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The Critical Necessity of the Future: Pusa Hydrogel, A Novel Approach to Convert Desert into Farmland

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Abstract:- Water scarcity is currently a major problem for humanity, particularly for the farming population. The total growth and development of a plant depends heavily on water. This issue has become exponentially more problematic because of climate change. India's population is expected to grow to 1.6 billion people by the year 2050, which will worsen the country's water shortage. The country only has 4% of the world's freshwater despite having 16% of the world's population. About 1122 BCM (690 BCM from the surface and 432 BCM from groundwater) of the nation's total water resources are usable, which is just 28% of water which comes from precipitation . A significant portion of this water is being diverted for irrigation in agriculture about 85% (688 BCM) , it may increase up to 1072 BCM by the year 2050, and at the same rate, water use in the home and industrial sectors could reach 29.2 BCM by 2025. Therefore, it is anticipated that water availability in the agricultural sector, mainly for irrigation, will decline to 162.3 BCM. Taking all these factors into account, scientists worked to come up with an alternative solution to this ongoing issue. The United States Department of Agriculture invented the notion of hydrogel in the 1960s (USDA). Hydrogels initially do not receive much attention due to their poisonous nature, high cost, and short lifespan because of their starch-based structure, which was vulnerable to soil bacteria. Maintaining this restriction Pusa Hydrogel, a cellulosic hydrogel, was created at the Indian Agriculture Research Institute (IARI).

Keywords:- *Pusa Hydrogel, Water Scarcity, and Water Productivity.*

I. INTRODUCTION

Water, which directly affects plant metabolism, is one of the most essential components for crop growth and development. Crops cannot use inputs to their full capacity without an appropriate supply of water. Natural resources are deteriorating quickly and causing significant crop production difficulties. The world is experiencing a food crisis, there are more mouths to feed due to population growth, and droughts are becoming more frequent and severe due to climate change. Water, one of the most important natural resources, is essential to the establishment and expansion of agriculture, which in turn reveals information about the yield and commercial feasibility of a particular crop. Only 3% of the world's water is freshwater, and by 2050, it is predicted that 87 countries would experience a water shortage. Water shortages in India have recently gotten much worse, which has had a large impact on crop productivity because agriculture will be the main driver of demand as a result of a growing population. Two-thirds of the global population is anticipated to experience water scarcity by 2025,India has already stepped into the economic and physical water scarcity zone. In addition to this, the economics of water usage in all areas are impacted by the high cost of fuels and electrical energy used to draw groundwater and poor water use efficiency. A significant fall in groundwater level is also a result of excessive removal for agricultural and other applications. The scientists are being forced by this deteriorating situation to look for practical solutions to fulfil future water needs. In order to keep these things in mind Scientists from the Indian Agriculture Research Institute in New Delhi created the "Pusa Hydrogel" with the world's water shortage expected to intensify by 2025 in mind. Pusa Hydrogel is a cross-linked, semi-synthetic material superabsorbent polymer made from derivatized cellulose-grafted-anionic polyacrylate. The beauty of this gel is that it can function even at temperatures above 30 °C and when salts and fertilisers are present, where most hydrogels are known to fail to function, mostly because of their structural degeneration. Early hydrogels were starch-based and under field conditions they didn't work well because of their susceptibility to soil microbes. Scientists at the Indian Agriculture Research Institute (IARI)

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created the Pusa-Hydrogel, cellulose-based hydrogel, which performs significantly better in real-world settings. This substance showed a 350-times swelling potential in pure water, frequently exceeding 500 times its weight (IARI,2012). Pusa Hydrogel's capacity to swell increased when temperature rose to 50 degrees without having a negative impact on the polymer matrix. This was created by IARI scientists who took into account the soil type and climate of the Indian subcontinent. This was intended primarily for tropical and subtropical climates. So, several comparable products were tested in India but failed in real-world settings before Pusa Hydrogel emerged as a fresh alternative.

