Pusa Hydrogel: An Innovative Technology for Soil Moisture Conservation

Sandip Kumar Gautam[1]*, Sandeep Kumar[2] and Suneel Kumar[3]

[1]SMS (Soil Science), [2]Senior Scientist & Head, [3]SMS (Seed Tech.),
KVK, Bahraich-II, ANDUAT, Kumarganj, U.P.

Corresponding Author
Sandip Kumar Gautam
Email: gauthamkumar97344@gmail.com

OPEN ACCESS

Keywords

Pusa Hydrogel, Soil Moisture Conservation, Water-Use Efficiency, Drought Management, Sustainable Agriculture.

How to cite this article:

Gautam, S. K., Kumar, S. and Kumar, S. 2026. Pusa Hydrogel: An Innovative Technology for Soil Moisture Conservation. *Vigyan Varta* 7 (11): 130-136.

ABSTRACT

Water scarcity and declining soil moisture availability are major challenges affecting agricultural productivity, particularly in arid and semi-arid regions. Pusa Hydrogel, a superabsorbent polymer developed by the Indian Agricultural Research Institute (IARI), New Delhi, offers an innovative approach to improving soil moisture conservation and water-use efficiency. This hydrogel can absorb and retain large quantities of water relative to its weight and gradually release moisture to plant roots during water-deficit conditions. Its application enhances soil water retention, improves seed germination, supports plant growth, and reduces irrigation requirements. Pusa Hydrogel is particularly beneficial for rainfed agriculture, sandy soils, and drought-prone areas where moisture stress significantly limits crop productivity. Furthermore, its judicious application may improve nutrient-use efficiency and crop resilience under changing climatic conditions. Thus, Pusa Hydrogel represents a promising technology for sustainable water management, efficient resource utilization, and improved agricultural productivity under limited water availability.

INTRODUCTION:

Agriculture is the largest consumer of freshwater resources worldwide, accounting for nearly 70% of global freshwater withdrawals and approximately 80% of freshwater use in India (FAO, 2023). The increasing demand for food due to rapid

population growth, coupled with declining water resources, has intensified pressure on agricultural systems. Climate change has further aggravated the problem through irregular rainfall patterns, prolonged droughts, increased temperatures, and frequent extreme weather events. Under such circumstances, efficient water management has become one of the most critical challenges facing modern agriculture.

In India, nearly 52% of the net cultivated area remains rainfed and depends largely on monsoon rainfall. Rainfed agriculture contributes substantially to national food production but suffers from frequent moisture stress due to uneven rainfall distribution. Moisture stress during critical crop growth stages often results in reduced germination, poor plant establishment, restricted nutrient uptake, and ultimately lower crop yields. Therefore, technologies that improve soil moisture retention and water-use efficiency are essential for sustaining agricultural productivity under changing climatic conditions.

One such innovative technology is **Pusa Hydrogel**, developed by scientists at the Indian Agricultural Research Institute (IARI), New Delhi. Pusa Hydrogel belongs to the category of super absorbent polymers (SAPs) and has the remarkable ability to absorb and retain large quantities of water relative to its own weight. The absorbed water is stored within the polymer matrix and released gradually according to crop requirements. This unique property enables hydrogel-treated soils to maintain adequate moisture levels for longer periods, thereby reducing irrigation frequency and improving crop performance under water-limited conditions.

Pusa Hydrogel has emerged as an important tool for moisture conservation in field crops, horticultural crops, vegetables, plantations, and forestry systems. It not only improves soil water availability but also enhances nutrient-use efficiency, promotes root growth, and increases crop productivity. Consequently, it is increasingly recognized as a valuable component of climate-resilient and sustainable agricultural systems.

1. Historical Development of Pusa Hydrogel

1.1 Need for Hydrogel Technology

The concept of water-absorbing polymers originated from efforts to develop materials capable of retaining large quantities of water in agricultural soils. Traditional irrigation methods often result in significant water losses through evaporation, runoff, and deep percolation. In coarse-textured soils, water rapidly drains beyond the root zone, making it unavailable to plants. These limitations prompted researchers to explore alternative technologies that could store water within the root zone and release it gradually.

The need became particularly important in India due to:

A) Increasing groundwater depletion.

B) Declining rainfall reliability.

C) Expansion of agriculture into marginal lands.

D) Rising irrigation costs.

E) Climate change-induced drought risks.

Recognizing these challenges, scientists at IARI initiated research aimed at developing a soil amendment capable of improving water retention while remaining economically viable for Indian farming conditions.

1.2 Development at IARI

The Indian Agricultural Research Institute developed Pusa Hydrogel through extensive research on super absorbent polymers suitable for agricultural use. The hydrogel was

designed to perform effectively under diverse Indian soil and climatic conditions. Several laboratory and field trials were conducted to evaluate its water absorption capacity, stability, environmental safety, and impact on crop productivity.The technology was subsequently refined and released for agricultural applications. Since then, Pusa Hydrogel has been recommended for use in cereals, pulses, oilseeds, vegetables, fruit crops, medicinal plants, and forestry plantations.

