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Prospective of hydrogel for ornamental plants

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Abstract
In India more than 68 % area is under dry land condition and more than 40 % of the area faces the problem of insufficient rainfall. To overcome this problem, Hydrogel may prove as a convenient and eco-friendly feasible option to achieve the goal of crop productivity under conditions of water scarcity. Hydrogels are cross-linked polymers with a hydrophilic group which have the capacity to absorb large quantities of water without dissolving in water. It is commonly known as plant gel or super absorbent polymers which can absorb 400-1500 times water by its dry weight. When its surroundings begin to dry out, the hydrogel gradually releases up to 95 % of its stored water. As it is hydrophilic in nature, it has good swelling capacity, lack of toxicity and controlled water released thus, it has an immense scope to grow ornamental plants. It plays an important role in conserving water, reducing irrigation frequency and release sufficient moisture to grow roots of ornamental plants. It improves plant growth and density, increase flowering and dense foliage. Moreover, it helps to plant withstand prolonged moisture stress as well as delays onset of permanent wilting point. Hydrogels also improve the physical soil properties like soil porosity, soil permeability and water infiltration which will significantly reduce surface runoff and soil erosion.

Keywords: Hydrogel, polymers, water absorption, soil properties, water stress, moisture

Introduction
Water scarcity is a global issue which is increasing day by day due to increasing population and un-even rainfall. In India 70 % population depends upon the agriculture and total agriculture land is 159.7 million ha. Out of this more than 68 % area is under dry land condition and more than 40 % of the area faces the problem of insufficient rainfall. India ranks 13^{th} place in the world with regard to water scarcity. By using hydrogel this problem can solve and also can save the water without compromising on crop production.

Hydrogel are cross-linked polymers with a hydrophilic group which have the capacity to absorb large quantities of water without dissolving in water. It is also known as 'Plant gel' or 'super absorbent polymers'. It is undissolved in water due to cross-linked polymers but without cross-linkage it is dissolve in water. Hydrogel can absorb more than 400-1500 times water by its dry weight. Water absorption rate is depending on the structure of hydrogel and quality of water. Hydrogels can absorb and hold rain water as well as irrigation water. Therefore, helps to reduce deep percolation by using gravitational water as well as capillary water. When surrounding area of media is dry out the hydrogel gradually release up to 95 % of its stored water and then hydrogel again expose to water and they start water absorption. Most of the agriculture hydrogel prepared by grafting and cross-linking of water absorbent polymers. Earlier agricultural hydrogel is starch base but starch is sensitive to microbial activity. So, cellulose based hydrogel is made by cross with synthetic polymer like polyacrylamides which is more durable. Agricultural hydrogel is semi-synthetic in nature.

Hydrogel application in various stream
Hydrogel used as water saving materials and soil conditioners in agriculture. It is beneficial in arid region or in water stress conditions. Hydrogel based dressing reduce pain at the wound site through a cooling effect and low adherence to tissue. Due to jelly like structure of hydrogel it is also used in contact lens. Due to moisturizing properties, it can be used in moisturizer or cosmetic products. Smart hydrogel has a stimuli. It has ability to absorbs and release active ingredients depending on various stimuli such as pH, temperature etc. Thus, it used in drug delivery. Moreover, hydrogel also use in tissue engineering, biosensor, food industries and aqueous gel for fire-fighting.

Classification of hydrogel

Hydrogel can be classified on the bases of different criteria such as based on source, method of preparation, structure and charge.

1) Based on sources

Based on sources, hydrogel is classified in to three groups' *i.e*. natural hydrogel, synthetic hydrogel and semi-synthetic hydrogel

i. Natural hydrogel: They are polysaccharide-based such as cellulose, starch, alginate, agarose and polypeptide based such as gelatine, collagen.
ii. Synthetic hydrogel: They are petrochemical-based such as polyacrylic acid, methacrylic acid, vinyl acetate, polyethylene glycol.
iii. Semi-synthetic hydrogel: They are combination of natural and synthetic hydrogel.

2) Based on method of preparation

Based on preparation methods, hydrogel is classified as (i) Homopolymeric: The polymeric network is made from a single species of monomer. (ii) Co-polymeric: The polymeric network is composed of two or more different monomer species with at least one hydrophilic component and (iii) Multipolymer hydrogel: They are made of two independently cross-linked synthetic and/or natural polymers, contained in a network form.

