17. Hydrogels in Water Stress Agriculture

Manuj Awasthi

C. S. Azad University of Agriculture and Technology,
Kanpur, Uttar Pradesh, India.

Amit Bhatt

Shri. Guru Ram Rai University,
Dehradun, Uttarakhand, India.

Abstract:

One of the main ecological constraints that prevent agriculture from being sustainable is the availability of water in areas that are semi-arid or arid and under rain-fed conditions. The super absorbent polymer (agricultural) is water-absorbing and cross-linked so that it bonds with water molecules to absorb aqueous solutions. By reducing evaporation, deep percolation, and runoff losses, this novel method of water management in water-stressed conditions conserves soil moisture in the active rooting zone of crops. Due to the irregular spatial and temporal distribution of rainfall in the world's arid and semiarid climates, water scarcity is a major environmental issue that seriously hinders the sustainability of agriculture. Under conditions of moisture stress, a variety of physiological changes have been observed, including a decrease in water potential, stomatal closure, a decrease in photosynthetic rate, morphological rate, decile yield, and plant quality by limiting overall plant growth. Patra et al., (2022) agricultural hydrogels are water retention granules that expand their unique size to various stretches when they contact with water. When the rhizosphere zone dries out during a drought, it can absorb and store a significant amount of moisture and release it back into the soil to reduce the amount of water needed by crops. It assumes diverse parts in farming including soil-water retainer, supplement and pesticide transporters, seed covering, soil disintegration minimizer, and food added substances. It is extraordinary in that it can improve various soil physicochemical, hydro-physical, and biological properties. At the same time, it can reduce the frequency of irrigation, improve water and nutrient use efficiency, and increase the yield and quality of field, ornamental, vegetable, and other crops. The soil, crops, and environment are not harmed by these biodegradable materials. Consequently, the addition of the hydrogel polymer will be a promising and practical technological device for increasing crop productivity in moisture-stressed environments.

Keywords:

Hydrogel, water stress, hydrophysical and biologicall etc

17.1 Introduction:

Hydrogel is also known as ‘root watering crystal, "water retention granules," or "raindrops."

It has special absorbency and biodegradability thanks to its three-dimensional networks of versatile hydrophilic macromolecules that are cross-linked and loosely held. These networks are connected by covalent bonds or physical interactions. When these organic polymers come into contact with water that is readily available, they have a one-of-a-kind capacity to rapidly absorb a significant amount of moisture thanks to their super absorbent structure. During the soil drying process, these materials uniformly desorb the stored moisture to the surrounding soil and rhizosphere zones (Gaikwad *et al.*, 2017). When moisture is scarce for an extended period, water stress can be avoided by having more water available in the soil. The hydrogel's ability to retain moisture is due to the hydrophilic functional groups that are attached to the polymer backbone, and their resistance to dissolution is due to the cross-links that exist between the network chains. The very spongy polymers are both normally happening and of engineered beginning commonly produced using oil-based commodities. However, the synthetic polymers are one of a kind because they exhibit a high degree of swelling and shrinking in response to environmental changes.

A. Highlights of Hydrogel:

- The ideal hydrogel materials ought to have the following characteristics:
- The capacity to absorb a lot of water.
- The plant-specific desired rate of absorption and desorption capacity
- Lowest concentration of solubles and residual monomer
- Stability and durability during storage and swelling
- Excellent biocompatibility and biodegradability
- Superior performance across a broad temperature range
- Subsequent to expanding, water becomes unbiased in Ph.
- Lack of color, absence of odor, and nontoxic
- Improve the biological, chemical, and physical properties of the soil.
- Photostability, rewetting capacity for a more extended time frame, minimal expense material, and eco-accommodating

B. How do Water retention and release behavior work in a Hydrogel?

- Water absorption in a hydrogel is caused by the hydrophilic groups of the polymer chain-acrylamide, acrylic acid, acrylate, and carboxylic acid, etc.
- Hydrogen atoms react and emerge as positive ions when water enters the hydrogel system through osmosis when the polymers come into contact with it.
- This process leaves a few negative ions along the length of the polymer chain. These negative charges repulse one another and force the polymer chain to loosen up and open up and draw in water particles and tie them with hydrogen holding (Kalhapure *et al.*, 2016).
- During this process, the hydrogel can function as a miniature water reservoir and absorb more than 400 to 1500 times its dry weight in water. While the encompassing around the root zone starts to evaporate, the hydrogel slowly administers up to 95% of its put-away water to establish assimilation (Peterson 2002).
- Under rewetting conditions, rehydration begins and the water storage process continues.

