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Review Article

Categories and Application Fields and Manufacturing Process and Action Mechanism of Water Retaining Agent

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Water retaining agent (WRA) is a kind of functional polymer material with strong water absorption capacity. It can absorb and release water repeatedly and is often used for crop growth in water shortage areas. It is of great significance to the development of water-saving agriculture. There are many kinds of water retaining agents, and with the development of science and technology, the raw materials for making water retaining agents tend to be diversified. And they are more and more widely used in many fields closely related to our life, such as industry, food production, medical treatment, and greening, and the manufacturing process is more and more mature. In addition, the water absorption capacity of water retaining agent is not only related to its own components but also related to the external environment. The water absorption mechanism and the factors affecting water absorption capacity of water retaining agent were explored as follows.

1. Introduction

At present, the shortage of water resources is becoming more and more serious in many countries and regions. The area of arid and semiarid areas is increasing, and soil erosion and ecological environment are deteriorating, which has seriously affected the agricultural development and human living environment in various countries. The farmland drought stress caused by water shortage is the key factor affecting the sustainable development of agricultural production and food yield. By 2030, the global water demand is expected to increase by nearly 50%, which will exacerbate the shortage of water resources, while agricultural water has consumed 70% of the world's fresh water [1]. When the soil water holding capacity is low and the water evapotranspiration is high, it will not only affect the growth of crops but also cause permanent damage to soil and microorganisms. Therefore, how to effectively use soil water to overcome the adverse effects of drought on plant growth has become the focus of domestic and foreign attention and research. Water retaining agent has been widely concerned by scholars all over the world since it was made for the first time. So far, the performance of the material has made a great breakthrough and developed rapidly. The application of water retaining agent is an important technology in water-saving agriculture in recent years, which can save water and fertilizer. Agricultural chemicals such as fertilizer, herbicide, and insecticide are essential in crop growth, but the large application of these chemicals will seriously pollute the environment. It is found that the mixed application of water retaining agent and agricultural chemicals can not only improve the utilization rate of agricultural chemicals but also reduce the pollution to the environment. Rational application of water retaining agent can obtain the best economic and ecological benefits, and its application in agricultural production and other fields is becoming more and more common.

2. Categories of WRA

Water retaining agent is a water-soluble polymer crosslinking material developed in recent 20 years, which is a kind of super absorbent polymer (SAP). With the gradual expansion of the application range, the raw materials for making water retaining agent are also gradually diversified. Therefore, there are more and more kinds of water retaining agent on the market. At present, water retaining agents are mainly divided into three categories according to the source of raw materials [2]: synthetic polymerization, natural polymer modification, and organic-inorganic composite [3–5]. Among them, natural polymer modification includes starch [6], cellulose [7, 8], and humic acids [9, 10]. Synthetic polymeric water retaining agent is a kind of water retaining agent with the largest varieties and the largest industrial output. Its types mainly include polyacrylic acid, polyvinyl alcohol, polyacrylonitrile, polyacrylamide, and polyoxyethylene. Although this kind of water retaining agent has high water absorption ratio, its cost is high, and it will not be easy to degrade and cause environmental pollution after a large number of applications [11]. Natural polymer modified water retaining agents are the first developed super absorbent materials. It is composed of natural polymer materials with a wide range of sources, low prices, certain water absorption capacity, and multiple grafting siteswhich are modified and then grafted with acrylic acid, acrylamide, etc. There are many kinds of natural polymer modified water retaining agents, mainly including starch, cellulose, humic acids, lignin modification, amino acid, and chitosan; at present, the first three categories are studied more. Organic-inorganic composite water retaining agent is generally a kind of super absorbent material with strong water absorption capacity and low price obtained by grafting and polymerization of minerals with acrylic acid, acrylamide, etc. The commonly used minerals mainly include kaolin, bentonite/montmorillonite, talc, attapulgite clay, sericite, and diatomite. The synthesis of organic-inorganic composite water retaining agent is of great significance for the efficient development of natural mineral resources and the improvement of the utilization value of minerals. In addition, in recent years, many universities and research institutes have chosen to use some raw materials with wide sources and low prices to develop and prepare other new water retaining agent products with strong water absorption capacity, fast water absorption speed, long duration, low price, and wide application range, such as bamboo fiber grafted acrylate polymer water retaining agent [12], seaweed biological water retaining agent [13], modified cotton stalk cellulose salt resistant water retaining agent [14], apple pomace water retaining agent [15], and other new water retaining agents [16–18], which have the advantages of easy degradation, green environmental protection, and low cost.

At present, there are many kinds of water retaining agents, which can be mainly divided into the following categories according to the source of raw materials, as shown in Table 1.

3. Application Fields of WRA

Nowadays, water retaining agent has been widely used, initially only in agriculture, but now, it has been gradually applied to many fields, such as greening, food, medical treatment, and architecture, and its application is becoming more and more common [19–26].

With the development of modern industry, many cultivated lands are seriously polluted by heavy metals. Studies have shown that the application of water retaining agent can reduce the harmful impact of arsenic (As) on crops by reducing oxidative stress, thus improving soil physical properties and reducing the damage of heavy metal to crops [27]. In the petroleum industry, processing oil sand to extract asphalt will produce a large number of mature fine tailings (MFT). The poor consolidation and drainage capacity of MFT can cause serious environmental problems. The use of super absorbent polymers can quickly dehydrate MFT to produce dense MFT, so as to reduce the harm to the environment. In terms of water and soil conservation, some experimental results showed that the effect of 1.5% water retaining agent content in soil is the best. At this time, the antiscouring capacity of soil can be improved by 68.9%, and the water retention performance can be improved by 11.1%, which is of great significance for plant growth and prevention of water and soil loss [28]. At present, carbohydrates are widely used as water retaining agent in frozen aquatic products, which solves the problems of easy corruption and deterioration and decline in quality and economic value of aquatic products during cold storage and transportation. Its mechanism is that sugar can change the state of bound water in protein molecules, replace the bound water on the surface of protein molecules, and combine to it, so as to inhibit protein denaturation and improve the quality of aquatic products such as crayfish during frozen storage [29].

Every year, millions of metric tons of water retaining agent are produced in the world and used in different fields. In addition to the high application rate in industrial production, soil and water conservation, and aquatic product processing and storage, the consumption of water retaining agent in the world in personal health and medical care is many orders of magnitude higher than that in any other fields. In terms of living hygiene, the core body of baby diapers is composed of super absorbent molecules and nonwovens. After absorbing urine, the ultra-high content of water absorbent polymer can firmly lock the water, not easy to reverse osmosis, and can keep dry for a long time [30]. The same principle is applied to sanitary cotton. In terms of health care, the plaster is also applied to the principle of water retaining agent, which can maintain humidity and help patients recover.