3) Based on structure

Amorphous, semi crystalline and crystalline are three different types of hydrogel which are classified on the basis of its structure. Amorphous is the non-crystalline gel while semi crystalline gel are complex mixture of amorphous and crystalline phases.

4) Based on charge

Hydro gel is also classified based on ionic charges like, (i) Non-ionic (ii) Ionic and (iii) Zwitter ionic gel.

Characteristics of ideal hydrogel

They are non-toxic material having no colour and odour. High water absorption capacity in saline and hard water conditions and perform very well even at high temperature therefore suitable for arid and semi-arid conditions. It improves the physical condition of soil such as porosity, bulk density, water holding capacity and permeability. It has the lowest soluble content and residual monomer. Hydrogel has high durability and stability in the swelling environment and during the storage. Cross-linked variants of polyacrylamide have shown greater resistance to degradation (10%-15% per year); hence, they are more stable for longer periods around 2-5 years (Tyagi *et al*., 2019) [9]. After swelling of hydrogel in water, it neutralize the pH. It has high biodegradability without formation of toxic species following the degradation. It is a photo stable material. It is economical.

Benefits of hydrogel to ornamental plants

Hydrogel improves seed germination percentage and emergence rate. Root growth and density of ornamental plants can be enhanced. It promotes early and dense flowering with longer flower duration. Hydrogel shortens the establishment period for seedlings. It improves the yield and quality of flower. It helps to postpone the commencement of the permanent wilting point.

Mechanism of retention and release of water

Mechanism behind retention and release of water by hydrogel is based on osmosis and reverse osmosis. When hydrogel powder is in contact with water, it absorb water and swollen and when surrounding area begin to dry out, at that time hydrogel gradually release water. Application of hydrogel polymer used to create a water reservoir near the root zone of the plants.

First the hydrogel is in powder form, in this situation concentration of hydrogel is very high and around area concentration is low. So, water enters into the hydrogel and swollen. At the time of dry surrounding area, concentration of hydrogel is less than surrounding area. So, water release into soil or in plant. This all process is about osmotic pressure difference.

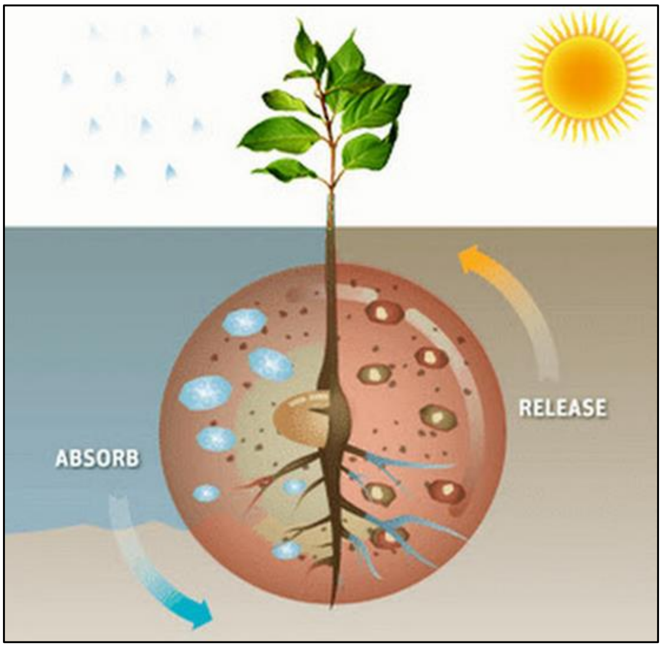


Fig 1: Mechanism of retention and release of water

Water absorption mechanism of hydrogel

The hydrophilic groups (*viz.* acrylamide, acrylic acid, acrylate, carboxylic acid, etc.) of the polymer chain are responsible for water absorption in hydrogels. The acid groups are attached to the main chain of the polymer. When these polymers are put in water, the latter enters into the hydrogel system by osmosis and hydrogen atoms react and come out as positive ions. This leaves negative ions along the length of the polymer chain. Hence, the hydrogel now has several negative charges down its length. These negative charges repel each other. This forces the polymer chain to unwind and open up. They also attract water molecules and bind them with hydrogen bonding. Hydrogel can absorb more than 400-1500 times its weight of water by this mode. When its surroundings start to dry out, the hydrogel gradually dispenses up to 95 % of its stored water. When exposed to water again, it will rehydrate and repeat the process of storing water. This process can last up to 2–5 years, by which time biodegradable hydrogel decomposes.

