Review Article

HYDROGEL IN DRYLANDS: A REVIEW

ABSTRACT

Significant amounts of water and nutrients are held in reserve by hydrogels due to their three-dimensional polymeric network. The capacity of hydrogels to absorb water lowers the frequency of irrigation, which is beneficial for agricultural application. When applied to soil, it functions well as a nutrient mobilizer and a reservoir for water. Applying hydrogel will be a profitable and advantageous way to boost agricultural crop yield and sustainability in settings where moisture is scarce.Because of their three-dimensional polymeric network, hydrogels can store large amounts of water and nutrients. Because hydrogels can absorb water, less irrigation is required, which is advantageous for agricultural use. It works well as a water reservoir and nutrient mobilizer when added to soil. In environments where moisture is limited, applying hydrogel will be a profitable and beneficial strategy to increase agricultural crop productivity and sustainability.

Keywords: Agriculture; Dryland; Hydrogel; Irrigation; Polymer

1. INTRODUCTION

According to Johnson and Veltkamp (1985), hydrogel, also known as super absorbent polymer, is an amorphous polymer that is cross-linked, hydrophilic, biodegradable, and capable of retaining water at least 400 times its original weight. It also makes at least 95% of the stored water available for crop absorption.A polymer that is combined with soil works as a slow-release source of water in the soil because it hydrates to form an amorphous gelatinous mass and can absorb and desorb water over an extended period of time. The hydrogel particles in the soil can be thought of as "miniature water reservoirs," from which water is drawn out when roots require it due to an osmotic pressure differential. Because they contain hydrophilic moieties, hydrogels are hydrophilic polymers with a three-dimensional network structure that can absorb a lot of water (Habib et al., 2015). Van n Bemmelen originally used the term "hydrogel" in 1984 (van Bemmelen, 1894). The hydrogel can be converted into solid, semi-solid, and liquid states by adjusting its physicochemical characteristics and the crosslinking reaction (Varaprasad et al., 2017).

2. CHARACTERISTICS OF SUPERABSORBENT POLYMER- HYDROGEL:

A few number of studies on the application of polymers in agriculture have been conducted in India. Recently, numerous companies operating under various trade names have been introducing polymers into India with the goal of promoting their use in dryland agriculture to conserve both water and nutrients.Depending on the type of polymer, application technique, crop type, etc., the dose of polymers might range from 2.5 to 60 kg ha-1. The American company Union Carbide introduced super absorbents to the market in the beginning of the 1960s. Superabsorbent materials are those that can absorb water 20 times their weight in moisture (Abedi-Koupai and Sohrab, 2004;Chirino et al., 2011; Crous, 2017).However, the discovery of additional cross-linked polymers that are very inexpensive and have a high water-holding capacity (400–2000 times their weight) has rekindled interest in the application of polymers in agriculture. A range of polymers, both soluble and amorphous, have found commercial application in agriculture. Water-soluble polymers are utilized as soil conditioners since they don't gel. They consist of polyvinyl alcohol, polyethylene glycol, polyacrylates, and polyacrylamides. The main purposes of water soluble polymers' development were to stabilize and aggregate soils, prevent erosion, enhance percolation, and increase agricultural production on deficient and unstructured soil.Water-absorbent polymers can absorb up to 1,000 times their weight in pure water and form gels, depending on the type of polymer and the conditions during synthesis. They are called super absorbents or hydrogels because of their extraordinary capacity to absorb water and produce gels. Hydrogels can be divided into three primary groups: (i) polyacrylates; (ii) starch-graft co-polymers; and (iii) acrylamide-acrylate co-polymers.A major issue in many places of the world due to compromise agriculture farming is desertification and water scarcity. Desertification is the term used to describe the deterioration of land in dry, semi-arid, and arid regions due to a variety of reasons, mostly human activity but also environmental fluctuations.Using synthetic materials with strong water absorption and retention capabilities at high pressure or temperature is the solution to this issue. Super Absorbent Polymers (SAPs) are systems of this sort. For every dry gram of hydrogel, the super absorbent polymer may hold 400–1500 g of water, with 95% of the water being available for plant absorption.

