, S. (2007). Synthesis of porous poly (N-isopropylacrylamide) gel beads by sedimentation polymerization and their morphology. J Appl. Polymer Sci. 104(2):842.
Google Scholar

Tomaszewska, M. and Jarosiewicz, A. (2002). Use of polysulfone in controlled-release NPK fertilizer formulations.*J Agric Food Chem*. 50(16):4634–4639.
Google Scholar

Viero, PWM, Chiswell, KEA and Theron, JM. (2002). The effect of a soil-amended hydrogel on the establishment of a Eucalyptus grandis clone on a sandy clay loam soil in Zululand during winter. *Southern African Forestry Journal*. 193(1):65–75.
Google Scholar

Wang, X., Lu, S., Gao, C., et al. (2014). Biomass-based multifunctional fertilizer system featuring controlled-release nutrient, water-retention and amelioration of soil.*RSC Advances*. 4(35):18382–18390.
Google Scholar

Woodhouse, J.M. and Johnson, M.S. (1991). Effect of superabsorbent polymers on survival and growth of crop seedlings. *Agricultural Water Management*. 20(1):63–70.
Google Scholar

Woodhouse, J.M. and Johnson, M.S. (1991). The effect of gel-forming polymers on seed germination and establishment. *J Arid Environ*. 20:375–380.
Google Scholar

Yang, L., Chu, J.S. and Fix, J.A. (2002). Colon-specific drug delivery: new approaches and *in vitro/in vivo* evaluation. Int. J Pharmaceu. 235:1-15.
Google Scholar

Yazdani, F., Allahdadi, I. and Akbari, G.A. (2007). Impact of superabsorbent polymer on yield and growth analysis of Soybean (Glycine max L.) under drought stress condition. *Pakistan Journal of Biological Science*. 10(23):4190– 4196.
Google Scholar

Zaman, M., Siddique, W., Waheed, S., Muhammad, S.S., Mahmood, A. and Qureshi, J. (2015). *et al*. Int. J Biol Pharm Allied Sci. 4(12):6581-6603.
Google Scholar

Zhao, W., Jin, X., Cong, Y., Liu, Y. and Fu, J. (2013). Degradable natural polymer hydrogels for articular cartilage tissue engineering. J ChemtechBiotech. 88(3):327-39.
Google Scholar