In short, water retaining agent has been applied to various fields of life, providing great convenience for people's production and life. The specific application in each field is shown in Table 2.

4. Manufacturing Process of WRA

Although the water retaining agent is widely used in China, the research on the super absorbent resin material in China is still relatively backward compared with foreign countries, and there are still some difficulties in mass production due to a series of problems such as complex manufacturing technology. However, with the increasing demand of water retaining agent, it is particularly important to study the

Table 1: Categories of WRA.

Synthetic polymerization		Polyacrylic acids
		Polyvinyl alcohol
		Polyacrylonitrile
		Polyacrylamide
		Polyoxyethylene
Natural polymer modification	Starch	Starch grafted monobasic acid (such as starch grafted acrylonitrile and starch grafted acrylic acid,)
		Starch grafted polyacid (starch grafted acrylic acid and acrylamide, starch grafted methyl acrylate and propylene alcohol, etc.)
		Carboxymethylated starch
		Phosphate esterified starch
		Starch xanthate
	Cellulose	Cellulose/acrylic polymer/montmorillonite super absorbent composite water retaining agent
		Cellulose grafted acrylonitrile hydrolysate
		Crosslinking of epichlorohydrin after carboxymethylation of cellulose
		Hydroxypropyl cellulose
		Xanthated cellulose
		Cellulose-humic acid-acrylic acid water retaining agent
	Humic acids	Humic acid-polyacrylic acid water retaining agent
		Humic acid-acrylamide-acrylic water retaining agent
		Humic acid-clay-polyacrylic acid water retaining agent
		Humic acid-starch-polyacrylic acid water retaining agent
	Other natural	Pectin
		Chitosan
		Agarose
		Proteins (soybean protein, etc.)
Organic-inorganic composite		Kaolin/sodium alginate grafted acrylic acid and acrylamide composite water retaining agent
		Organic bentonite/acrylic acid copolymer composite super absorbent water retaining agent
		Mica powder polypropionic acid crosslinked water retaining agent
New water retaining agent		Bamboo fiber grafted potassium acrylate water retaining agent, bamboo fiber grafted acrylamide water retaining agent
		Modified bamboo fiber water retaining agent
		New seaweed biological water retaining agent (using seaweed and acrylic acid as raw materials)
		Modified cotton stalk cellulose salt tolerant water retaining agent (with cotton stalk and acrylic acid as raw materials)
		Aminoethyl chitosan-acrylic acid water retaining agent
		Xanthate-humic acid-nitrogen (2-hydroxyethyl) ethylenediamine degradable water retaining agent
		Chitosan-citric acid-urea water retaining agent
		Apple pomace water retaining agent

characteristics and manufacturing process of super absorbent resin material [31, 32].

At present, the preparation methods of water retaining agent are mainly divided into 5 kinds, which are aqueous solution polymerization, inverse suspension polymerization, inverse emulsion polymerization, bulk polymerization, and radiation crosslinking polymerization. Among them, aqueous solution polymerization is the most widely used method at present. This method mainly uses water as solvent and neutralizes acrylic monomer through alkaline solution to prepare sodium acrylate solution and then adds crosslinking agent and initiator, after crosslinking, drying and a series of processes to prepare a high absorbent resin [33]. The inverse suspension polymerization method mainly uses organic solvents; in addition to adding crosslinking agent and initiator, it also needs to add dispersant to disperse the reactant into oil and then polymerize, then the polymer suspension is finally prepared by relying on the initiator, and the product is insoluble in water, so that the required product can be finally prepared by separation method. The initiator used in inverse emulsion polymerization is oil soluble, which is reacted inside the droplet. Bulk polymerization only uses the monomer itself to participate in the polymerization reaction, and the prepared polymer is only the bulk without adding any other reactants. Radiation crosslinking polymerization mainly uses energy radiation; under the irradiation of radiation energy, the temperature increases rapidly, and the reactants are evenly heated; this method is

Table 2: Application fields of WRA.

Field	Specific application
Agriculture	Vegetable cultivation, soil mixing, seedling transplantation, seed coating, edible fungus culture
Water and soil conservation	Retain and store water and effectively avoid soil erosion
Desertification control	Reduce surface runoff, reduce sand loss, and significantly improve the wind erosion resistance of soil
Remediation of heavy metal pollution	Reduce the absorption of heavy metals such as copper and lead in soil by plants
Landscaping	Seedling raising, transplanting, lawn planting, fertilizer conservation and seedling moisturizing
Grass industry	Golf course, football field
Living hygiene	Diapers, tampons, ice pads
Industry	Petrochemical industry, cable, papermaking, sensor, fire extinguishing appliance, fiber products, cosmetics, expansion toys, heavy metal ion adsorbent, oil absorbing materials
Food production	Fresh keeping bag preparation, thickening stabilizer, food dehydration, aquatic product processing and storage
Medical care	Ointment, cream, and other drugs with moisturizing and gelling effects, medical bandages, cotton balls, artificial skin, intelligent carriers for controlling drug release, and plasters
Architecture	Plugging, water plugging, and mud solidification
Other	Road dust suppression

simple, and the purity of the prepared product is high. In industrial production, synthetic polymeric water retaining agents and natural polymer modified water retaining agents are mainly synthesized by aqueous solution polymerization and inverse suspension polymerization, and organic-inorganic composite water retaining agents and some new water retaining agents are also synthesized by aqueous solution polymerization.

These methods have their own advantages and disadvantages, as shown in Table 3 below. Appropriate methods shall be selected according to the actual situation.

There are many kinds of water retaining agents, and a kind of water retaining agent can be synthesized by a variety of methods. Among them, the bulk polymerization method is easy to explode and is not recommended. In the following, the specific processes of several preparation processes commonly used are briefly described, such as aqueous solution polymerization, inverse suspension polymerization, inverse emulsion polymerization, and radiation crosslinking polymerization. Each method can be used for different types of water retaining agent production but should be selected according to actual production conditions.

4.1. Aqueous Solution Polymerization Method [34, 35]. Taking kaolin/sodium alginate grafted acrylic acid and acrylamide composite water retaining agent as an example, the raw materials are kaolin, sodium alginate, etc., and the aqueous solution polymerization method is adopted. In this reaction, N,N-methylene bisacrylamide was used as crosslinking agent, and $(NH_4)_2S_2O_8$ was used as initiator. After the reaction, the product was sheared, dried, crushed, and screened to obtain the required powdered water retaining agent. The specific reaction process is shown in Figure 1.

4.2. Inverse Suspension Polymerization Method [36]. The inverse suspension polymerization method mainly uses light hydrocarbons as the continuous phase and sodium acrylate aqueous solution as the dispersed phase. The final product is obtained through suspension polymerization and surface crosslinking in the polymerization kettle, distillation. The specific reaction process is shown in Figure 2.

