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Hydrogel Technology in Agriculture

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India has 16% of the global population but just 2.45% of the world's land area and 4% of its water resources. Domestic and commercial water demand could reach 29.2 BCM by 2025. Thus, a reduction to 162.3 BCM in irrigation water availability is anticipated.

Therefore, there is a pressing need for improved water use efficiency in order to manage water resources effectively. Since home use of water is only 5% and industrial use is 15%, respectively, and there are no further opportunities to lower the amount of water in these sectors, the emphasis should be on the agriculture sector for water conservation without sacrificing crop yield.

Various strategies for water conservation and lowering agricultural water use Ex situ techniques These methods of collecting water are often mechanical, such as bench terracing, contour bunding, creek bunding, etc. This category also includes micro irrigation systems, such as drip and sprinkler irrigation. In situ techniques (a) Tillage techniques, such as minimum, zero, and conservation tillage (b) Cultural customs, such as opening furrows between crop rows and sowing on ridges; the furrow method; compartmental bunding; mulching; etc. (b) The use of chemicals like gels and antiperspirants.

Introduction

In order to absorb huge amounts of water without dissolving in it, hydrogels are cross-linked polymers having a hydrophilic group. The hydrophilic functional groups connected to the polymer backbone give it its water absorption capability, whilst the cross-links between network chains give it its dissolving resistance. Widely utilised as a synthetic hydrogel, polyacrylamide (C_3H_5NO) n is a polymer made of acryl amide subunits. It can be produced through cross-linking or as a straightforward linear chain structure. Because it dissolves in water, linear linked polyacrylamide cannot be used to make a hydrogel that absorbs water.

Absorption mechanism of hydrogel

The hydrophilic groups in the polymer chain, such as acryl amide, acrylic acid, acrylate, carboxylic acid, etc., are what allow hydrogels to absorb water. The polymer's

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primary chain is joined to the acid groups. These polymers interact with the water when it is added, causing hydrogen atoms to react and emerge as positive ions. Water then enters the hydrogel system by osmosis. The polymer chain is left with negative ions as a result. The hydrogel now contains numerous negative charges running down its length as a result. These opposite charges push apart from one another. By using this mode, hydrogel may absorb more than 400 times its weight in water. The hydrogel releases up to 95% of the water it has accumulated over time as its surrounds start to get dry. It will rehydrate and continue to store water when it is once more exposed to water. Biodegradable hydrogel decomposes after this process, which can span between two and five years.

Uses of hydrogel

Hydrogels are employed to increase soil's capacity to absorb water. They are made by grafting and cross linking water-absorbent polymers (polyacrylamide) onto a backbone polymer chain made from cellulose derivatives (carboxymethyl cellulose). These hydrogels are more environmentally friendly and biodegradable. Agricultural hydrogels need not only be able to absorb water, but also release it gradually in accordance with the needs of the plants, unlike superabsorbent polymers used in sanitary applications, which must have the quick rate of fluid absorption and ability to maintain it under high load.

Preparation and absorption of hydrogel

Radiation exposure causes some of the carbon bonds between the glucose molecules in the cellulose chain to break, creating free radical sites on the polymeric backbone (Figure 4). A cellulose-acryl amide graft copolymer is created when cellulose radicals produced during irradiation combine with one side of acryl amide. Ca^{++} and Mg^{++} ions can be found in water. These ions interact with the negative ion sites in the polymeric chain of hydrogel as it absorbs water, forming non-soluble salts that block the negative ion sites. As the water becomes more salty and there are more wetting and drying cycles, the obstruction gets worse.

Key Characteristic features of hydrogel

- They have a minimum absorption capacity of 400 times their dry weight in pure water, which they can release gradually as the crop plant requires.
- Due to their neutral pH, they have no impact on the availability of nutrients, the chemical makeup of the soil, or the effectiveness of other agrochemicals such as fertilisers, herbicides, fungicides, insecticides, etc.

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- Hydrogels have been shown to enhance the physical characteristics of soils (viz. porosity, bulk density, water holding capacity, soil permeability, infiltration rate, etc.).
- Increasing soil porosity improves root growth and density, seed germination and seedling emergence rates, and reduces soil erosion by reducing soil compaction.It also increases biological/microbial activities in the soil, which increase oxygen/air availability in root zone of the plant
- Hydrogels delay the onset of permanent wilting point and decrease crop irrigation needs due to decreased water loss through evaporation, which helps plants tolerate prolonged moisture stress.
- The crop's ability to hold onto water and the amount of nutrients that are leached from the soil are both decreased.
- When hydrogel is applied to sandy soils, many enzyme activities that are indicative of the microbial population in the soil (such as acid phosphatase, alkaline phosphatise, dehydrogenase, protease, and urease) are elevated.
- All types of soil and crops may be employed using agricultural hydrogel. Nurseries, seedling beds, crops susceptible to moisture stress, water-intensive crops, and container gardens and pot cultures are where its advantages are most readily apparent.
- Agricultural hydrogel application rate is dependent on soil texture; for clay soil, it is 2.5 kg/ha (at the soil depth of 6–8 inches). Up to 5.0 kg/ha for sandy soil (at the soil depth of 4 inches)

Method of application

- To prepare a nursery bed for transplants, evenly spread 2 g/m2 (or the suggested rate) of a hydrogel nursery bed mix over the top 2 inches of the nursery bed. Before planting, mix 3-5 g/kg of soil in a pot culture.
- For the majority of crops, a low rate of treatment, between 1 and 2 kg/acre, is effective. Lessening impact of salt and fertiliser solutions on hydrogel swelling ratio. When used to develop vegetable and flower nurseries, the hydrogel-amended sandy loam soil and medium without soil, such as sand, cocopit, etc., shown a delay in the commencement of permanent wilting point when compared to control (2–6 days).

- In hi-tech horticulture, the application shortened the time it took for chrysanthemum cuttings to germinate and establish themselves (18 days) in comparison to the control crop (28 days).
- Lessened the number of times drip fertigation was applied to horticultural crops grown in sheltered and open fields, respectively.
- In comparison to control, hi-tech farming significantly increased production and water usage efficiency for the majority of the test crops.

Hydrogels are environment friendly

- Labile bonds are bonds that can be broken under physiological conditions either enzymatically or chemically over time. Biodegradable hydrogels have labile bonds either in the polymer backbone or in the cross-links utilised to generate the hydrogels.
- After deterioration, CO2, water, and ammonia are the byproducts.
- While polyacrylamide itself is non-toxic, the monomer acrylamide, which is utilised to produce hydrogels, is neurotoxic. Acrylamide residue is not found in crop products that are cultivated with hydrogel application because the polyacrylamide can never rebuild its monomer. As a result, there is no acrylamide residue left in the soil following hydrogel decomposition, especially when cellulose is utilised as the backbone.

Conclusion:

Dry farming is made easier by hydrogel. Since the majority of India's land is in arid and semiarid regions, more effective water management is crucial for agriculture. One strategy to conserve water is to use good management techniques in agriculture to keep the soil moist and maximize its capacity to hold water. This characteristic has led to numerous practical uses for these new materials, particularly in agriculture to increase soil water retention and plant water delivery