- This polymer can increment water maintenance in soil which works with higher water take-up and water use effectiveness, hence assisting in diminishing the water with focusing on of plants and expanding crop development and yield.
- Depending on the current conditions in the environment, these undergo volume transition in response to physical and chemical stimuli (Ahmed 2015).
- The hydrogels do not alter the physicochemical properties of the soil because they are biodegradable and decompose in the soil after being used for two to five years.

C. Classification of Hydrogel:

Hydrogel for agricultural use can be divided into three categories based on its source:

a. Natural hydrogel,
b. Semiartificial hydrogel, and
c. Artificial hydrogel (Mikkelsen 1999).

Based on their chemical composition and arrangement, the petroleum-based synthetic hydrogels that are currently on the market are primarily divided into the following three categories:

a. Starch-polyacrylonitrile graft polymers (starch copolymers)
b. Vinyl alcohol-acrylic acid copolymers (polyvinyl alcohols)
c. Acrylamide sodium acrylate copolymers (cross-linked polyacrylamides)

17.2 Pusa-Hydrogel:

The pusa-hydrogel is a great innovation for the future because it can address the most pressing issue of water. Farmers should use it to alleviate stress on the water table, which is decreasing at an alarming rate. It is feasible and friendly of farmers. The kind gesture made by the scientist at IARI, New Delhi, to be supported by the government, as should the farmers' easy access to the greatest invention of the decade. This invention is suitable for all Indian soil conditions and helps crops survive in the harshest conditions, like drought and high temperatures (Kritika *et al.,* 2021). Pusa-Hydrogel is a super absorbent polymer that is semi-synthetic, cross-linked, and derivatized from cellulose-graft-anionic polyacrylate.

There are approximately 160 million hectares of agricultural land in India, of which approximately 39 million are irrigated with underground water, 22 million through canals and rivers, and approximately two-thirds are dependent on the monsoon. India has a poor irrigation management system due to the widespread use of flood irrigation, which depletes the groundwater table. The Pusa-hydrogel was created by scientists from the Indian Agricultural Research Institute in New Delhi in response to the alarming rate of water scarcity that the world will face by 2025. As the condition of water availability appears to be, more than 100 million people live in areas with poor water quality, and more than 54% of areas are about high to extremely high-water stress conditions, it is anticipated that by 2025, two-thirds of the world's population will face water scarcity.

According to the findings of scientists, pusa-hydrogel can be used on all crops, including wheat, paddy, sugarcane, groundnut, potato, strawberry, tomato, onion, carrot, mustard, cauliflower, cotton, chrysanthemum, turmeric, and others.

A. Benefits:

a. **Water use Efficiency:** After being applied, it absorbs 350 times its actual weight in total water presence before being released later. As a result, the interval time for irrigation is increasing, as is the scheduling time for irrigation.
b. **Temperature resistant:** It is ideal if there is limited access to water, as it can withstand temperatures up to 50 ^{0}C in dry conditions.
c. **Soil Requirements:** Pusa-hydrogel is appropriate with all kinds of soils accessible in Indian circumstances possibly it is fundamental or acidic.
d. **Economic to the farmer:** The average cost of the product available in the market is as low as Rs.1000-1400/kg.
e. **Environment friendly:**
    - Helps in root penetration.
    - Helps in improving soil characteristics.
    - Helps to increase the density of soil.
f. **Application Method:** It requires a basal dose of 2.5-3.0kg/ha. It is applied to the field at the hour of planting or before the water system.
g. **Yield Attributes:** Recent research revealed that various crops' yields increased by 18-22% when tested in the IARI, New Delhi, field conditions for two years. It also revealed that the irrigation requirements were limited to three irrigations per crop (scheduling) and that some crops were also tested in rainfed conditions.

17.3 Use of Hydrogel in Agriculture:

The dirt water accessibility is the main ecological element for the endurance of plants and the microbiological populace and essentially decides the rural action in the water-scant area. Environment tough low-water-requiring harvests and varietal determinations, effective water the board rehearses through micro irrigation with legitimate water system booking, and elective utilization of soil conditioners like very permeable polymers are a portion of the mechanical mediations wisely applied in farming for overseeing water in the dirt and easing the developing plants from unfavorable dry spell conditions. Hydrogels are white sugar-like hygroscopic granules or tiny beads that swell in water or an aqueous solution to form a clear gel made of individual particles. By using a cross-linker to polymerize acrylic acid, the synthetic polymers are made. Potassium polyacrylate is a significant component utilized in hydrogel innovation and is showcased as a hydrogel for farming. The expanding limit and gel modulus rely enormously upon the amount and kind of cross-linker utilized.

These have a biodegradation rate of 10-15% per year and are nontoxic, nonirritating, and noncorrosive. Biodegradability relies upon the substance arrangement of these polymers as well as the synthetic and organic climate of the dirt. As the binding forces of water in the hydrogels are lower than the suction force of roots, the super absorbent polymers have a great potential to absorb and store water several hundred times their original dry weight.