4.3. Inverse Emulsion Polymerization Method [37]. The production of polyacrylamide by inverse emulsion polymerization is a hot spot in the current research. It takes hydrocarbons as the continuous phase, with the help of emulsifiers, the aqueous solution of monomers is fully dissolved in the oil phase, and polymerization occurs under certain conditions. This polymerization method overcomes the shortcomings of the traditional process and simplifies the process. Compared with the traditional synthesis method, the conversion and the relative molecular weight of polyacrylamide synthesized by inverse emulsion polymerization are greatly improved. The specific reaction process is shown in Figure 3.

4.4. Microwave Radiation Polymerization Method [38]. The synthesis of montmorillonite/starch modified superabsorbent resin by microwave radiation has realized the integration of polymerization and drying, avoided the complex and time-consuming treatment process, directly prepared the dried resin, further simplified the process, shortened the reaction time, reduced the cost, and has obvious advantages. The specific reaction process is shown in Figure 4.

5. Action Mechanism of WRA

5.1. The Function of WRA. Water retaining agent is a high molecular polymer which water absorption capacity depends on the hydrophilic functional group connected to the main chain of the polymer. It can absorb water hundreds or even thousands of times more than its own weight and has the ability of continuous water absorption and repeated water absorption and release capacity [39]. It is called "micro soil

Table 3: Manufacturing process of WRA.

Method	Advantage	Disadvantage
Aqueous solution polymerization	The operation is simple and safe. It is suitable for large-scale preparation, with less waste, low energy consumption in the production process, high initiation efficiency, and sufficient system mixing	The polymerization temperature is difficult to control
Inverse suspension polymerization	The reaction speed is fast, and the product is uniform and has high water absorption rate and strong water retention ability	The production process consumes a lot of energy and generates more reaction heat, and the solvent recovery cost is high
Inverse emulsion polymerization	The temperature is easy to control, the preparation process is simple, and the water absorption rate of the product is high	Higher cost
Bulk polymerization	Single reactant and simple operation	A large amount of heat is generated in the production process, which is easy to implosion
Radiation crosslinking polymerization	The operation is simple, the purity of the product is high, and the reaction can be carried out even at low temperature, no environmental pollution	A large amount of equipment investment is required in the early stage

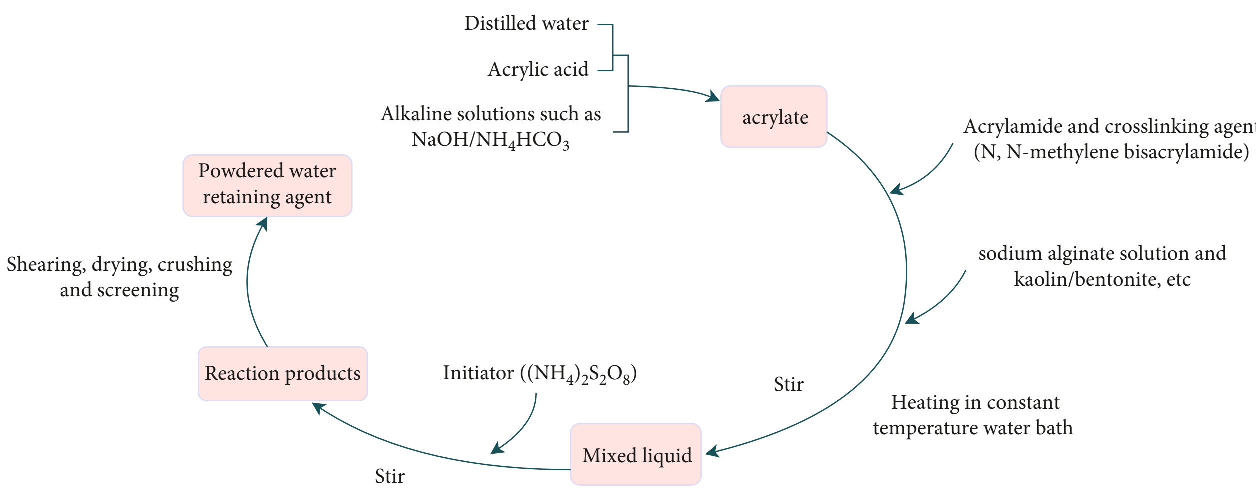

Figure 1: Aqueous solution polymerization method.

reservoir" in agriculture, which can improve soil structure and soil nutrition [40], improving soil water and fertilizer retention capacity and water use efficiency and can make the soil has sufficient water retention capacity even under adverse conditions, so as to achieve high quality and high yield of crops. In addition, the water retaining agent can absorb fertilizers and pesticides and release them slowly, so as to improve the utilization rate of fertilizers, reduce nutrient leaching, improve soil fertility, and increase the efficacy of pesticides. Some experimental results show that after the application of water retaining agent, the contents of quick acting nitrogen, quick acting phosphorus, and quick acting potassium in soil are significantly increased, and the effect is more obvious with the increase of the application amount of water retaining agent [41]. For example, super absorbent resin and fertilizer can be combined into controlled-release fertilizer by mixing, coating, or chemical methods, so as to greatly improve the utilization efficiency of fertilizer.

Water retaining agents are often used as soil regulators to promote plant growth by regularly providing nutrients and water to plants. When the soil around the root zone of a plant begins to dry out, the water retaining agent releases water and nutrients to the plant, which can slowly release nutrients and water and provide rich nutrients and water environment for plants, thus promoting plant growth [42]. Slow release is a key feature of soil water retaining agents because valuable nutrients are released slowly from the polymer matrix, and plants can use these nutrients for longer periods of time [43].

Soil microorganisms are the driving force for the transformation and circulation of soil organic matter and soil nutrients and play an important role in the formation of soil fertility. The use of water retaining agent can affect the water content in soil, and the soil water content is the key factor affecting the microbial activity in soil [44]. One study showed that the application of water retaining agent would not have detectable adverse effects on soil microbial community and might even enhance soil microbial activity [45]. Microorganisms can exchange materials with surrounding soil through water, which can improve the nutrient availability of plant rhizosphere soil, promote the absorption of trace elements by plants, increase the survival ability of plants in