A. Pusa Hydrogel

Pusa Hydrogel is a superabsorbent semi-synthetic cross-linked cellulose-grafted-anionic polyacrylate polymer. It is a biodegradable gel made of carboxymethyl cellulose with a 2–5 year shelf life in the soil. When we examine the future while taking the water scarcity constraint into account, it's a fantastic invention. Farmers all throughout India swiftly embraced this innovation, consideringits properties like high fluid absorption in the presence of fertilisers, capacity to absorb at high temperatures, cellulose backbone, and matrixqualities on the health and productivity of crops. It works as a slow-release source of water because it mixes with soil to generate an amorphous, gelatinous material that can absorb and desorb over an extended period of time.

B. Pusa Hydrogel characteristics

- Cellulose makes up the backbone (a natural polymer)
- Wide range of absorbency at high temperature (40-50 °C)
- Pusa hydrogel has enhanced the physical qualities of soil by containing no measurable levels of the hazardous monomer (acrylamide), contains a low application rate (1–1.5 kg/acre), has improved root growth and density, and is least affected by the presence of salts in its near surroundings.
- A minimum of one year's worth of soil stability
- Absorbs at least 350 times its dry weight in clean water and releases it gradually
- Increases emergence rate, which enhances root growth and density and promotes seed germination and seedling emergence.
- Reduces the time it takes for nurseries to open and reduces the amount of watering and fertigation that crops need.
- Encourages early and abundant flowering, fruiting, and tillering.

C. Biochemical mechanism in soil

Hydrophilic functional groups connected to the polymer chain give hydrogels their ability to retain water; yet crosslinks between network chains prevent hydrogels from dissolving in water. Hydrogels simply absorb water by osmosis when it comes into touch with them. As a result, hydrogen atoms react and release positive ions. Because of this, negative ions form throughout the length of the chain, which causes the polymer chain to unravel because the negative ions oppose one another before drawing in water molecules and forming hydrogen bonds with them . In this way, hydrogels are capable of absorbing 400 times as much water as their own weight. It can endure up to 2-5 years before decomposing by dispensing up to 95% of its water when its surrounds start to dry out and then rehydrating when exposed to water once more.