They can also serve as a ‘miniature water reservoir’ in the soil and quickly release up to 95 percent of the water they absorb to thirsty plants in conditions of moisture stress or drought through osmotic pressure difference (Azzam 1980). Soil conditioners, reservoirs of water and nutrients, planting and transplanting gels, seed coatings for controlled seed germination, increased leaf water and chlorophyll content, soil aerators, and soil sterilization all make extensive use of hydrogels in arid and semiarid regions (Abobatta 2018).

These polymers are generally utilized in cultivating for their capacity for holding higher soil water maintenance for longer periods and slow arrival of water and supplements to plants, filling in as supports against brief dry spell pressure in unfriendly atmospheric conditions to decreasing the gamble of plant disappointment during crop foundation, advancing development and improvement of the plant, diminishing the evapotranspiration rate, and getting better return and nature of harvests (Abedi-Koupai, *et al.,* 2008). Hydrogels form aqueous gels despite coming into direct contact with the matrices of the soil. This aqueous gel serves as a water reservoir for the plant-soil system. These hydrogelled particles are embedded in a matrix, and the plant's roots use them to get water when they need it (Yangyuoru *et al.,* 2009). These materials are environmentally friendly and non-toxic (Soubeihkh 2018).

17.3.1 Some Effects of Hydrogel on The Properties of Plants and Soil:

Oxygen radicals and lipid peroxidation can result from droughts caused by a soil's lack of water production (Wang and Gregg 1990). The morphology of the plant may suffer as a result, with reduced leaf area, decreased leaf height, and, ultimately, leaf damage. Therefore, even in adverse climates, the application of hydrogels can be a lifesaver for increasing crop yield and plant growth (Taylor and Halfacre 1986). According to Bearce and McCollum's (1997) hydrogel extends the shelf life of potted plants and reduces the need for frequent irrigation. The benefits of hydrogel in horticulture have been reported by several researchers. Additionally, it may increase the soil's capacity to hold water.

MacPhail *et al.,* (1980) found that different doses of ‘Vitera-2-Hydrogel’ have a significant impact on turfgrass and bluegrass survival under moisture stress in greenhouse tests. They also summarized that tree species in this region can effectively combat high temperature and moisture stress by adding hydrogel to the soil before planting (Tomáková *et al.,* 2020).

A. New Features of Hydrogel for Use in Agriculture:

The characteristics of hydrogels as soil conditions are as follows:

- Resistant to salt concentrations in soil.
- Improve the physical, chemical, and biological properties of soil.
- Encourage seed germination, growth of seedlings, root development, plant density, and yield.
- Under drought stress, more water absorption in excess water and gradual release.
- Reduce moisture stress on the plants and ensure that they can withstand prolonged moisture stress.

- Delay the onset of the permanent wilting point in the arid environment due to intense evaporation.
- Increase water consumption efficiency.
- Reduce water loss through evaporation and leaching to improve water efficiency.
- Lower irrigation costs, crop fertilizer requirements, and frequency.
- Maximum soil durability and stability.
- No threats to the environment.
- Suitable for hot and dry climates due to its high performance at high temperatures (40-50 ^{0}C).

B. Methods for Using Hydrogel in Agriculture:

As a type of soil conditioner, hydrogels are used to stabilize surface soils, prevent crust formation, improve poor structure soil by aggregation at greater depths, increase water-holding capacity, and encourage plant growth and development. The texture of the soil determines how quickly hydrogel should be applied in agriculture. It is 2.5 kg ha-1 at 6-8 soil depths in clay soil, and up to 5.0 kg ha-1 at 4 soil depths in sandy soil.

There are primarily two ways to apply hydrogels to soils:

a. **Dry method to subsoil:** a dry polymer like polyallylamine (PAAm) or polyvinyl alcohol (PVA) is mixed with sandy soil to a depth of 15 to 25 centimeters and moistened to cause swelling before cultivation.
b. **Wet method to topsoil:** the polymer solution is sprayed onto initially wetted topsoil, followed by drying for water-stable aggregate stability and immediate sowing. This improves the structure of the soil as well as increases its capacity for water penetration and retention. The use of water can be reduced, soil erosion can be reduced, and soil hydraulic conductivity can be increased using this wet method. The hydrogel can also be mixed with pesticides and micronutrients in the spray method.