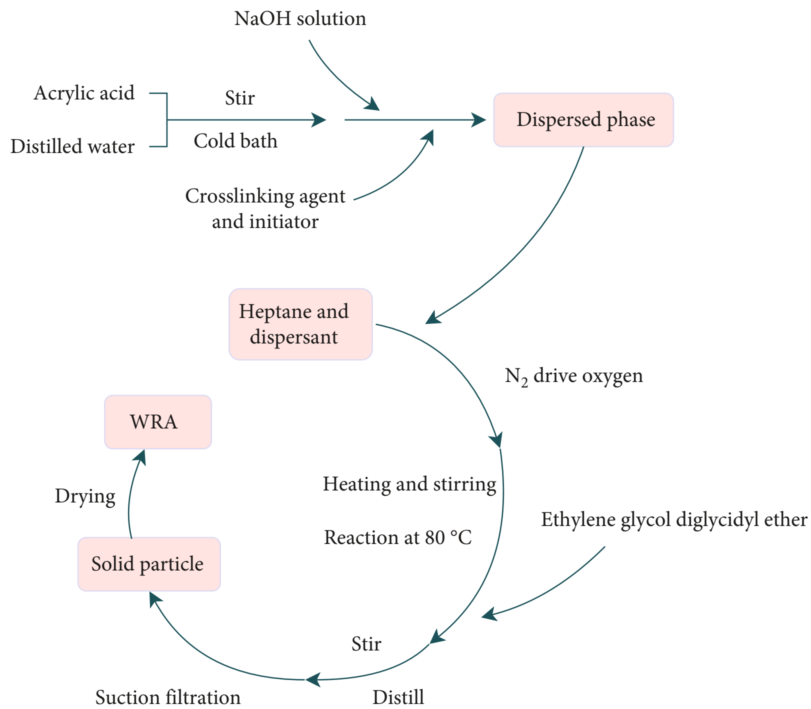

Figure 2: Inverse suspension polymerization method agent.

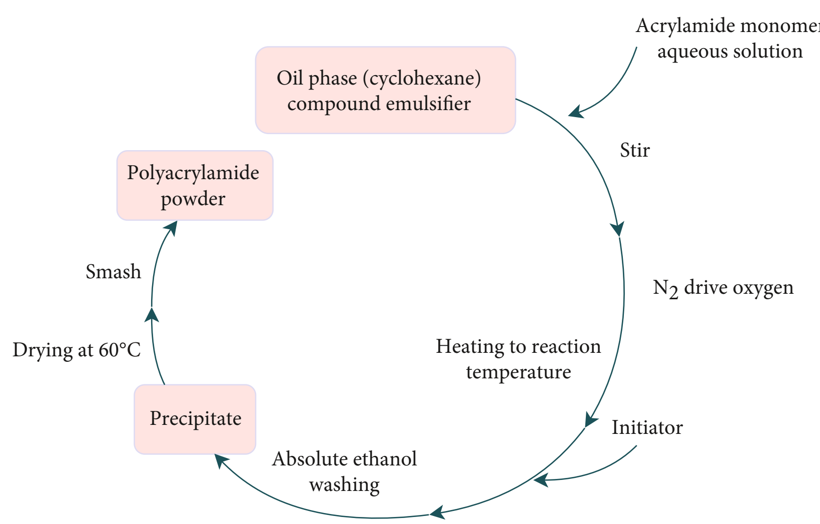

Figure 3: Inverse emulsion polymerization method.

harsh environment, and improve the tolerance of plants to drought, saline alkali, and flooding [46]. When the soil is dry, the microorganism activity is affected; at this time, the water content in the soil is so low that the diffusion of the substrate is limited; then, the growth process of the microorganism is hindered because of the lack of nutrients [47], which affects the growth of plants. Gao et al. found that the duration of water stress had a great impact on the structural diversity and richness of microbial community in the rhizosphere of greenhouse grapes. Short-term water stress (such as anthesis stage) could improve it; however, long-term severe stress (such as fruit expansion period) has a significant inhibitory effect on the structural diversity of microbial community. Soil microbial groups play a very important role in soil ecosystem, which quantitative characteristics can characterize the quality and fertility of soil [48], and play a decisive role in the yield and quality of crops. It is also found that applying an appropriate amount of polyaspartic acid water retaining agent (PASP) in cotton field can significantly improve the richness and diversity of bacterial and fungal communities. Bacteria are more sensitive to PASP than fungi, and the application of PASP has a greater impact on bacterial communities [49]. Wang et al. studied the effects of different application levels of water retaining agents on

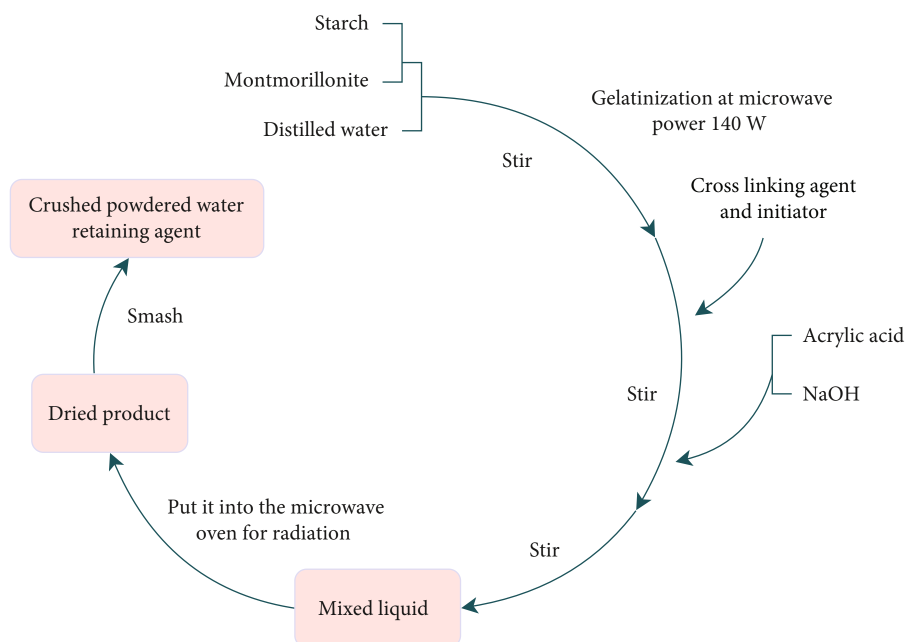

Figure 4: Microwave radiation polymerization method.

the physical properties and microbial activities of poplar soil and found that the application of water retaining agents could significantly increase the number of bacteria, fungi, total amount of microorganisms, and respiration rate of microorganisms in poplar soil; on the one hand, the reason may be that water retaining agent can reduce soil bulk density, increase soil porosity, and significantly improve soil physical properties; on the other hand, the improvement of soil physical properties is more conducive to enhancing root activity of poplar seedlings, stimulate the root system to secrete a large number of inorganic and organic substances, thus increasing the necessary nutrients and energy sources for the growth and reproduction of microorganisms, and also can make the microorganisms more active, and the increase of the number of microorganisms is also conducive to improving the turnover efficiency of soil organic matter and thus enhances the fertility [50].