2. Definition and Concept of Pusa Hydrogel

Pusa Hydrogel is a cross-linked super absorbent polymer capable of absorbing and storing water hundreds of times its own weight. It acts as a miniature water reservoir in the soil. When water from rainfall or irrigation becomes available, the hydrogel particles absorb and retain it. As soil moisture decreases, the stored water is gradually released into the surrounding root zone where it becomes available to plants.Unlike conventional water storage systems, Pusa Hydrogel stores water directly in the crop root zone. This localized storage significantly improves water-use efficiency and reduces moisture stress during dry periods.

The hydrogel repeatedly undergoes cycles of:

1. Water absorption
2. Swelling
3. Water storage
4. Gradual water release
5. Shrinkage

These cycles may continue for several years depending upon soil conditions and management practices.

3. Chemical Composition and Structure

3.1 Chemical Nature

Pusa Hydrogel is composed of synthetic polymer chains containing highly hydrophilic functional groups. These functional groups possess a strong affinity for water molecules and are responsible for the exceptional water absorption characteristics of the material.

Common hydrophilic groups include:

- Carboxyl groups (-COOH)
- Hydroxyl groups (-OH)
- Amide groups ($-CONH_2$)

These groups attract and bind water molecules through hydrogen bonding and osmotic forces.

3.2 Cross-Linking Structure

A distinctive feature of hydrogels is their three-dimensional cross-linked network structure. Cross-linking connects polymer chains into a stable matrix that prevents dissolution when water is absorbed.

The cross-linked structure provides:

- Mechanical stability
- High water-holding capacity
- Repeated swelling and shrinking ability
- Long-term persistence in soil

3.3 Physical Characteristics

Pusa Hydrogel typically appears as:

- White granular particles
- Odorless material
- Insoluble in water
- Non-toxic substance
- Environmentally safe soil amendment

The granules expand substantially upon hydration, forming gel-like structures capable of retaining large amounts of water.

4. Mechanism of Water Absorption and Release

4.1 Water Absorption Process

When irrigation water or rainfall enters the soil, hydrogel particles absorb water through osmotic forces. Water molecules move into the polymer network where they become trapped within microscopic pores.Research indicates that Pusa Hydrogel can absorb approximately 350–500 times its own weight in water under ideal conditions (Narjary *et al*., 2012).

The absorption process involves:

- Hydration of polymer chains.
- Expansion of the polymer matrix.
- Entrapment of water molecules.
- Formation of swollen gel structures.

4.2 Water Storage

After hydration, the hydrogel acts as a reservoir. The stored water remains available within the soil profile and is protected from rapid evaporation and deep percolation losses.This storage function is particularly valuable in sandy soils where water retention is naturally poor.

4.3 Controlled Water Release

As surrounding soil begins to dry, differences in water potential develop between the hydrogel and the soil. Consequently, stored water moves gradually from the hydrogel into the soil solution where it becomes available for plant uptake.

This controlled release mechanism:

- Maintains root-zone moisture.
- Reduces water stress.
- Supports continuous plant growth.
- Enhances crop survival during dry spells.

5. Importance of Pusa Hydrogel in Modern Agriculture

5.1 Addressing Water Scarcity

Water scarcity is one of the greatest constraints to agricultural productivity in many parts of the world. Groundwater resources are declining rapidly, and irrigation water is becoming increasingly expensive. Under these circumstances, technologies that improve water-use efficiency are essential.

Pusa Hydrogel contributes to water conservation by:

- Increasing soil moisture storage.
- Reducing irrigation frequency.
- Minimizing water losses.
- Enhancing water-use efficiency.

5.2 Climate Change Adaptation

Climate change is expected to increase the frequency and intensity of droughts in many agricultural regions. Moisture conservation technologies such as hydrogel can improve resilience by buffering crops against short-term water deficits.Hydrogel-treated soils maintain moisture availability for longer periods, thereby reducing crop vulnerability to rainfall variability.

5.3 Sustainable Agriculture

Sustainable agriculture aims to maximize productivity while conserving natural resources. Pusa Hydrogel aligns with this objective by improving water efficiency, reducing nutrient losses, and enhancing soil health without causing environmental degradation.

(Continued sections would include: Effect on Soil Physical Properties, Effect on Soil

Chemical Properties, Soil Biological Properties, Effect on Root Growth, Crop Growth and Physiology, Water Use Efficiency, Crop-wise Responses Including Linseed, Economic Analysis, Future Prospects, Conclusion, and Complete References.)

6. Physical Properties of Pusa Hydrogel

The effectiveness of Pusa Hydrogel in agricultural soils largely depends upon its physical properties. These properties determine the hydrogel's ability to absorb, retain, and release water under different environmental conditions.

6.1 Water Absorption Capacity

Water absorption capacity is the most important characteristic of Pusa Hydrogel. Under favorable conditions, the hydrogel can absorb approximately **350–500 times its own weight in water**. This remarkable capacity enables small quantities of hydrogel to store substantial amounts of moisture within the root zone.

The absorption capacity is influenced by:

- Soil texture
- Water quality
- Salt concentration
- Soil pH
- Temperature

Hydrogels generally absorb more water in distilled water than in saline solutions because dissolved salts reduce osmotic potential.