C. Effect of Hydrogel Polymer on the Properties of the Soil:

The following ways can be used to improve the soil properties of arid and semiarid regions when hydrogel is applied as a soil conditioner or amendment (Neethu *et al.,* 2018)**:**

Through aggregation, stabilization, and solidification, you can alter the physical (such as porosity, bulk density, water-holding capacity, soil permeability, percolation and infiltration rate, soil temperature, etc.), chemical (such as CEC, etc.), and biological environments of course-textured soil. You can also prevent crust formation. You can achieve a favorable growth medium by reducing the bulk density of the soil and providing a better ventilation and moisture regime for supporting plant viability, growth, and reducing irrigation frequency due to a decrease in water losses from leaching and evaporation; control seepage by the formation of soil membranes that regulate the movement of water and nutrients downwards; improve aeration and soil drainage; prevent salt toxicity injury to plants; increase water and nutrient use efficiencies; and play havoc roles in both light and heavy soils, where water scarcity prevailed.

D. Benefits of hydrogel in agriculture:

- Hydrogels surround plants' root zones and serve as miniature water reservoirs. It has a root capillary suction mechanism that allows it to slowly release water when there isn't enough water, and it can take in water from the environment 400 to 1500 times its weight.
- It is able to carry out the cyclic process of absorbing and releasing water, provide the highest level of plant-available moisture for quick seed germination and seedling establishment, and boost crop growth and high yield.
- The use of hydrogels keeps the moisture that is absorbed in the structure from freezing in cold places and makes it easy for the plants to get to it, regulating the temperature at which seedlings grow and preventing death by freezing.
- It can lower the osmotic moisture in the soil, save money on irrigation water, labor, and production, reduce crops' need for irrigation, alleviate drought conditions, prevent water and nutrients from being leached or runoff, improve plants' water and nutrient use efficiency, and restore soil microorganisms and enzymes.
- By delaying the onset of the plant's permanent wilting, it can help the plant withstand the prolonged moisture stress.
- It can reduce the excessive use of minerals, such as pesticides and micronutrient fertilizers.
- It can also prevent soil compaction, increase soil aeration, and release soil mineral nutrients.
- It can encourage plant growth that is stronger and healthier, as well as yield that can be sold.

E. Drawbacks of Using Hydrogel in Agriculture:

The absorptive capacity of hydrogel for water is affected by many factors, limiting its application in agriculture in many instances, as shown below.

The hydrogel's ability to absorb water is somewhat influenced by water hardness. The hydrogel loses a lot of its ability to absorb water as its hardness rises as a result of rising concentrations of Ca^{2+} and Mg^{2+} ions, mostly from fertilizers and irrigation water sources. These ions react with negative sites in the polymeric chain when hydrogel absorbs water, resulting in the formation of non-soluble salts that obstruct the negative ion sites.

This blockage gets worse as the water gets saltier and goes through more wetting and drying cycles (Kalhapure 2016). The majority of soils are capable of holding sufficient water for plant growth. The hydrogel will not resolve the issue if there is insufficient rainfall because the soil water is depleted. Similarly, it won't work at all if there is a good distribution of rainfall during the cropping season. Most of the time, the cost of the hydrogel is too high, which makes it hard to change the active rooting depth. As a result, its potential application is restricted to high-value crops only to reduce the frequency of irrigations or reduce stress between irrigations, particularly in situations in which water stress causes a decline in plant or crop quality and value. Its use is limited to the government and other well-funded organizations unless costs are drastically reduced, excluding private farmers and agriculturists who stand to benefit from its prudent use.

The texture of the soil, the kind of polymer used, how and when the hydrogel is applied, the nature of the crop species, and these factors all affect its efficacy. In most cases, dibbling should be used to apply the polymers to the soil near the root zone at a depth of 10 cm. Numerous examples demonstrated that the hydrogel had no or very little effect on soil amendment in terms of moisture conservation and yield improvement in several crops (Mandal *et al.,* 2015). When there is a shortage of water, rather than providing water to plants, it may, at times, absorb water from the biological system in an irreversible way, leading to the withering of plant stands.

17.4 Practical Assessment of Hydrogel in Agriculture:

The beneficial effects of applying different concentrations of hydrogel to different soil, crop, and climatic conditions on crop yields, soil moisture conservation, and water use efficiency.

According to the different researchers, the addition of a hydrogel-concerning control (without hydrogel) resulted in an increase in yield of 11.0-27.8 percent for sunflower, 14.8-51.3 percent for wheat, 27.8 percent for onion, 15.0% for apple, 55.7% for lemon, 6.2% for aerobic rice, and 33.0% for castor, Soybean accounts for 45.0%, pearl millet for 21.9-23.3 percent, banana for 14.9%, mustard for 5.3 percent, lentil for 50.3%, tomato for 20.9-250%, and sugar beet for 36.6 percent.

Hydrogel treatment increased water use efficiency by 14.43 percent for wheat, 9.0 percent for pearl millet, 5.52 percent for mustard, 100-216% for tomato (greenhouse), and 33.5 percent for sugar beet compared to control. In a similar vein, soil water retention was found to be 15.4-29.2% for sunflower, 5.9% for lemon, 23.7-37.2% for aerobic rice, 13.0% for pearl millet, 20% for banana, 15-25% for lentil, and 1.6-2.1-folds for tomato (greenhouse) in hydrogel treatment compared to control.