2.1. HYDROGEL STRUCTURE

According to Ullah et al. (2015), a hydrogel's solid state is a network structure made of crosslinked polymer chains. Due to the hydrogel's three-dimensional network structure, its molecular weight approaches infinity (Rosiak et al., 1995). The mesh size and the molecular weight of the polymer chain between the crosslinks are the most crucial molecular characteristics that form the hydrogel structure (Figure 1) (Ganji et al., 2010).The hydrogel is made of a polymer known as carboxylic acid. The polymer's primary chain is broken by the acid groups. The hydrogel reacts with these acid groups in the presence of water, releasing the hydrogen atom and leaving the polymer chain with many negative charges along its length.(Note: H_3O^+ indicates the presence of an acid and is another method to write H+ in solution.)

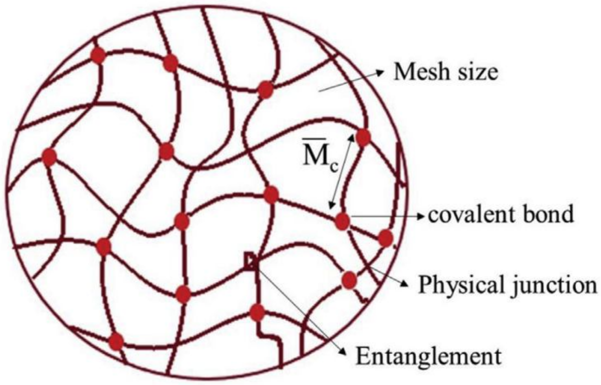

Fig. 1. Structure of hydrogel at a molecular level (Aswathy *et al*., 2020)

3. **SALIENT FEATURES**

1. Shows maximal absorbency at temperatures between 40 and 500C, which is typical of both dry and semi-arid soils.

2. 400 times its dry weight in water is absorbed and then gradually released.

3. Stable in soil for a year at the very least

4. Less impacted by sodium

5. Low soil application rates: 1-2 kg/ha for horticultural nursery crops and 2.5–5 kg/ha for field crops

6. Minimizes fertilizer and herbicide leaching

7. Enhances the physical characteristics of soils and soilless materials

Enhances root growth and density 9. Boosts seed germination and seedling emergence rate
10. Assists plants in withstanding extended moisture stress

11. Shortens time needed to create a nursery

12. Lessens the need for fertigation and irrigation of crops

13. Encourages early and abundant fruiting, blooming, and tillering.

14.delays the permanent wilting point's development

15. Shorter chrysanthemum nursery establishment time (18 days as opposed to 28 days in control)

16. Profound root development that improves the efficiency of water and nutrient utilization

17. A reduction in the quantity of fertigation booms needed to grow tomato crops in the field and nurseries (37 against 52 in the control).

18. A notable improvement over control in terms of seed germination and seedling growth efficiency

AGRICULTURAL HYDROGELS CAN CHANGE THE PHYSICAL PROPERTIES OF SOILS BY:

1. Increasing their water-holding capacity
2. Lowering runoff and erosion
3. Cutting back on irrigation frequency
4. Improving water usage efficiency
5. Increasing soil permeability and infiltration
6. Lessen the soil's propensity to compress
7. Enhance plant growth.

5. DESIRABLE CHARACTERISTICS OF HYDROGEL FOR APPLICATIONS IN AGRICULTURE

1. High capability for absorption in hard and salted water

2. The best absorbency under load (AUL) 3. The least amount of soluble content and monomer residue

4. Affordable

5. Extreme stability and robustness in a swelling environment and when being stored

6. Gradual biodegradability without harmful species creation

7. pH neutrality following edema in water

8. Stability of photos

9. The ability to re-wette

6. ENVIRONMENTAL SAFETY ASPECTS RELATED TO HYDROGEL

1. The unreacted monomers found in finished goods, such as acrylamide, acrylate, and acrylic acid, are intrinsically hazardous.

2. chemicals known as super absorbent polymers (SAPs) are technically irreversible to harmful initiating chemicals; that is, they cannot revert to their initial monomers.

3. The ionic and microbiological media in the soil moderately biodegrade it, ultimately converting it to carbon dioxide and ammonia.

4. Research conducted globally has revealed little to no consistent negative impact on soil microbial populations.

5. Our team has developed a highly easy-to-use and effective HPLC method to assess the residual monomer content in the hydrogels.

6. The absence of any detectable leftover unreacted monomer has been verified, indicating Pusa Hydrogel's safety for the environment.