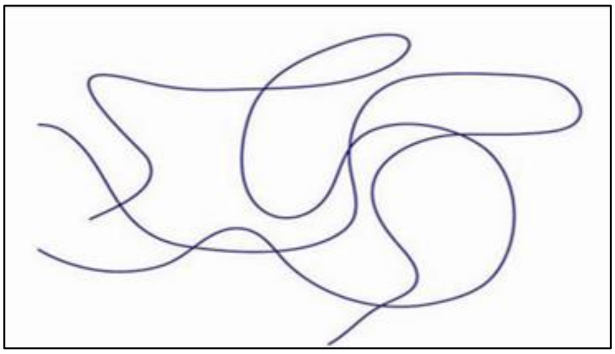


Fig 2: Hydrogel polymer chain before water contact

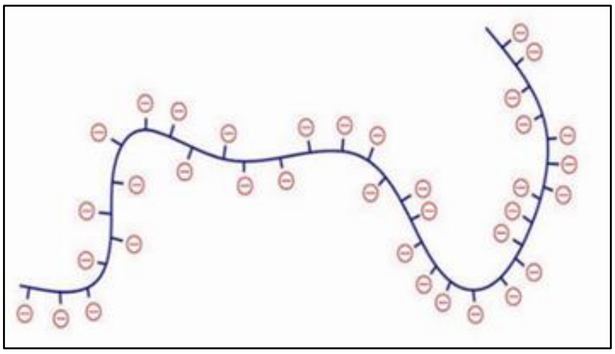
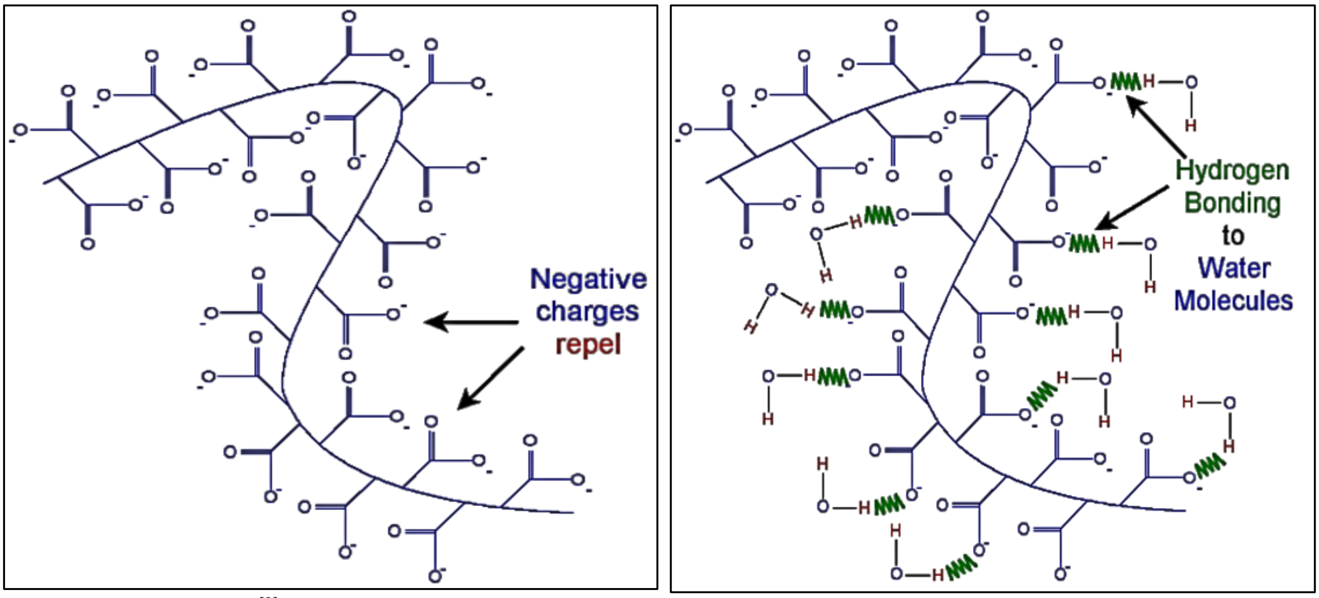