This strongly suggest that application of hydrogel to the soil increased the yield of various crops. This could be due to the polymer's adequate availability of water and the indirect supply of nutrients to the plants under moisture stress, which allowed for adequate translocation of water, nutrients, and photosynthates, ultimately leading to a higher economic yield.

When hydrogel is applied, more water is available in the soil, which helps plants avoid water stress during prolonged droughts. Free pore volume will be created within the soil during the hydrogel's water release phase, providing additional space for root growth, air and water infiltration, and storage. It also maintains its swelling capacity despite a strong resistance to soil pressure at high soil depth. At the same time, water is stored in the rhizosphere to prevent plant nutrient and water losses from deep percolation and nutrient leaching. The plant can be given nutrients and water for a long time in this way (Pattanaaik *et al.,* 2015). When the soil is treated with super absorbent polymers, germination, seedling emergence, vigor, stability of plant growth, and yield can all be guaranteed in drought stress. By increasing the soil's capacity to hold water, the application of hydrogel reduces the need for irrigation for several crops when there is a lack of or limited supply of water (Taylor and Halfacre 1986).

In addition, the incorporation of super absorbent polymers into the soil improves its physical properties as well as the availability of water. As a result, crop irrigation requirements are reduced, which in turn increases plant growth and yield. When compared to untreated soil, the addition of hydrogel amendments as a cultural practice in coarse sandy loam soil increased seedling growth of wheat and barley, reduced evaporation loss, and improved soil water storage, making it useful for improved plant establishment in drought-prone environments. According to Zangooinasab *et al.,* (2012), when applied in conjunction with appropriate irrigation, hydrogel could completely conserve moisture while also increasing crop yield and quality.

According to Pattanaaik *et al.,* 2015, Assam lemon crops experienced severe water stress from October to March, resulting in low crop water productivity. However, the soil's water-holding capacity increased from 28.74 to 34.63% when stockosorb was applied at 100 g per plant, increasing the yield to 130.2 fruits per plant from 83.6 fruits per plant in the control plot. The application of hydrogel has resulted in an increase in yield. This could be because the soil was wetter for a longer period of time, resulting in increased microbial activity and reduced fruit drops as a result of water stress. Under the water regime of 87.5 percent of the recommended amount of irrigation, Grand Nain banana plants demonstrated that the application of hydrogel increased bunch weight and fruit yield (Kassim, *et al.,* 2017).

According to Liu *et al.,* (2016), superabsorbent polymers helped the coffee tree's leaves gain total dry weight, chlorophyll, and soluble sugar. In comparison to the absence of hydrogel, the application of 2.5 kg ha^{-1} of hydrogel to medium black soil resulted in a 33% increase in rainfed castor seed yield (Naik *et al.,* 2020). Ramanjaneyulu *et al.,* (2018) found that the long duration, intermediate nature, and inherent capacity to withstand short-term droughts of hydrogel did not result in an increase in rainfed castor seed yield in alfisols. Salokhiddinov *et al.,* (2020) discovered that under automorphic soil conditions based on improved traditional furrow irrigation technology, the use of highly swellable polymer hydrogels enabled cotton crop experiments to reduce irrigation water consumption by 15-17 percent in the first year, 12-14 percent in the second year, and 9-11 percent in the third year. The interval between irrigations was increased by 10 to 12 days and the number of irrigations decreased as a result of the longer period of soil moisture conservation.

On the other hand, according to Austin and Bondari's (1992), adding hydrogel to soil, pine bark, or peat moss did not increase plant growth, yield, or berry weight. Adding hydrogel to organic matter for use in soil amendments posed a risk to young blueberry plants that could result in death and provided little or no economic benefit. In a similar finding, the application of hydrogel did not improve wheat yield according to Meena *et al.,* (2015). However, despite its drawbacks, the hydrogel is regarded as an inexpensive alternative to water management equipment that contributes to the creation of a favorable environment for the enhancement of the effectiveness of soil and water management in the horticultural and agricultural sectors.

17.5 Potential Applications of Nano-Based Hydrogel in Agriculture:

According to Vandavallia *et al.,* (2015), nanotechnology is the modern tool for precise input utilization in modern agriculture practices to achieve higher crop resource efficiency.