6.2 Swelling Capacity

When water enters the polymer matrix, the hydrogel expands significantly. This phenomenon is known as swelling.

Swelling increases:

- Water storage volume
- Moisture retention capacity
- Root-zone water availability

The swelling process is reversible, allowing the hydrogel to repeatedly absorb and release water over several years.

6.3 Water Retention Capacity

After swelling, the hydrogel stores water within its three-dimensional network. The stored water remains available for gradual release, thereby reducing water losses through evaporation and deep percolation.Studies have shown that hydrogel-treated soils retain moisture for significantly longer periods than untreated soils (Narjary *et al*., 2013).

6.4 Durability and Longevity

Pusa Hydrogel remains functional in soil for approximately 3–5 years, depending on environmental conditions and management practices.

Factors affecting longevity include:

- Soil temperature
- Microbial activity
- Moisture cycles
- Soil pH

Because of its long functional life, a single application can provide benefits for multiple cropping seasons.

7. Mechanism of Water Absorption, Storage and Release

7.1 Water Absorption Mechanism

The hydrogel contains numerous hydrophilic functional groups capable of attracting water

molecules. During irrigation or rainfall, water enters the polymer network due to osmotic pressure differences.

The process involves:

1. Contact between water and polymer particles.
2. Attraction of water molecules by hydrophilic groups.
3. Penetration of water into the polymer matrix.
4. Expansion of the network structure.
5. Formation of swollen gel particles.

As the hydrogel absorbs water, its volume may increase several hundred times.

7.2 Water Storage Mechanism

The absorbed water becomes physically trapped within the polymer network.

This stored water:

- Remains protected from evaporation.
- Is retained near the crop root zone.
- Reduces deep percolation losses.
- Enhances soil moisture availability.

The hydrogel therefore acts as a micro-reservoir embedded within the soil profile.

7.3 Water Release Mechanism

Water release occurs when the surrounding soil begins to dry.

As soil moisture decreases:

- Soil water potential becomes lower than hydrogel water potential.
- Water moves from hydrogel to soil.
- Plant roots absorb the released moisture.

This process continues until equilibrium is restored.The gradual release mechanism enables crops to access water during periods of limited rainfall or delayed irrigation.

8. Effect of Pusa Hydrogel on Soil Physical Properties

Soil physical properties strongly influence water movement, root growth, nutrient availability, and crop productivity. Hydrogel application significantly improves several physical characteristics of soil.

8.1 Soil Water Holding Capacity

Water-holding capacity refers to the amount of water that soil can retain after excess water has drained away.

Hydrogel application increases:

- Field capacity
- Available water content
- Root-zone moisture storage

Research indicates that hydrogel-treated soils may retain 15–30% more available water compared with untreated soils (Bhardwaj *et al*., 2007).

Improved water-holding capacity:

- Reduces drought stress.
- Enhances crop survival.
- Supports continuous growth.
- Improves irrigation efficiency.

8.2 Soil Porosity

Hydrogel improves soil porosity by:

- Increasing pore space.
- Enhancing water infiltration.
- Improving root penetration.

- Promoting gas exchange.

Better porosity facilitates healthy root development and microbial activity.

8.3 Soil Bulk Density

Bulk density is an important indicator of soil compaction.Hydrogel application generally reduces bulk density because swollen hydrogel particles occupy space within the soil profile.

Reduced bulk density:

- Improves root growth.
- Enhances aeration.
- Increases infiltration.
- Facilitates nutrient movement.

REFERENCES

Azevedo, T. L. F., Bertonha, A., Freitas, P. S. L., &Gonçalves, A. C. A. (2002). Effects of hydrogel doses on soil water retention. *Revista Brasileira de Engenharia Agrícola Ambiental*, 6(3), 1–5.

FAO. (2023). *The State of Food and Agriculture*. Food and Agriculture Organization, Rome.

Narjary, B., Aggarwal, P., Singh, A. K., Chakraborty, D., & Singh, R. (2012). Water availability in different soils in relation to hydrogel application. *Geoderma*, 187–188, 94–101.

Zohuriaan-Mehr, M. J., &Kabiri, K. (2008). Superabsorbent polymer materials: A review. *Iranian Polymer Journal*, 17(6), 451–477

Bhardwaj, A.K., Shainberg, I., Goldstein, D., Warrington, D.N. and Levy, G.J. (2007). Water retention and hydraulic conductivity of cross-linked polyacrylamides in sandy soils.*Soil Science Society of America Journal*, 71: 406–412.

Narjary, B., Aggarwal, P., Singh, A.K., Chakraborty, D. and Singh, R. (2013). Hydrogel and moisture conservation in agricultural soils. *Current Science*, 104(9): 1237–1244.

Johnson, M.S. (1984). The effects of gel-forming polyacrylamides on moisture storage in sandy soils.*Journal of the Science of Food and Agriculture*, 35: 1196–1200.

Zohuriaan-Mehr, M.J. and Kabiri, K. (2008). Superabsorbent polymer materials: A review. *Iranian Polymer Journal*, 17(6): 451–477.