7. In a year, these kinds of hydrogels totally break down into carbon dioxide, water, and ammonia.

8. For the majority of crops, the recommended application rate of Pusa hydrogel is quite low: 2.5 kg ha-1, or 2.5 ppm per unit weight of soil.

9. Pusa Hydrogel is semi-synthetic in nature, resulting in a lower load of monomer components in the final product, in contrast to commercial materials that are entirely synthetic.

7. **SIGNIFICANCE OF HYDROGEL**

The application of hydrogel has been shown to significantly improve the quality of agricultural produce in terms of fruit size and color, yield enhancement (10–50%), and increased plant biomass. The dry yield of kidney beans, maize, tomatoes, and flaxseed oil plant is increased by using super absorbent polymer. Additionally, it has led to a 30–50% decrease in the frequency of irrigation, which has reduced labor-intensive tasks associated with regular irrigation, especially for vegetables. It has a high benefit-to-cost ratio, improves the hydro-physical environment of the soil, and reduces fertilizer dose by 22–30%. The polymer lowers the rate of ammonium leaching and releases fertilizer agent into the soil matrix.Polymers can improve permeability in heavy soil and reduce fertilizer leaching while also boosting water retention in light soils.

The bulk density, or apparent specific weight, of soil is increased by the biodegradation of super absorbent polymers. Super absorbent polymer has been found to be an efficient material for lessening the impacts of drought stress, enhancing plant performance and tolerance to stressors. In addition to preventing crust development and increasing aggregate durability, super absorbent polymers also lessen soil erosion and stop runoff from farms. The use of hydrogel also has the major advantage of inhibiting the accumulation of proline and soluble carbohydrates by blocking the deep penetration of root environment water and leaching salts.Hydrogel finds significant uses in the biomedical industry, as well as in the removal of dyes, heavy metal ions, agriculture, sanitary napkins, pH sensors, biosensors, and supercapacitors (Bahram et al., 2016).

Table I. Agricultural hydrogel products available in India (Kalhapure*et al.*, 2016)

Trade name	Manufacturing company
Pusa Hydrogel	IARI, New Delhi
Waterlock 93N	Acuro Organics Ltd, New Delhi
Agro-forestry water absorbent polymer	Technocare Products, Ahmedabad
Super absorbent polymer	Gel frost packs, Kalyani enterprises, Chennai
Hydrogel	Chetex Speciality Ltd, Mumbai
Rain drops	M5 Exotic Lifestyle Concepts, Chennai

8. EFFECT OF HYDROGEL ON WATER USE EFFICIENCY

Hygroscopic compounds that resemble white sugar are commonly utilized as super absorbent polymers to increase irrigation efficiency. In comparison to other levels of polymer application (0, 0.25, 1.25, and 1.75%), the use of water soluble polymers at a rate of 0.75% w/w with 50% achievable moisture depletion to tomato in sandy loam soil achieved the maximum water use efficiency (153.6 kg m-3). Compared to the untreated sandy soil, the application of carboxymethyl cellulose at 2% and 4% dose with compost @ 5 tons ha-1 increased maize production by 25 and 34%, respectively. Both soil conditioners worked better together to improve water use efficiency than when applied separately.

8.1. EFFECT OF HYDROGEL ON ROOT ACTIVITIES

The root characteristics of tomatoes, such as root length, root volume, and root fresh and dry weight at harvest, rose significantly with an increase in hydrophilic polymer concentration. This is because the hydrophilic polymer effectively maintained water in the roots for a longer period of time. In comparison to the control, Volkamar and Chang (1995) found that hydrophilic polymer @ 1.87 g plant-1 increased root biomass. Similar to Taylor and Halfacre's (1986) findings, Sendur et al. (2001) determined that hydrophilic polymers greatly increased root length and root dry weight when compared to the control.

During the 2011–12 Rabi season, Rohit Kumar and a colleague conducted a field experiment at the C6 block of the Bihar Agricultural College Farm, Sabour, Bhagalpur, to investigate the effects of hydrogel on the growth and yield of maize as well as the properties of the soil, the productivity of the water, and the economics of applying hydrogel to maize. The treatments consisted of six sub-plot treatments with hydrogel dosages (control, 50, 75, 100, 125, and 150 percent recommended dose) and two main plot treatments (two hydrogel sources, Stockosorb and Pusa gel). The study's findings are as follows:

1. The hydrogel's sources, stokosorb and pusa gel, had no appreciable effect on the economics of production, the physical characteristics of the soil, or the water productivity of the rabi maize crops.