According to Srivastava *et al.,* (2018), this technology gives hope for new developments in agricultural application and soil management. A material that synthesizes or prepares, characterizes, and manipulates its structures and devices in such a type of dimensional scale where particular or specific materials are reduced from macro dimensions to nano dimensions and their physical and chemical properties are improved manifold by Duncan (2011) defines as the term ‘Nanotechnology’. With the use of this technology, different products containing nanoparticles can be used to create new opportunities in the agricultural sector. The advantages of NTs greatly increase the production of nano fertilizers, nano pesticides, nano herbicides, and nano sensors for environmentally friendly, sustainable agriculture (Brooks 2014). Due to the ever-increasing human and livestock population, numerous anthropogenic activities, and ongoing global climate change, water is becoming a finite natural resource. Designed materials with good water absorption and retention capacities, such as nanocomposite hydrogels at high pressure or temperature (Gupta 2018), can solve this critical issue.

The structure of most hydrogels is typically a three-dimensional cross-linked polymer network with hydrophilic and hydrophobic components. According to Li *et al.,* (2011), they typically swell when placed in moist conditions, increasing in size without altering their inherent properties. Vundavalli *et al.,* (2015) created a novel biodegradable poly (acrylamide-co-acrylic acid)/silver-coated superabsorbent hydrogel nanocomposite for agricultural use that kept these soil moisture absorption and retention capabilities in mind. The nanoparticles had a mean diameter of 200 nm, as reported by Liu *et al.,* (2008) and Bajpai *et al.,* (2014) according to electron microscopy scanning. The water-holding ratio was 7.5% and 3.5% higher in the soil with silver-coated hydrogel and soil with hydrogel, respectively, when compared to the original soil (Vundavallia *et al.,* 2015). The water absorbency rate of silver-coated hydrogel nanoparticles is comparatively higher in distilled water and tap water in comparison to 1% sodium chloride solution.

As a result, the silver-coated hydrogel has superior water absorption, improved water retention, and soil capacity for moisture preservation, making it suitable for plant growth and yield enhancement. Kayalvizhy (2014) synthesized and characterized the nanocomposite, revealing that the diffusion mechanism, which lowers the osmotic pressure between internal and external superabsorbents, always determines the swelling rate, resulting in a decrease in both capacity and rate. Some of the conventional nanocomposite hydrogels are regarded as soil pollutants and are not biodegradable. According to Cannazza *et al.,* (2014), issues about environmental protection have increased the significance of biodegradable hydrogels for agricultural commercial applications. Chitosan-based hydrogel beads have a higher loading capacity thanks to their increased porosity, expanded polymer chains, increased surface area, decreased crystallinity, and improved access to internal sorption sites (Vakili *et al.,* 2014). The preparation procedure is straightforward. Peng *et al.,* (2015) discovered that chitosan-halloysite nanotube composite hydrogel beads improved and accelerated the adsorption process over pure chitosan hydrogel beads. According to Montesano *et al.,* (2015), the high-water retention properties of cellulose-based hydrogels for vegetable crop-growing media make them extremely useful for crop production. Because these composites, as opposed to conventional fertilizers, are fully accessible to plants and readily available to them, the association of fertilizer with hydrogel nanomaterials opened up new possibilities for crop production processes.

According to Corradini *et al.,* (2010), chitosan nanoparticles are an intriguing material for controlled fertilizer release systems. Hydrogel nanoparticles, which are easily soluble, are used to load and/or encapsulate nano fertilizers, allowing for a more gradual release of nutrients into the soil. According to Sun *et al.,* (2014), nano-fertilized biodegradable hydrogels easily diffuse into roots through simplistic and apo plastic pathways and are transferred through the xylem tissue to the plants' above-ground parts, such as the stems and leaves. In addition, (Sheng *et al.,* 2015), SAPs have been used in conjunction with pesticides to control their release rates and encourage the effective utilization of both pesticides and water.

17.6 Conclusion:

In arid and semiarid regions, water is becoming the most important constraint on sustainable crop production. Hydrogel can be used as a soil conditioner to improve the hydro physical, physicochemical, and biological environments of the soil, increase the capacity of the soil to retain and release water, increase irrigation, water, and nutrient use efficiency, increase agricultural produce yield and quality, and maintain the quality of the environment. In water-stressed areas, this hydrogel technology may become a practical and revolutionary method for increasing yield (for cereals, vegetables, oilseeds, flowers, spices, plantations, etc.) and relieving soil moisture stress. This review assumes that farmers and other stakeholders would benefit greatly from the widespread application of hydrogel to optimize water resource management for increased agricultural yield.

A. Future Aspects:

With the rising interest in water and remembering its shortage in the coming many years, it is viewed as an aid to horticulture and to improve society. It is the need of great importance that we work to utilize the accessible assets, particularly water productively. Pusa-hydrogel is the future of agriculture, particularly in Indian conditions where the country will face water-related issues. Farmers and the government must use pusa hydrogel in field operations to improve water efficiency and soil properties to use water effectively. It is likewise very much expected to keep up with the regular environmental work on the groundwater table and save the assets for people in the future.

