

# Significance of hydrogel and its application in agriculture

**Bhaskar Narjary<sup>1</sup>, Pramila Aggarwal<sup>2</sup>, Satyendra Kumar<sup>3</sup> and M.D. Meena<sup>4</sup>**

*The need for more arable land in view of increasing agricultural production has renewed interest in the development of novel soil conditioner materials with new methods and lower rates of application. Hydrogel is basically a water absorbing polymer; classified as cross-linked, absorbing aqueous solutions through hydrogen bonding with water molecules. Agricultural hydrogels are referred to as water retention granules because they swell to many times their original size when they come in contact with water.*

**I**N the early 1980's, water-absorbing polymers or hydrogels were introduced for agricultural use. These polymers are cross linked structures and formed a three dimensional network. Depending on synthetic conditions, type and density of covalent bonds that form cross-links, these polymers can absorb up to 500-600 times their weight in pure water and form gels. Most of the hydrogels marketed for agriculture come from cross-linked polyacrylamides and cross-linked acrylamide-acrylate copolymers, as they remain active for a much longer time.

## Types of hydrogel

There are two broad classes of polyacrylamide (PAM) hydrogels; soluble (linear) and insoluble (cross-linked). Linear PAM dissolves in water and has been successfully used in reducing irrigation-induced erosion in agricultural fields. Cross linked PAM does not dissolve, but forms a gel when water is added and is often used in agriculture, landscape, and



Hydrogel granules

nursery situations as a way of retaining moisture. Insoluble PAM products are marketed as “superabsorbent gels” or “hydrating crystals.” Instead of dissolving, these gels absorb water, swell many times of their original size. As they dry, water is slowly released to the soil.

## How do hydrogel work?

Hydrogels are characterized by negative (anionic), positive (cationic) or neutral charge. These charge classes are found in both linear and cross-linked polyacrylamide hydrogels. The charge determines how they will react with soils and solutes. Briefly, clay components of soils have a negative charge; heavy metals have a positive charge, and other commonly found minerals in soils and water



Hydrogel granules soaked with water

possess either a positive or a negative charge. Therefore, cationic hydrogel's (+) generally bind to clay components (-) and act as flocculants, anionic hydrogel (-) cannot directly bind to clay (-) and may act as dispersants. However, anionic hydrogel can bind to clay and other negatively charged particles in the presence of ionic bridges, such as calcium ( $\text{Ca}^{+2}$ ) and magnesium ( $\text{Mg}^{+2}$ ). However, in any given situation hydrogels will act in which manner is hard to predict, as the chemical interactions between the gels, soil components, and dissolved substances are complex and occur simultaneously. Electrical charges,

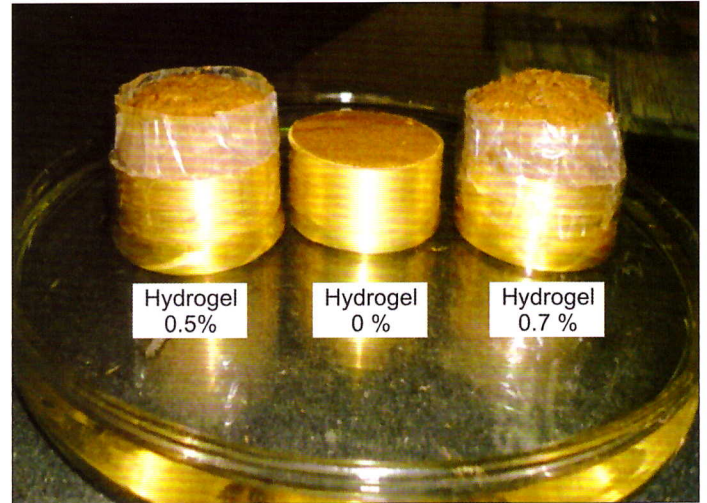
<sup>1,3&4</sup>Scientists, Central Soil Salinity Research Institute, Karnal, Haryana 132 001

<sup>2</sup>Principal Scientist, Indian Agricultural Research Institute, New Delhi, Delhi 110 012





Hydrogel applied in a wheat field (application rate 5 kg/ha, mixed with 1 kg of dry sand and applied in rows at 5-7 cm soil depth along with seeds by using a manually drawn seed drill)



Swelling behavior of hydrogel

hydration levels, van der Waals forces, and hydrogen bonding all modify the affinity of the gel for other compounds. The polyacrylamide polymer contains a complex array of positively charged, negatively charged and neutral chain segments, all with varying affinities for other molecules. The stronger the attraction between the gel and surrounding solutes and soil particles, the greater the ability of the gel to absorb water, create aggregates, and stabilize soil structure.

### Importance of hydrogel

Hydrogels were developed to improve the physical properties of soil in view of:

- Increase water-holding capacity of the soil
- The use of hydrogels leads to increased water use efficiency since water that would have otherwise leached beyond the root zone is captured
- Enhance soil permeability and infiltration rates
- Reduce irrigation frequency
- Reduce fertilizer leaching
- Reduce compaction tendency of soil
- Reduce soil erosion and water run-off
- Hydrogels help reduce water stress

of plants resulting in increased growth and plant performance (especially in structureless soils in areas subject to drought).

- Cross-linked polyacrylamide hydrogels are also being considered as potential carrier for insecticides, fungicides and herbicides.