5.2. Water Absorption Mechanism of WRA. The use of water retaining agent is of great significance to agriculture; so, the study of its mechanism is also of great importance [51–54]. The water absorption mechanism of water retaining agent is mainly closely related to its own molecular structure, which is the result of the balance between the molecular expansion caused by electrostatic repulsion after ionization of polymer electrolyte and the crosslinked network structure of resin itself hindering molecular expansion. The molecular chains of this polymer compound are connected and wound, and the molecules show a complex three-dimensional network structure, which makes it have a certain degree of crosslinking. There are many hydrophilic groups such as hydroxyl and carboxyl groups on its crosslinked network structure. When in contact with water, the hydrophilic groups on the molecular surface ionize and combine with water molecules to form hydrogen bonds, which absorb a large amount of water in this way. In the process of water absorption, electrolytes are ionized in water, the electrostatic repulsion between ions with the same electrical conductivity leads to the expansion of molecular chains, while the concentration of ions in the resin increases, and the osmotic potential is different from the external water. Then, the water molecules enter the resin, and the water retaining agent is in gel state; even under the pressure condition, it is not easy to separate water [55]. And because the crosslinked network structure and hydrogen bonding effect of the resin itself inhibit the infinite expansion of the gel, when the two functions reach equilibrium, the water absorbent is saturated with water, and when the water in the gel is exhausted, as long as the molecular chain is not destroyed, its water absorption ability can still be restored; that is, it can repeatedly absorb water and release water. The mechanism of water absorption is shown in Figure 5.

In addition, for natural polymer modified water retaining agents, such as humic acid water retaining agents, the structure of humic acid contains carboxyl, phenolic hydroxyl, carbonyl, alcohol hydroxyl, and other active functional groups, which determine the hydrophilicity, adsorption and high complexation ability of humic acid. When in contact with water, the humic acid on the surface of water retaining agent can act as a polymer surfactant and mechanical barrier. It makes the particles of the water retaining agent disperse rapidly and evenly, effectively overcomes the surface gel phenomenon, promotes the water molecules to penetrate into the water retaining agent evenly, and improves the water absorption performance. The starch in the starch water retaining agent has good film-forming, thickening, and water absorption. The introduction of starch molecules rich in hydroxyl active groups into the water retaining agent not only improves its water retaining performance but also reduces the production cost and improves

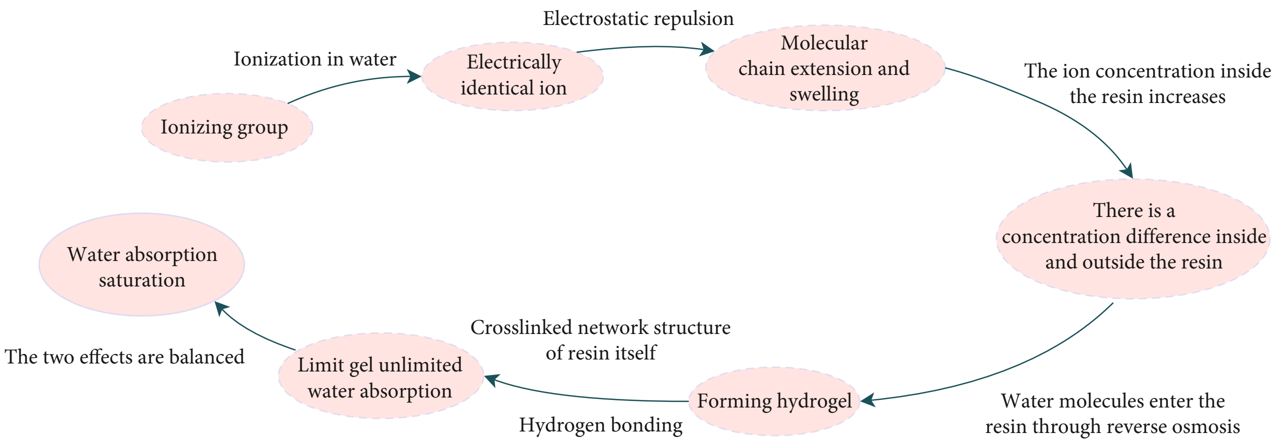

Figure 5: Water absorption mechanism of WRA.

the disadvantage that the water retaining agent is not easy to degrade. The cellulose introduced into the cellulose water retaining agent is nontoxic, tasteless, pollution-free, uneven, and porous on the surface and has good water absorption capacity. At the same time, the main chain of cellulose contains a large number of hydroxyl groups, which can provide many different grafting sites. Taking cellulose as a component of water retaining agent can improve the problems of high cost, poor salt resistance, and difficult degradation of water retaining agent. Therefore, cellulose water retaining agents are widely used in agricultural and forestry fields which with low requirements for water absorption, but high requirements for salt resistance, gel strength, and degradation performance, which is an important direction for the green and sustainable development of water retaining agents in the future [10]. For organic-inorganic composite water retaining agents, kaolin, which has hygroscopicity and water swelling property, is a layered silicate clay mineral with hydrophilic property. It can be well crosslinked with organic monomers and also acts as a crosslinking agent to a certain extent. Together with the crosslinking agent added in the reaction, it has an impact on the crosslinking of the sample, which helps to form a polymer with kaolin microparticles as the main grid point and moderate crosslinking degree, which is conducive to improving the salt resistance of the polymer [4]. Montmorillonite is a kind of layered silicate, which has natural nanostructure, strong adsorption capacity, and ion exchange performance. The reactive hydroxyl groups on the surface of its lamellar structure make it more advantageous to obtain high-performance composite resin by in situ polymerization with organic materials. Some new water retaining agents were as follows, such as seaweed biological water retaining agents, because there are a large number of seaweed polysaccharides in seaweeds, the seaweeds are activated by the new double enzymatic hydrolysis technology, and the acrylic monomers are grafted on the natural high molecular seaweed polysaccharide extract for copolymerization. The water retaining agents prepared have the advantages of strong water absorption and long service life [13, 56]. As a good material rich in cellulose, apple pomace is cheap and easy to obtain. After refining, extraction, and chemical modification, it can be prepared into a polymer with good water absorption and water retention.