17.7 References:

1. Abedi-Koupai J, Sohrab F and Swarbrick G. 2008. Evaluation of hydrogel application on soil water retention characteristics. Journal of Plant Nutrition 31(2): 317–331.
2. Abobatta W. 2018. Impact of hydrogel polymer in the agricultural sector. Advances in Agriculture and Environmental Science 1(2):59–64.
3. Ahmed E M. 2015. Hydrogel: preparation, characterization, and applications: a review. Journal of Advanced Research 6(2):105–121.
4. Austin M E and Bondari K. 1992. Hydrogel as a field medium amendment for blueberry plants. HortScience 27(9):973-974.
5. Azzam R A. 1980. Agricultural polymers, Polyacrylamide preparation, application and prospects in soil conditioning. Communications in Soil Science and Plant Analysis 11(8): 767–834.

6. Bajpai A, Tripathi N and Saxena S. 2014. Nanocomposites based on natural biodegradable materials: effect of post-preparative γ-irradiation on the swelling properties, Open Journal of Organic Polymer Materials 4(1):10–15.
7. Bearce B C and Mccollum R W. 1997. A comparison of peat-like and noncom posted hardwood-bark mixes for use in pot and bedding-plant production and the effects of a new hydrogel soil amendment on their performance. Florists Review 161: 21–66.
8. Brooks J. 2014. Policy coherence and food security: the effects of OECD countries' agricultural policies. Food Policy 44: 88–94.
9. Cannazza G, Cataldo A, Benedetto E D, Demitri C, Madaghiele M and Sannino A. 2014. Experimental assessment of the use of a novel superabsorbent polymer (SAP) for the optimization of water consumption in agricultural irrigation process. Water 6(7):2056–2069.
10. Corradini E, DeMoura MR and Mattoso LHC. 2010. A preliminary study of the incorporation of NPK fertilizer into chitosan nanoparticles. Express Polymer Letters 4(8):509–515.
11. Duncan TV. 2011. Applications of nanotechnology in food packaging and food safety: barrier materials, antimicrobials and sensors. Journal of Colloid and Interface Science 363(1):1–24.
12. Gaikwad GS, Vilhekar SC, Mane PN and Vaidya ER. 2017. Impact of organic manures and hydrophilic polymer hydrogel on conservation of moisture and sunflower production under rainfed condition. Advance Research Journal of Crop Improvement 8(1): 31–35,
13. Gupta H. 2018. Role of nanocomposites in agriculture. Nano Hybrids and Composites 20: 81–89.
14. Kalhapure A, Kumar R, Singh VP and Pandey DS. 2016. Hydrogels: a boon for increasing agricultural productivity in water-stressed environment. Current Science 111(11):1773–1779.
15. Kassim FS, El-Koly MF and Hosny, SS. 2017. Evaluation of super absorbent polymer application on yield and water use efficiency of Grand Nain banana plant. Middle East Journal of Agriculture Research 6(1):188–198.
16. Kayalvizhy E. 2014. Synthesis and characterization of poly (N-tertamylacrylamide-co-acrylamide/sodium acrylate) gold nanocomposite hydrogels. Paripex-Indian Journal of Research, Chemistry 3(5):23–26.
17. Kritika A, Singh A and Kaushal S. 2021. Pusa Hydrogel: A boon to Indian Agriculture. Just Agriculture (multidisciplinary e-newsletter) 1(8):1-3.
18. Li S, Zhang H, Feng J, Xu R and Liu X. 2011. Facile preparation of poly (acrylic acid-acrylamide) hydrogels by frontal polymerization and their use in removal of cationic dyes from aqueous solution. Nanocomposites-New Trends and Developments 280: 95–102.
19. Liu X, Li F, Yang Q and Wang X. 2016. Effects of alternate drip irrigation and superabsorbent polymers on growth and water use of young coffee tree. Journal of Environment and Biosciences 37(4): 485–491.
20. Liu Z, Jiao Y, Wang Y, Zhou C and Zhang Z. 2008. Polysaccharides-based nanoparticles as drug delivery systems. Advanced Drug Delivery Reviews 60(15):1650–1662.
21. MacPhail JM, Emens JL, Harney PM and Tsujita MJ. 1980. Effect of viterra 2-hydrogel on germination; seedling growth and sod establishment of Kentucky bluegrass. Canadian Journal of Plant Science 60(2):665–668.