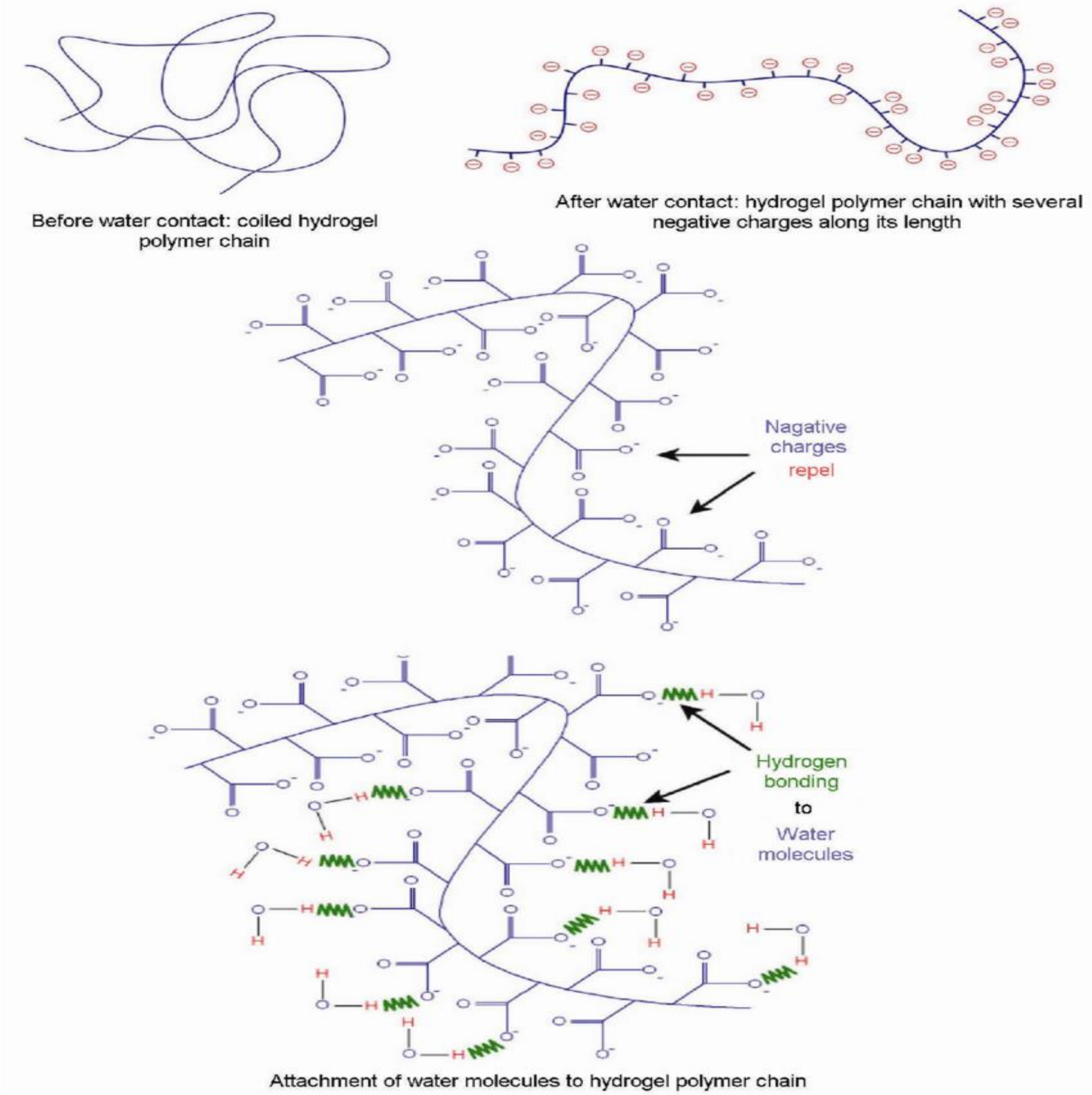

Fig. 1: Biochemical mechanism in soil

D. Behaviour of hydrogels in soil

Hydrogels can produce unreacted monomers including acrylamide, acrylic acid, and acrylate that are present in their completed polymer, but this is a misperception regarding how they degrade. However, in practise hydrogels can never return to their original monomers since it is not possible to undertake a reverse reaction.The ionic and microbiological media in the soil help hydrogels biodegrade, ultimately converting them to ammonia , carbon dioxide and water . When cellulose is utilised as the backbone of the polyacrylamide, there is no residual quantity of acrylamide present in the soil after decomposition since the polyacrylamide can never rebuild its monomer.

- **Recommended dose** : 2.5–5.0 kg/ha

E. Application Techniques

Depending on the type of soil, apply 2.5 kg/ha with a soil depth of 15 to 20 cm for clayey soil and 5.0 kg/ha with a soil depth of 10 cm for sandy soil.

Its technique of application varies:

- For the crops on the field,prepare a 1:10 hydrogel and fine dry soil combination, and then apply it alongside seeds and fertiliser.
- For every square metre of nursery bed, evenly distribute 2gm of Pusa hydrogel at a depth of 5cm.
- Before planting, mix 3-5 g of soil per kg in pot culture.
- Make a free-flowing solution of 2 g of hydrogel per litre of water for the transplanting case, then let it sit for an hour to settle. Plant roots should be dipped in the solution before being transplanted to the field.

F. Footprints of hydrogel polymer on soil properties

Hydrogel polymer put positive footprints when we talk about as a soil conditioners or amendments on the arid and semiarid regions in the following ways :

- In the coarse textured soils, it has been seen that it improves the soil structure by altering the physical (viz; soil permeability , porosity , bulk density , water holding capacity , percolation and infiltration rate , soil temperature , etc .) chemical (CEC, etc.) and biological environment through aggregation , stabilization, and solidification.
- Prevent crust formation .
- Soil water retention capacity has been increased , high water supply to plant roots , and reduce irrigation frequency by lowering water loss by leaching and evaporation .
- Provide a favourable plant growth medium by lowering soil bulk density , supplying better ventilation and moisture regime for supporting plant growth , and yield .
- Inhibit soil loss by water and wind erosion and runoff .
- Enhancing soil microbial activity

G. Crop reaction to hydrogel

Since the hydrogel is having a strong impact on plant growth & development so , its implications will be imperative to discuss here so that we can correlate and will have more understanding on the hydrogel.

