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Hydrogel and Its Utilisation in Agriculture

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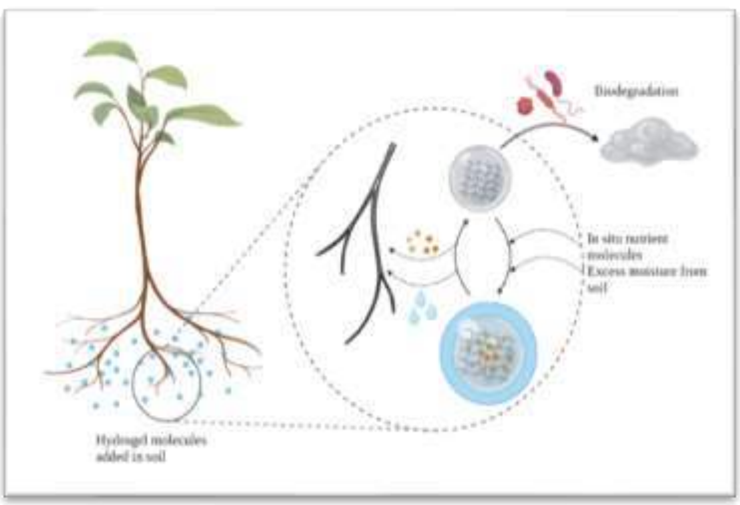
Hydrogel is an amorphous substance with a quasi-solid phase that is sometimes referred to as "raindrop," "water retention granules," and "root watering crystal." It has three-dimensional networks of flexible hydrophilic macromolecules that are cross-linked and loosely held, joined by covalent bonds or physical contacts, and possesses absorbency and biodegradability that are specifically engineered. These polymers are organic and possess a special property that allows them to quickly and efficiently absorb a significant amount of moisture from readily available water thanks to their highly absorbent nature. Over the course of the soil drying process, these materials uniformly and slowly release the stored moisture into the surrounding soil and rhizosphere zones.



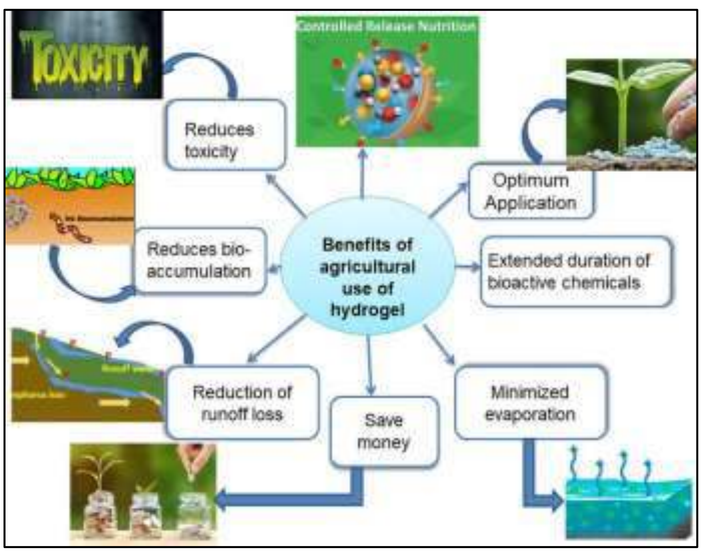
Arid nations require a lot of water, especially virtual water, to meet their daily demands. By 2050, it is predicted that global water uses by livestock, industrial, domestic, and irrigation applications will increase by 21% **[3]**. As a result, using the newest technology to improve the potency of water and nutrients used in agriculture may become increasingly important in the long run, especially in arid regions where water resources are scarce. Due to their potential to solve a variety of issues pertaining to crop productivity, soil development, and water management, these materials have drawn more and more attention in the agricultural community. Hydrogels have bright futures in agriculture, providing creative answers for productive and sustainable agricultural methods. Food security is increasingly threatened by rising food consumption and diminishing water supplies, among other factors [1].

Hydrogels have the potential to enhance ecologically sustainable agriculture through their ability to conserve water, minimize chemical runoff, and encourage responsible water management. They support the objectives of precision and environmentally sustainable farming methods.

Classification of Hydrogel

Based on its composition, intended purpose, and physical and chemical characteristics, hydrogels can be divided into a number of groups. The following are some typical hydrogel classifications:

1. Starch-polyacrylonitrile graft polymers (starch copolymers)
2. Vinyl alcohol-acrylic acid copolymers (polyvinyl alcohols)
3. Acrylamide sodium acrylate copolymers (cross-linked polyacrylamides)