5.3. Factors Affecting Water Absorption Rate

5.3.1. The Water Absorption Capacity of WRA Is Related to the Content of Each Component. In the process of preparing water retaining agent, the neutralization degree also affects its water absorption capacity and affects the water absorption by affecting the electrostatic repulsion of network chain and internal and external osmotic pressure [57]. With the increase of neutralization degree, the water absorption increases first and then decreases gradually. When the neutralization degree is low, the ionization degree of hydrophilic groups such as –COOH and -SO_3H is low, the number of strong hydrophilic groups such as -COO^- and -SO_3^- fixed on the network chain is small, the electrostatic repulsion generated by negative charge is weak, the polymer chain is not easy to stretch, the osmotic pressure inside and outside the network is small, and the system is acidic; at this time, more highly active acrylic monomers are easy to self-crosslink, which is not conducive to improving the water absorption of the resin. The neutralization degree increases, the ionization degree increases, the number of strong hydrophilic groups such as -COO^- and -SO_3^- increases, the electrostatic repulsion increases, and the network structure is relatively extended, which increases the water absorption of the polymer. When the neutralization is too large, the larger ionization degree increases the Na^+ content of the network, shields the negative charges on -COO^- and -$SO3^-$ on the molecular chain, weakens the electrostatic repulsion, and makes the molecular chain difficult to stretch and weak water absorption capacity. Therefore, the selection of the best neutralization degree is also very important to the water absorption capacity.

The amount of initiator also has a great influence on the water absorption capacity of water retaining agent. When the amount of initiator is small, the free radicals produced are less, the grafting points on the molecular chain are less, the grafting rate is low, and the water absorption of the polymer is low; when the amount of initiator increases, more free radicals are produced and more grafting points on the molecular chain; so, the water absorption is high. However, when the amount of initiator is too large, too many grafting points will lead to narrow network pores, accelerate the chain termination rate of macromolecular chain, reduce the degree of polymerization and molecular weight, increase the water solubility of the polymer, and further reduce the water absorption of the polymer. However, when the amount of initiator is too large, there will be potential safety hazards such as explosion.

The size of polymer network space is directly related to the amount of crosslinking agent, which affects the water absorption. Crosslinking agent is essential in the production of water retaining agent. When the amount of crosslinking agent is small, the number of crosslinking points of the system is small, the crosslinking density is low, the micropore of resin network is large, and the water absorption is poor. However, when the amount of crosslinking agent is too large, the crosslinking density is too large, the micropores of resin network are too narrow, and water molecules are not easy to enter; so, the water absorption becomes poor. Therefore, the best concentration of crosslinking agent should be selected so that the water absorption of polymer can reach a higher level.

In recent years, soil in some areas has been salinized to varying degrees; so, it is also very important to improve the water absorption capacity of water retaining agent under saline and alkaline conditions. When the amount of acrylamide is small, the amount of -$CONH_2$ in the system is small, and the synergistic effect with -COONa increases the water absorption and salt resistance of the resin. When the amount of acrylamide is greater than a certain value, with the increase of acrylamide concentration, there are more and more -$CONH_2$ in the polymer, and the defect of insufficient hydrophilicity of -$CONH_2$ is obvious, which is not conducive to the water absorption of the polymer [58].

5.3.2. Water Absorption Is Related to pH. In the acidic soil, most of the carboxylic acid anions of water retaining agent are protonated; on the one hand, the hydrogen bond interaction between carboxylates is enhanced, resulting in additional physical crosslinking. On the other hand, the electrostatic repulsion between carboxylates is limited, the network structure shrinks, and the water absorption ratio decreases. In alkaline soils, due to excess Na^+'s "charge shielding effect", that is, additional cationic protection carboxylate anion prevents effective anion exclusion, resulting in the reduce of osmotic pressure and a decrease in mobile ion concentration between polymer and water phases, then leading to a decrease of water absorbency [59]. When the soil pH is near neutral, some carboxylates are ionized, and the hydrogen bond interaction is broken; then, the water absorption capacity is improved, and the water absorption rate is the highest at this time [60].

5.3.3. Water Absorption Is Related to Solution Conductivity and Ambient Temperature. The charge valence and mineral salt concentration of external solution will also affect the water absorption capacity of water retaining agent. With the increase of solution conductivity, the water absorption of hydrophilic polymer decreases [61], because the combination of hydrophilic groups of polymer and salt will prevent the entry of water. In addition, salt will inhibit the electrostatic interaction between polymer and water molecules [62, 63], resulting in the decrease of polymer water absorption.

Some studies also found that hydrophilic polymers can show thermal sensitivity, when they are applied in soil, the adsorption of anionic polymers on clay will increase with the increase of temperature, which is due to the decrease of hydrogen bond between polymer and water and the increase of permeability of polymers to internal clay structure. Therefore, the water absorption efficiency of water retaining agent is also affected by the salinity and temperature of soil and irrigation water [64].

6. Discussion

Although there are many breakthroughs in the research of super absorbent polymer in China, there are still some shortcomings such as high cost, cumbersome preparation, and environmental pollution, which limit the wide use of the water retaining agent. At present, the application of water retaining agent in agriculture is still in the stage of small-scale test and demonstration, and the systematic application research and discovery of the mechanism of water saving and water conservation are still immature. It is still necessary to carry out extensive experimental research in different regions, different soil types, and different crops, constantly summarize experience, and obtain reliable data for popularization and application, so as to facilitate the multi-field and large-scale application of water retaining agent.

With the continuous progress of science and technology in the future, the preparation process of water retaining agent will be more streamlined, the performance will be gradually improved, and the application prospect will be broad. In the near future, the application of water retaining agent will be more common and more closely related to people's daily life.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest

The authors declare no conflict of interest.

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References

[1] P. L. Kashyap, X. Xiang, and P. Heiden, "Chitosan nanoparticle based delivery systems for sustainable agriculture," *International Journal of Biological Macromolecules*, vol. 77, pp. 36–51, 2015.

[2] X. Y. Xie, W. Fang, Y. Zhang, S. Zhu, Y. Xiong, and G. Chen, "Research and development situation and prospect of water retention agents," *Chemistry & Bioengineering*, vol. 30, pp. 8–13, 2013.

[3] F. Xue, *Study on Salt-Resisting Superabsorbent Composite Based on Organic Bentonite and Acylic Acid Copolymer*, Shaanxi University of Science and Technology, 2012.

[4] B. Huang, X. Fan, J. Du, and Y. Li, "Preparation and application of organic-inorganic water retaining agent," *New Chemical Materials*, vol. 47, pp. 243–247, 2019.

[5] X. U. Ao, L. Yan, Y. L. Lou, Y. Y. Sui, L. Zhang, and L. Z. Guan, "Water absorption characteristics of cross-linked substance of Mica powder and poly acrylic acid and its impacts on soil Potassium status supplying," *Bulletin of Soil & Water Conservation*, vol. 29, pp. 141–144, 2009.

[6] X. Wang, *Study on the synthesis and application of the starch super absorbent resin with phosphorus*, Huazhong Agricultural University, 2010.

[7] Q. Chen, *Preparation process and properties of cellulose water retention material*, North University of China, 2012.

[8] N. Li, *Study on cellulose/acrylic polymer/MMT superabsorbent composites*, Shaanxi University of Science & Technology, 2010.