The presence of water in soil is essential for survival of a plant. Liquid water ensures the feeding of plants with nutritive elements, which makes it possible for the plants to obtain better development. Cross-linked networks of hydrophilic polymeric chains of hydrogel can swell in water and hold a large amount of water while maintaining the physical dimension structure.

Hydrogels potentially influence soil permeability, density, structure, evaporation and infiltration rates of water through the soils. Particularly, the hydrogels reduce irrigation frequency and compaction tendency, stop erosion and water runoff, and increase the soil aeration and microbial activity.

In arid areas, the use of hydrogels in the sandy soil increase its water-holding capacity, seems to be one of the most significant means to conserve water for plants. The hydrogel serve as

the “miniature water reservoirs” in soil. Water will be removed from these reservoirs upon the root demand through osmotic pressure difference. The hydrogels also act as a controlled release system by favoring the uptake of some nutrient elements, holding them tightly, and delaying their dissolution. Consequently, the plant can still access some of the fertilizers, resulting in improved growth and performance rates. It can also be used as retaining materials in the form of seed additives (to aid in germination and seedling establishment), seed coatings, root dips, and for immobilizing plant growth regulator or protecting agents for controlled release.

Non-cross-linked anionic polyacrylamides have been used to reduce irrigation-induced erosion and enhance infiltration. Its soil stabilizing and flocculating properties improve runoff water quality by reducing sediments, chemical oxygen demand (COD), pesticides, weed seeds and microorganisms in run-off.

### Effects of synthetic soil conditioners on plant establishment and growth

Hydrogels were developed to increase water holding capacity of



amended media, and have been used to aid plant establishment and growth in dry soils. Hydrophilic polymers have been used to establish tree seedlings and transplanted in the arid regions of Africa and Australia to increase plants survival. Generally, the most favorable results for seed emergence and water infiltration came from an anionic polymer where, a cationic polymer was less effective.

The performance of the gel on plant growth depends on the method of application as well. It was shown that spraying the hydrogels as dry granules or mixing them with the entire root zone is not effective. Better results seem to be obtained when the hydrogels are layered, preferably a few inches below soil surface. However, generalizations should be avoided when interpreting results as a number of factors such as type of hydrogel, particle size, rate of application and type of plant has to be taken into consideration.

#### Effect on water use efficiency

Water use efficiency reflects the relation between the production and the total seasonal water used, *i.e.* yield produced in kg by each cubic meter of water used. Water held in the expanded hydrogel is intended as a soil reservoir for maximizing the efficiency of plant water uptake. Mixing of super absorbent materials (hydrogel) as hydrophilic organic polymeric products with sandy soil increases the soils capacity to store water. The water stored in this way is available to plants for considerable time. Moreover, germination process, plant growth, nutrient uptake by plants and both water and fertilizer

efficiency was beneficially increased by mixing the plant pits in sandy soil with hydrogel.

#### Application of hydrogel granules

Depending on the salt content of the water one kilogram of hydrogel can absorb water up to 500-600 times of their weight. Hydrogel can be applied wet (liquid) or dry (granule) formulation.

#### Dry Application

For proper functioning, hydrogel should be kept in a dry place. Mix the desired amount of hydrogel (5kg/ha) with dry, fine sand of less than 0.25 mm size in a 1:10 ratio.

For vegetable crops, mix the mixture of hydrogel and sand with upper 5 cm of soil.

For economical use, hydrogel should be applied in line where seed is to be sown.

#### Wet Application

- Mix the granules in water and allow them to stand for 60-90 minutes (hot water works faster). Once the polymer is all soaked up, the application rate is roughly one part hydrated polymer to four parts soil. Best for small applications such as repotting house plants, planting shrubs, small trees and bedding plants.

Some commonly superabsorbent hydrophilic polymer (hydrogel) used in agriculture are; Pusa Hydrogel; Luquasorb; Agrosoak; Soil Moist; Waterlock®; Stockosorb®; Jalshakti

#### Stability of hydrogels

Hydrogels are basically organically produced synthetic polymers and can

be degraded by both living and non-living environmental factors. Exposure to ultraviolet radiation, chemical oxidizers, fertilizer salts, mechanical abrasion, and freeze-thaw events will degrade the polymer, result in breaking down to smaller fragments. These smaller fragments do not possess same properties as the larger polymers, and thus the hydrogel's water-retaining capacity and other properties are reduced and ultimately lost. Gels that are applied to soil surfaces experience these environmental stresses most frequently and will degrade most rapidly in the presence of high levels of solar UV. Naturally occurring soil microbes have been identified as active decomposers of both soluble and cross-linked polyacrylamide gels. Decomposers include bacterial species (*Bacillus sphaericus* and *Acinetobacter* spp.) and white rot fungi (*Dichomitus squalens*, *Phanerochaete chrysosporium*, and *Pleurotus ostreatus*). The fungal species solubilize the polymer, which is then susceptible to further degradation by other soil microbes.

#### SUMMARY

There are many uses of hydrogel in agriculture, due to its water holding capacity. Hydrogels are polymers that can absorb up to 500-600 times their weight in pure water and form gels. They are therefore used to increase water holding capacity of amended media so as to aid in the establishment and growth of plant crops in dry soils. When used in the arid regions of Africa and Australia, hydrogel has been shown to help in increasing the plants survival. ■

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