3. The maximum grain yield of maize was produced at 150% of the authorized hydrogel dosage.

4. The application of the 75% suggested dose of hydrogel yielded the highest net return.

5. When 15% of the necessary dose of hydrogel was applied, the highest water productivity (or water use efficiency) was achieved.

6. The application of hydrogel improved the physical characteristics of the soil in terms of bulk density, porosity, and water holding capacity; the ideal dosage of hydrogel was determined to be 125%.

9. BIODEGRADABLE NANO-HYDROGELS IN AGRICULTURAL FARMING

The current technology employed in agriculture is called nanotechnology. Changes in the amount and distribution of rainfall have a major impact on agricultural output yield in dry land areas. Rainfed agriculture makes for 70% of the 143 million hectares of total cultivated land in the nation. Forty-two percent of the nation's total food grain production comes from the dry land areas.Soil moisture is the single most important element preventing the production of the second crop following rice. According to Hayat and Ali's (2004) assessment, moisture stress from low and unpredictable rainfall is the factor limiting crop yield in arid and semi-arid regions.The Department of Biotechnology at Acharya Nagarjuna University in Nagarjunanagar and Guru Nanak Institute of Technology in Ibrahimpatnam R.R. Dist, Telangana created the silver coated nano-clay composite cross-linked polyacrylamides polymers between 2009 and 2014.

By using 8% acrylic acid, 1-5% acrylamide, 0.9% ammonium persulphate as an initiator, 0.12% N-methyl biscrylate as a cross-linker, and 10% clay at a reaction temperature of 65ºC while nitrogen gas was present, silver-coated hydrogels were created. To create SAP coated in silver, 10% silver nitrate was applied before to the polymerization procedure. The polymerized sample that had dried was ground into a fine powder using a hefty wooden mortar. The product's ability to sorb water was investigated for use in agriculture.

9.1. **Modification of Hydrogel**

There are three applications for nanostructured clay: powder, aqueous suspension, and jelly-consistence. After adding the clay and agitating the water to a perfect homogeneity, 1 g of dry hydrogel is added. The water is then heated to 65°C. After letting it stand for ten minutes to solidify SAP, it is filtered through a Buchner funnel. To dry, the filter cake is moved to a china dish.

9.2. **Determination of Degree of Swelling:**

To test the polymer's degree of swelling, 250 mg of produced Super Absorbent Polymer is added to a glass beaker along with 250–300 ml of distilled water or 50 ml of 0.9 wt% NaCl solution. The beaker is then left to stand. Following the polymer's achievement of the equilibrium-swelling condition, it is weighed and filtered using a paper or 30µm filter cloth.

The ratio of the weighed-out sample to the weighed-in sample, expressed in g/g, is then used to determine the degree of swelling. Every calculation is performed three times with an accuracy of ±5%. The polymer concentration and crosslinking density affect the rate of swelling (Okay, 2010).

According to Ramesh Vundavallia et al. (2015), the soil containing hydrogel and soil coated with silver had a water-holding ratio that was 3.5% and 7.5% greater, respectively, than the original soil. This demonstrates how well the silver-coated hydrogel absorbs water from the soil, increasing the soil's ability to keep water and its efficiency in using it. Rainwater or irrigation water can be cleverly stored in the hydrogels coated in silver, up to 130–190 times its weight. One of the main benefits over traditional coated slow-release fertilizers is this.

10. **CONCLUSION:**

The application of hydrogel in nearly all test crops (cereals, vegetables, oilseeds, flowers, spices, etc.) has improved yield and increased plant biomass while also significantly improving the quality of agricultural produce in terms of fruit size and color. Additionally, it has improved the hydrophysical environment of the soil, reduced the frequency of irrigation, decreased the dosage of fertilizers, and produced a high benefit-cost ratio. Hydrogel prevents nutrients from seeping into groundwater and retains them where they are needed—directly at the roots in water solution—by reducing the frequency of watering by up to 70%. This saves water and time.TThis also reduces the need for irrigation and fertilizer. Agricultural hydrogels offer a great deal of potential to enhance the physical, chemical, and biological characteristics of soil in addition to being utilized to save water during irrigation. Therefore, using hydrogel will be a profitable way to boost sustainable agricultural output in a climate that is moisture-stressed.

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1.

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