Applications of Hydrogel in Agriculture

1. **Soil Conditioners:** To increase soil fertility and structure, hydrogels are used as soil conditioners. They improve the aeration and soil water retention, guaranteeing that plants get regular supplies of nutrients and water.
2. **Water Retention and Irrigation Management:** When plants require water, hydrogels have the capacity to absorb and hold vast amounts of it, releasing it gradually into the soil. This water management technique helps crops resist drought conditions, conserves water, and lessens the need for frequent watering.
3. **Nutrient Delivery:** Certain hydrogels are made to contain both nutrients and water. They have the ability to progressively release nutrients, guaranteeing that plants get an adequate amount of vital minerals. The requirement for repeated fertilization may be lessened by this controlled-release characteristic.
4. **Crops Grown in Non-Arable Lands**: Hydrogels facilitate the control of water and nutrients, making it possible to grow crops on unarable ground. In regions with low soil quality, this is crucial.
5. **Environmental Sustainability**: By limiting the environmental effect of chemical pesticides and fertilizers, avoiding nutrient leaching, and lowering water waste, the use of hydrogels in agriculture promotes sustainable farming methods. Many beneficial bacteria have been encapsulated with hydrogels or sodium alginate formulations for biological control and the improvement of biodegradation [2].
6. **Osmotic Moisture:** It can lower soil osmotic moisture, save labor, money, and irrigation water; lessen crop irrigation needs; lessen drought conditions; stop water and nutrient runoff and leaching; increase plant water and nutrient use

efficiency; and replenish soil microbes and enzymes.

Although hydrogels have many benefits for agriculture, its usage needs to be carefully controlled to make sure that it fits local circumstances and best practices. When utilizing hydrogels, farmers should take into account variables including crop type, application rates, soil type, and temperature to maximize their advantages.

Methods of Hydrogel Application in Agriculture

Hydrogels are used as soil conditioners to improve the structure of poor-structured soil at deeper depths by aggregating the soil, stabilize surface soils to prevent crust formation, increase the capacity of the soil to store water, and stimulate plant growth. In agriculture, the texture of the soil affects how quickly hydrogel is applied. When the soil depth is between 6 and 8 inches in clay soil, it is 2.5 kg ha^{-1}; at 4 inches in sandy soil, it might reach 2.5-kilogram ha^{-1}. When using hydrogels in soils, there are primarily two approaches:

- ❖ **Dry Method to Subsoil**: To prepare the subsoil for agriculture, a dry polymer, such as polyvinyl alcohol (PVA) or polyallylamine (PAAm), is applied by mixing it with sandy soil to a depth of 15 to 25 cm. This allows the soil to swell. Following the swelling of the polymer, the soil's structure is enhanced, and its ability to absorb and hold water is raised.
- ❖ **Wet Method to Topsoil**: After first wetting the topsoil, the polymer solution is sprayed over, and the soil is immediately seeded and dried to provide aggregate stability that is stable in water. In addition to lowering soil erosion and increasing soil hydraulic conductivity, this wet approach can save water. Pesticides and micronutrients can also be combined with hydrogel in the spray approach.

Drawbacks of Using Hydrogel in Agriculture

Hydrogels provide a number of advantages in agriculture, but there are also some disadvantages and difficulties that should be taken into account. The following are a few disadvantages of hydrogel application in agriculture:

Cost: Because hydrogels may be somewhat costly, some farmers could be discouraged from adopting them, particularly those who operate in low-resource environments. An obstacle to adoption may be the initial outlay of funds.

1. **Environmental Concerns**: The potential lack of biodegradability of certain hydrogels, particularly synthetic ones, raises questions about their potential long-term environmental effects. This is particularly crucial for organic and sustainable farming methods.
2. **Application Complexity**: Hydrogel application in the field can be a difficult procedure that has to be properly mixed and incorporated into the soil. If executed incorrectly, the anticipated advantages could not materialize.
3. **Limited Nutrient Release**: While certain hydrogels have a progressive nutrient release rate, this may not correspond with the particular nutritional requirements of various crops, resulting in surpluses or deficits in certain nutrients.
4. **Clogging Irrigation Systems**: If hydrogels are not adequately filtered, they can occasionally clog the emitters in drip irrigation systems. Reduced water delivery and more maintenance may result from this.

5. **Residue Buildup**: Certain hydrogels may leave behind residues in the soil, which may eventually have an impact on crop development and soil characteristics.

It's critical that farmers and other agricultural experts thoroughly evaluate the unique circumstances of their farming operations as well as the properties of the hydrogel that's being utilized. To evaluate if employing hydrogels has more benefits than disadvantages in a particular scenario, consideration should be given to variables such as crop type, climate, soil type, and intended results. Furthermore, as hydrogel technology advances and study continue, some of these restrictions could eventually be addressed.

Conclusion

In dry and semiarid locations, water is increasingly the most important element limiting agricultural output sustainably. Applying hydrogel as a soil conditioner can boost the soil's hydro physical, physicochemical, and biological environments; it can also increase the soil's capacity to retain and release water; it can improve irrigation and water and nutrient use efficiencies; it can improve agricultural produce's yield and quality; and it can maintain the quality of the surrounding environment. In terms of improved yield (cereals, vegetables, oilseeds, flowers, spices, plantations, etc.) and reducing soil moisture stress, this hydrogel technology may prove to be a radical and realistically useful technique in water-stressed locations.

Hydrogels have a wide range of potential applications in agriculture, providing answers to urgent problems such soil erosion, drought, and water shortages. Hydrogels have the potential to become an increasingly important component of efficient and sustainable agricultural methods, promoting environmental preservation and food security, as science and technology develop. For best outcomes in a variety of agricultural contexts, farmers and agricultural specialists must comprehend the unique properties and application methods of hydrogels.

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