22. Mandal UK, Sharma KL and Venkanna K. 2015. Evaluating hydrogel application on soil water availability and crop productivity in semiarid tropical red soil. Indian Journal of Dryland Agricultural Research and Development 30(2):1–10.
23. Meena RP, Sharma RK and Tripathi SC. 2015. Influence of hydrogel, irrigation and nutrient levels on wheat productivity. Journal of Wheat Research 7(2):19–22.
24. Mikkelsen RL. 1999. Using hydrophilic polymers to control nutrient release. Fertilizer Research 38(1): 53–59.
25. Montesano FF, Parente A, Santamaria P, Sannino A and Serio F. 2015. Biodegradable superabsorbent hydrogel increases water retention properties of growing media and plant growth. Agriculture and Agricultural Science Procedia 4(451):451–458.
26. Naik AHK, Chaithra GM and Kumar NK. 2020. Effect of hydrogel on growth, yield and economics of rainfed castor. Journal of Pharmaceutical Innovation 9(7): 36–39.
27. Neethu TM, Dubey PK and Kaswala AR. 2018. Prospects and applications of hydrogel technology in agriculture. International Journal of Current Microbiology and Applied *Sciences* 7(5): 3155–3162.
28. Patra SK, Poddar R, Brestic M, Acharjee PU, Bhattacharya P, Sengupta S, Pal P, Bam N, Biswas B, Barek V, Ondrisik P, Skalicky M and Hossain A. 2022. Prospects of Hydrogels in Agriculture for Enhancing Crop and Water Productivity under Water Deficit Condition. International Journal of Polymer Science 15.
29. Pattanaaik SK, Singh B, Wangchu L, Debnath P, Hazarik BN. and Pandey AK. 2015. Effect of hydrogel on water and nutrient management of Citrus limon. International Journal of Agriculture Innovations and Research 3(5):1555–1558.
30. Peng Q, Liu M, Zheng J and Zhou C. 2015. Adsorption of dyes in aqueous solutions by chitosan-halloysite nanotubes composite hydrogel beads. Microporous and Mesoporous Materials 201:190–201.
31. Peterson D. 2002. Hydrophilic polymers-effects and uses in the landscape. Restoration and Reclamation Review 75.
32. Ramanjaneyulu AV, Madhavi A and Anuradha G. 2018. Agronomic and economic evaluation of hydrogel application in rainfed castor grown on alfisols. International Journal of Current Microbiology and Applied Sciences 7(7): 3206–3217.
33. Salokhiddinov A, Hamidov A, Khakimova P, Mamatov S and Boirov R. 2020. Effect of hydrogels on moisture storage of irrigated automorphic soils in Uzbekistan. IOP Conference Series: Materials Science and Engineering 883(1).
34. Sheng WB, Ma SH, Li W, Liu ZQ, Guo XH and Jia X. 2015. A facile route to fabricate a biodegradable hydrogel for controlled pesticide release. RSC Advances 5(18):13867–13870.
35. Soubeihkh AA. 2018. Effect of fertilizer packages and polymers on onion yield and quality under Bahariya Oasis conditions. Middle East Journal of Agriculture Research 7(4):1769–1785.
36. Srivastava R, Awasthi K and Tripathi D. 2018. Nanotechnology towards sustainable agriculture. International Journal of Scientific Research in Physics and Applied Sciences 6(6):155–158.
37. Sun D, Hussain HI and Yi Z. 2014. Uptake and cellular distribution, in four plant species of fluorescently labeled mesoporous silica nanoparticles. Plant Cell Reports 33(8):1389–1402.
38. Taylor KC and Halfacre RG. 1986. Hydrophilic polymer effect on nutrient and water availability to Ligustrumludicum ‘compactum’ grown in pinebark medium. Horticultural Science 18.

39. omášková I, Svatoš M and Macků J. 2020. Effect of different soil treatments with hydrogel on the performance of drought-sensitive and tolerant tree species in a semi-arid region. Forests 11(2).
40. Vakili M, Rafatullah M and Salamatinia B. 2014. Application of chitosan and its derivatives as adsorbents for dye removal from water and wastewater: a review. Carbohydrate Polymers 113:115–130.
41. Vundavallia R, Vundavallia S, Nakkab M and Rao DS. 2015. Biodegradable nano-hydrogels in agricultural farming - alternative source for water resources. Procedia Materials Science 10:548–554.
42. Wang YT and Gregg LL. 1990. Hydrophilic polymers-their response to soil amendments and effect on properties of a soilless potting mix. Journal of the American Society for Horticultural Science 115(6): 943–948.
43. Yangyuoru M, Boateng E, Adiku SGK, Acquah D, Adjadeh TA and Mawunya F. 2009. Effects of natural and synthetic soil conditioners on soil moisture retention and maize yield. Journal of Applied Ecology 9(1).
44. Zangooinasab SH, Emami H, Astarai A and Yari A. 2012. Hydrogels astakvzorb and irrigation effects on growth and establishment of seedlings of haloxylon. Soil Water Research Institute.