[9] Z. J. Guo, L. Zhang, Q. Wei, C. H. Hou, and B. L. Zhang, "Current and development of superabsorbent polymer with humic acid," *Phosphate & Compound Fertilizer*, vol. 29, pp. 34–37, 2014.

[10] J. Zhang, D. Hou, Y. J. Xin, and Y. Bao, "Advance of research on natural polymer modification water-holding agent," *Shaanxi Journal of Agricultural Sciences*, vol. 66, pp. 76–80, 2020.

[11] J. Wei, H. Yang, C. Hui, T. Tan, and M. A. Ashraf, "Using polyaspartic acid hydro-gel as water retaining agent and its effect on plants under drought stress," *Saudi Journal of Biological Sciences*, vol. 23, no. 5, pp. 654–659, 2016.

[12] X. Yu, Y. Peng, and Q. Xu, "Water holding capacity and nutrient retention with bamboo sawdust regenerated super absorbent polymers," *Journal of Zhejiang A & F University*, vol. 34, pp. 473–483, 2017.

[13] H. Niu, K. Li, G. Yan, and J. Tang, "Preparation and properties of alga super absorbent polymer," *New Chemical Materials*, vol. 50, pp. 157–160, 2022.

[14] S. Fan, Y. Wang, N. Li, and X. Lv, "Study on preparation and properties of salt tolerant and water retaining cellulose of modified cotton stalk," *Journal of Tarim University*, vol. 31, pp. 53–58, 2019.

[15] Y. Chen, M. Liu, L. Yang, H. Jing, Y. Guo, and J. Zhang, "Study on synthesis and swelling properties of apple pomace-based superabsorbent resin," *Storage and Process*, vol. 20, pp. 122–127, 2020.

[16] S. Fang, G. Wang, P. Li et al., "Synthesis of chitosan derivative graft acrylic acid superabsorbent polymers and its application as water retaining agent," *International Journal of Biological Macromolecules*, vol. 115, pp. 754–761, 2018.

[17] J. Zhang, Y. Wang, and Q. Guo, "Study on preparation and properties of biodegradable superabsorbent resin of xanthate/humic acid/N(2-hydroxyethyl) ethylenediamine," *Shaanxi Journal of Agricultural Sciences*, vol. 67, pp. 57–62, 2021.

[18] A. Narayanan, R. Kartik, E. Sangeetha, and R. Dhamodharan, "Super water absorbing polymeric gel from chitosan, citric acid and urea: Synthesis and mechanism of water absorption," *Carbohydrate Polymers*, vol. 191, pp. 152–160, 2018.

[19] Z. Liang, X. Cai, H. Hu, Y. Zhang, Y. Chen, and Z. Huang, "Synthesis of starch-based super absorbent polymer with high agglomeration and wettability for applying in road dust suppression," *International Journal of Biological Macromolecules*, vol. 183, pp. 982–991, 2021.

[20] A. Farkish and M. Fall, "Rapid dewatering of oil sand mature fine tailings using super absorbent polymer (SAP)," *Minerals Engineering*, vol. 50-51, pp. 38–47, 2013.

[21] X. Xu, Y. Zhang, and X. Jin, "The effects and liquid adsorption mechanisms of the composition layers of disposable diapers," *Technical Textiles*, vol. 31, pp. 19–23, 2013.

[22] L. Yang, Y. Yang, Z. Chen, C. Guo, and S. Li, "Influence of super absorbent polymer on soil water retention, seed germination and plant survivals for rocky slopes eco-engineering," *Ecological Engineering*, vol. 62, pp. 27–32, 2014.

[23] X. I. Wancui, X. I. Jingwen, X. I. Rongyu et al., "Research progress of water retaining agent for aquatic products," *Journal of Light Industry*, vol. 34, pp. 15–23, 2019.

[24] Y. Li, Y. Zhu, Y. Zhao, Q. Yang, and J. Ren, "Application of soil water-holding agent in afforestation of seedling planting in mouni area," *Forest Science and Technology*, vol. 62-63, 2020.

[25] D. Guo and L. Rao, "Development situation of superabsorbent polymer and its application in agroforestry and desertification restoration," *Journal of Basic Science and Engineering*, vol. 29, pp. 1372–1385, 2021.

[26] S. Wu, X. Chen, J. Du, J. Ge, and M. Yi, "Application of superabsorbent in agriculture," *New Chemical Materials*, vol. 46, pp. 247–251, 2018.

[27] H. R. T. Moghadam, "Super absorbent polymer mitigates deleterious effects of arsenic in wheat," *Rhizosphere*, vol. 3, pp. 40–43, 2017.

[28] L. Li, H. Zhang, X. Zhou, M. Chen, L. Lu, and X. Cheng, "Effects of super absorbent polymer on scouring resistance and water retention performance of soil for growing plants in ecological concrete," *Ecological Engineering*, vol. 138, pp. 237–247, 2019.

[29] Y. Sun, M. Zhang, B. Bhandari, and C.-H. Yang, "Ultrasound treatment of frozen crayfish with chitosan Nano-composite water- retaining agent: Influence on cryopreservation and storage qualities," *Food Research International*, vol. 126, p. 108670, 2019.

[30] Y. Yang and X. Chen, "Development status and trend of China's diapers core," *China Textile Leader*, vol. 44-46, 2021.

[31] L. Zhao, Y. Cai, H. He, W. Chen, Y. Xie, and Y. Diao, "Research progress on preparation method and application of super absorbent resins," *Engineering Plastics Application*, vol. 46, no. 346, pp. 143–148, 2018.

[32] Z. Li, "Situation analysis and optimization & upgrading recommendation on superabsorbent resin industry," *Chemical Industry*, vol. 34, pp. 21–25, 2016.

[33] Z. Pan and J. Gong, "Technical selection and engineering application of super absorbent resin," *Chemical Production and Technology*, vol. 24, p. 42, 2018.

[34] Y. Shi, L. Zhu, J. Zhang, L. I. Kun, and X. U. Xusheng, "Synthesis and property of composite super absorbent polymer,"

Journal of Nanjing Forestry University (Natural Sciences Edition), vol. 41, pp. 114–120, 2017.

[35] B. Li, Z. Han, F. Zhang, and L. Song, "Study on preparation of water-retaining agent by mixing acrylic acid and bentonite and its water retaining effect," *Jiangsu Agricultural Sciences*, vol. 46, pp. 289–292, 2018.

[36] Y. Han, X. Zhang, H. Li, S. Wu, H. Wei, and Z. Wu, "Study on synthesis of super absorbent polymer with large particle size by inverse suspension polymerization," *Liaoning Chemical Industry*, vol. 49, pp. 936–939, 2020.