Fig 3: Hydrogel polymer chain with several negative charges along its length after water contact



Source: Tyagi *et al.*, 2019 [9]

Fig 4: Attachment of water molecules to hydrogel polymer chain

Water absorption capacity of hydrogels

Hydrogel absorb more distilled water than the tap water and saline water (Kalhapure *et al.*, 2016) [4]. Tap water and saline water contains Ca^{+2} and Mg^{+2} ions. This are positive ions. Hydrogel contains negative charges on his surface. When this hydrogel absorbs tap water and saline water, Ca^{+2} and Mg^{+2} ions react with negative sites in polymeric chain, resulting in the formation of non-soluble salts which block the negative ion site. Thus, less water is absorb. This blockage increase with the salinity of water and further cycles of wetting and drying. Thus, it reduce the water absorption capacity of hydrogels.

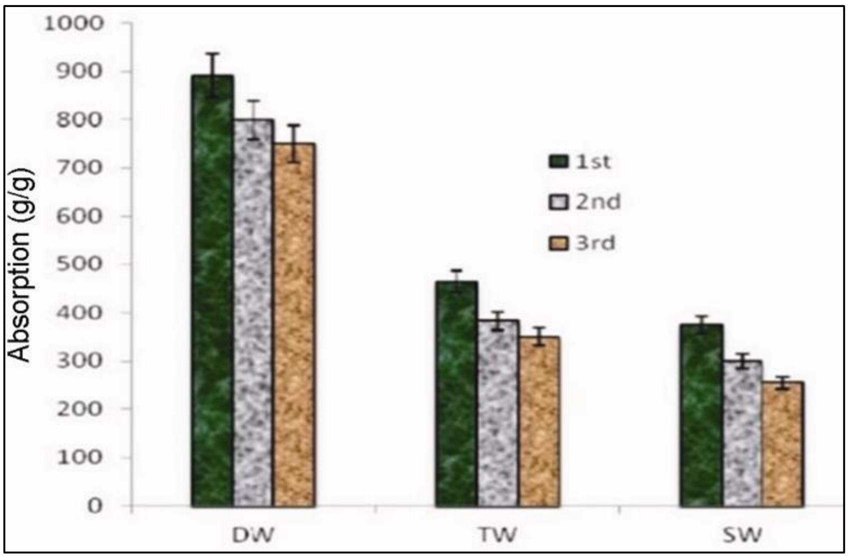


Fig 5: Absorption of distilled water (DW), tap water (TW) and saline water (SW)

Pusa Hydrogel

At temperatures above 30 °C and in presence of salts and fertilizer, most of the known hydrogels fail to perform, primarily because of the degeneration of their structures. Starch based commercially available products failed under field conditions because of their soil microbe prone nature. Keeping this limitation in mind, a cellulosic hydrogel termed 'Pusa Hydrogel' was developed by division of Agril. Chemicals, IARI, New Delhi. This product displayed a swelling potential of minimum 350 times, often exceeding 500 times its weight in pure water. Its swelling ratio increased with the rise in temperature up to 50 °C without any adverse effect on the polymer matrix structure. Pusa Hydrogel is a semi-synthetic, cross linked, derivatized cellulose-graft-anionic polyacrylate super absorbent polymer. It was designed specifically to perform in tropical and sub-tropical conditions of the country.