II. HYDROGEL'S IMPACT ON GROWTH

In barley and wheat, Akhtar et al. (2004) observed that more polymer in the soil led to higher dry matter production than the control. According to Anupam et al. (2005), the performance of hydrogel (0.5% w/w) in the soilless media in chrysanthemum cultivated in controlled environments showed most notable development with plant height, stem diameter, and number of leaves per plant as compared to control. Al-Harbi et al. (2006) concluded that adding hydrophilic polymer to the soil boosted the number of leaves and leaf area in cucumber plants. Silberbush et al. (2001) and Wang et al. (2001) both reported a considerable increase in canola dry matter yield as a result of hydrogel polymer. According to Yazdani et al. (2007), an increase in polymer dose was accompanied with an increase in total dry matter (leaves + stem + pod) in soybean. In comparison to control, soil treated with 225 kg ha-1 polymer had the highest total dry matter. Crop growth rate and leaf area index were higher in the crops that grew in soil with the highest dose of polymer (225 kg ha-1).

III. HYDROGEL'S IMPACT ON YEILD AND YEILD ATTRIBUTES

When soil was treated with superabsorbent polymer, Sender et al. (2001) observed an increase in the number of fruits, fruit weight, and yield per plant in tomato plants. El-Hady and Wanas (2006) came to the conclusion that at the same irrigation rate, a larger hydrogel application dose results in a better marketable yield, According to Yazdani et al. (2007) that, when compared to control, significantly increase in the soybean seed production by using hydrophilic polymers (225 kg/ha) (without polymer). Allahadi et al. likewise had comparable outcomes (2005). According to Khadem et al. (2010), applying 65% cow manure and 35% superabsorbent resulted in a 16.2% increase in grain output when compared to the control.

According to Nazarii (2010), the application of polymer has a tendency to enhance the weight of 100 sunflower seeds compared to the control. Islam et al. (2011) observed that the number of grains per plant increased 9.3% & 16.6%, respectively, in comparison to control, with modest application of superabsorbent polymer.

IV. HYDROGEL'S IMPACT ON THE PHYSICAL PROPERTIES OF SOIL

According to Uz et al. (2008), the usage of polyacrylamide increased macropore size in clay soil while decreasing it in clay sandy loam and loam. According to Karimi et al. (2009), adding polymer to peat soil lessened water stress and lengthened the period until wilting. Superabsorbent polymer is useful in enhancing soil water retention, according to Feng and S (2011). According to Nazarii et al. (2011), the use of superabsorbent polymer resulted in good water retention and drought protection. When polymers were added to coarse sand, Ekabafe et al. (2011) found that the water retention capacity increased by 171 to 402%.

V. HYDROGEL'S IMPACT ON ROOT ACTIVITIES

According to Volkammar and Chang (1995), adding hydrophilic polymer at 1.87g plant-1 to the soil boosted root biomass compared to the control. According to Sendur et al. (2001), hydrophilic polymers considerably increased both root length and dry weight when compared to control. According to Zhang et al. (2005), the hydrophilic polymer markedly enhanced root biomass compared to control, In Aleppo pine, Huttermann et al. (2006) found that applying hydrophilic polymer at 0.4% weight/volume resulted in increased root development.

VI. CONCLUSION

In dry and semiarid areas, water is increasingly the limiting constraint for sustainable crop production. The use of hydrogel as a soil conditioner can enhance the hydro physical, physicochemical, and biological conditions of the soil, as well as its capacity to hold and release water. It can also increase irrigation, water, and nutrient use efficiency, increase crop yield and quality, and maintain environmental quality. In terms of improved yield (cereals, vegetables, oilseeds, flowers, spices, plantations, etc.) and easing soil moisture stress, this hydrogel technology may become a practically useful and revolutionary technology in water-stressed locations. In India, where there will be water shortages, Pusa-hydrogel is the way of the future for agriculture. Farmers and the government must incorporate pusa-hydrogel into field operations to improve soil quality and water use efficiency in order to make the most effective use of the country's limited water resources. Additionally, it is essential for maintaining the natural ecology, raising the groundwater table, and conserving resources for future generations.

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