[37] W. Wu, "Study on Synthesis of Polyacrylamide Using Reverse Phase Emulsion Polymerization," *Advances in Fine Petrochemicals*, vol. 8, 2007.

[38] J. Shu, Q. Zhang, and D. Zhao, *In-Situ Polymerization of Montmorillonite (MMT)/Starch-Based Superabsorbent Polymer Composites by Microwave-Irradiation*, Science & Technology in Chemical Industry, 2017.

[39] B. Li, F. Zhang, Y. Li et al., "Retention effect of mineral superabsorbent composite on condensation water in arid areas in Xinjiang," *Arid Land Geography*, vol. 44, pp. 1135–1140, 2021.

[40] J. C. Wu, X. J. Guan, and Y. H. Yang, "Effects of ground cover and water-retaining agent on winter wheat growth and precipitation utilization," *Ying yong sheng tai xue bao = The journal of applied ecology*, vol. 22, no. 1, pp. 86–92, 2011.

[41] J. Liu, X. Luo, W. Fan, D. Huang, Y. Xin, and W. Zeng, "Effects of water retaining agent on the physical and chemical biological character of soil and the root tubers yield of cassava," *Chinese Agricultural ence Bulletin*, vol. 29, pp. 253–258, 2013.

[42] N. Singh, S. Agarwal, A. Jain, and S. Khan, "3-Dimensional cross linked hydrophilic polymeric network "hydrogels": An agriculture boom," *Agricultural Water Management*, vol. 253, p. 106939, 2021.

[43] M. Rizwan, S. R. Gilani, A. I. Durani, and S. Naseem, "Materials diversity of hydrogel: synthesis, polymerization process and soil conditioning properties in agricultural field," *Journal of Advanced Research*, vol. 33, pp. 15–40, 2021.

[44] L. Wang, "Effect of water status on nitrogen transformation and microbial properties of northeastern Mollisols," *Dalian Jiaotong University*, 2020.

[45] X. Li, J.-Z. He, J. M. Hughes, Y.-R. Liu, and Y.-M. Zheng, "Effects of super-absorbent polymers on a soil-wheat (_Triticum aestivum_ L.) system in the field," *Applied Soil Ecology*, vol. 73, pp. 58–63, 2014.

[46] H. X. Zhang, S. L. Zheng, W. C. Wei, B. C. Wang, O. M. Wang, and F. H. Liu, "Effects of water conditions on the diversity of soil microbial communities in the coastal reed wetlands," *Marine Sciences*, vol. 41, pp. 144–152, 2017.

[47] M. Chen, *Effect of soil moisture on microbial diversity in the rhizosphere of C.oleifera*, Central South University of Forestry and Technology, 2020.

[48] Y. Gao, Z. Huang, R. Zhang et al., "Effects of water stress during single growth period on soil enzyme activities and microbial communities in the rhizosphere of greenhouse grape," *Agricultural Research in the Arid Areas*, vol. 39, pp. 59–68, 2021.

[49] W. Liu, *Effect of polyaspartic acid water-retaining agent on soil microecology and isolation and identification of degrading bacteria*, Tarim University, 2021.

[50] Y. Wang, D. Jing, X. Fu et al., "Effects of application amount of super-absorbent polymer on soil physical characteristics and microbial activity under poplar seedlings," *Bulletin of Soil and Water Conservation*, vol. 37, pp. 53–58, 2017.

[51] L. I. Fangran, M. Zhao, H. Huo, Y. Zhao, and Z. Zhang, "Application research of polymer water-retaining agent on soil and water conservation," *Gansu Agricultural ence and Technology*, pp. 56–60, 2019.

[52] X. L. Dang, Y. L. Zhang, and Y. Huang, "Research status and prospect on application of water holding agents in agriculture," *Chinese Journal of Soil Science*, vol. 37, pp. 2352–2355, 2006.

[53] Z. Zhang and X. Qiao, "Mechanism of decreased water absorbency of crosslinking carboxymethyl cellulose by Mg and Fe cations," *Applied Chemical Industry*, vol. 49, pp. 844–849, 2020.

[54] L. Chang, L. Xu, Y. Liu, and D. Qiu, "Superabsorbent polymers used for agricultural water retention," *Polymer Testing*, vol. 94, p. 107021, 2021.

[55] F. Ai, X. Yin, R. Hu, H. Ma, and W. Liu, "Research into the super-absorbent polymers on agricultural water," *Agricultural Water Management*, vol. 245, p. 106513, 2021.

[56] G. Yan, W. Nie, H. Niu, K. Li, and J. Shang, "Study on water absorption and water retention performance and freezing resistance of seaweed biological water retention agent," *Modern Agricultural Sciences and Technology*, pp. 190–196, 2020.

[57] X. Chen, H. Song, Y. Xie, W. Lei, P. Zhong, and J. Wang, "Study on water absorption ratio of wood flour based super water absorbent resin," *Guangzhou Chemistry*, vol. 45, pp. 47–51, 2020.

[58] Y. Li, L. He, P. Hu, and Y. Xu, "Research on preparation and agricultural application of lignosulfonate-based super absorbent resin," *Plastics Science and Technology*, vol. 49, pp. 39–42, 2021.

[59] M. C. Piñero, M. Pérez-Jiménez, J. López-Marín, and F. M. del Amor, "Changes in the salinity tolerance of sweet pepper plants as affected by nitrogen form and high CO_2 concentration," *Journal of Plant Physiology*, vol. 200, pp. 18–27, 2016.

[60] X. Li, L. Zhang, H. Chang, Z. Zhang, and L. Chen, "Preparation and properties of cellulose-supported superabsorbent resin," *China Pulp and Paper*, vol. 40, pp. 1–12, 2021.

[61] H. Andry, T. Yamamoto, T. Irie, S. Moritani, M. Inoue, and H. Fujiyama, "Water retention, hydraulic conductivity of hydrophilic polymers in sandy soil as affected by temperature and water quality," *Journal of Hydrology*, vol. 373, no. 1-2, pp. 177–183, 2009.

[62] B. Xiong, R. D. Loss, D. Shields et al., "Polyacrylamide degradation and its implications in environmental systems," *Npj Clean Water*, vol. 1, no. 1, p. 17, 2018.

[63] C. Zhao, M. Zhang, Z. Liu, Y. Guo, and Q. Zhang, "Salt-tolerant superabsorbent polymer with high capacity of water-nutrient retention derived from Sulfamic acid-modified starch," *ACS Omega*, vol. 4, no. 3, pp. 5923–5930, 2019.

[64] C. D. V. Nascimento, R. W. Simmons, J. P. A. Feitosa, C. T. S. Dias, and M. C. G. Costa, "Potential of superabsorbent hydrogels to improve agriculture under abiotic stresses," *Journal of Arid Environments*, vol. 189, p. 104496, 2021.