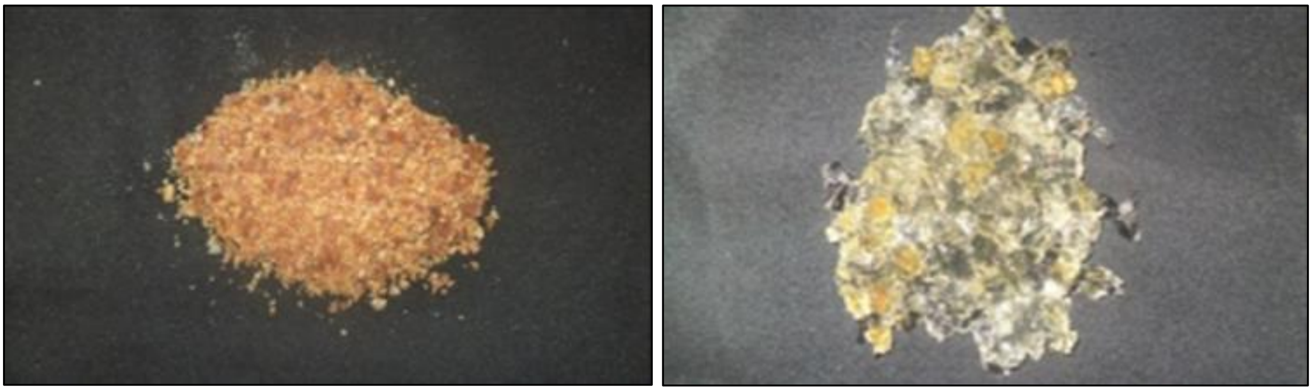


Fig 6: Pusa hydrogel (before and after swelling)

Application of hydrogel for ornamental plants

Hydrogel can be applied as dry and wet application in field, nursery bed and at the time of transplanting. For dry application, 5 kg of dry hydrogel mixed with 0.25 mm size fine sand in 1:10 ratio and apply along with the seeds or fertilizers or in the opened furrows before sowing in field. In vegetable and flower crop, mixture is applied at upper layer of soil or applied in a line where seed is to be sown.

For nursery bed, apply 2 g/m^2 of nursery bed mix of hydrogel uniformly in the top 2 inches of the nursery bed. In pot culture, 3–5 g hydrogel is mixed with one kg of soil before planting. Namita *et al.* (2012) [7] reported that, application of Pusa Hydrogel @ 0.5 % (20 g) per 5 kg media enhanced growth of *Coleus blumei* with least water requirement and save the water. Application of 40 g Pusa Hydrogel per 5 kg of potting media improved growth parameters of *Coleus blumei* and also increased watering frequency with less amount of water (Dawlatzai *et al.*, 2017) [3]. Madhu Bala (2018) [6] claimed that application of 40 g Pusa Hydrogel per 5 kg of potting media enhanced plant growth of *Philodendron xanadu* and showed dense foliage with efficient use of water by reducing irrigation frequency.

For transplanting application, a free-flowing solution is made by combining 2 g of hydrogel with 1 litre of water, allowing it settle for 30 minutes, then dipping the plant's roots in the solution before transplantation in the field. Wet application is ideal for small applications like repotting house plant, planting shrub and small trees. Applying hydrogel at a rate of 1 part hydrated polymer to 4 parts soil is the recommended procedure for wet application, which involves mixing granules in hot water for around 60 to 90 minutes. According to Anupama *et al.* (2007) [10], 0.5 % hydrogel amended medium absorbed more distilled water and nutrient solution and improved the seedling growth of *Dendranthema grand flora* with early establishment of rooted plants. Moreover, 0.5 % hydrogel enhanced post planting growth and flowering of chrysanthemum with reducing irrigation number. Kumar *et al.* (2016) [5] also observed improvement in floral characters and yields of *Dendranthema grand flora* with 0.5 % hydrogel application along with Red soil + FYM + Sand + Vermicompost. In *Verbena Canadensis,* 100 g plant gel application in the soil increased vegetative growth as well as flowering with extended flowering duration using less amount of water (Sharbazhery and Abu-bakr, 2017) [8]. Agaba *et al.*, (2011) [1] revealed that more biomass production of *Agrostis stolonifera* was achieved with less water by using 0.4 % hydrogel amended sandy soil.

Conclusion

In general, hydrogel is a cross-linked water-absorbing polymer that absorbs aqueous solutions by forming hydrogen bonds with the water molecules. The relevance of superabsorbent polymers i.e. hydrogels is vital for ornamental plants. Due to high water absorption capacity, application of hydrophilic polymers increase water holding capacity of amended media and enhance the growth of the plant and finally improves flowering and yield of flowers. Besides encouraging plant growth, Hydrogels can effectively minimize the required irrigation frequency mainly in areas where irrigation water is scarce commodity.

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