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The Use of Polymers in Agricultural Irrigation Water Management

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ABSTRACT

With the increase in the world population and the effects of climate change, the demand for diminishing water resources is increasing day by day. Usable fresh water resources are decreasing. The biggest user of fresh water resources is the agricultural sector. Therefore, increasing the management efficiency of water used in agriculture has become a necessity. Our country is among the countries that suffer from water shortage due to its ecological and climatic conditions. It will be among the countries that will be affected by drought and global warming in the coming years. Water and water resources, which are the source of life for all living things, are decreasing and disappearing day by day all over the world and in our country, or are becoming polluted and unusable. In our country, 72% of our water resources are used in agriculture, 18% in domestic use and 10% in industry.

By preventing the loss of water we put into the soil in agricultural production, we can get more efficiency from production by getting maximum benefit from irrigation. For this purpose, we can use polymers and polymer compounds in agricultural production to ensure water conservation in the soil. These compounds gradually release the water they have retained into the growing medium. For this reason, they are effective in preserving water in the soil in hot and arid climates. In this study, the general properties of polymers, their benefits in soil water conservation, usage methods and doses will be explained. And also, some information about the benefits of water holding polymers will also be given in the arid and semi-arid agricultural regions.

Keywords: irrigation, polymer compounds, water management.

INTRODUCTION

With global climate change, the extension of dry periods and the imbalance in precipitation lead to productivity losses in agricultural production. Drought is actually a normal and recurring climate event. It occurs due to decreasing rainfall spread over one or more seasons. However, increasing temperatures and decreasing precipitation in many parts of the world as a result of global climate change increase the frequency and severity of drought events.

The effects of drought are often first seen in agriculture and gradually spread to other water-dependent sectors. The meaning of drought in the agricultural sector is different from other sectors. Because the water available in the plant root zone during growth periods is more important for plants than the total precipitation during the year.

In Turkiye, significant decreases are observed in winter and autumn precipitation. Hydrological, agricultural and socioeconomic droughts occur due to meteorological drought. Loss of agricultural products, insufficiency of surface and groundwater, and insufficiency of drinking water in big cities are important problems.

There are quite complex but vital relationships between water and soil. A significant part of this relationship actually takes place in the terrestrial parts of the hydrological cycle. From this perspective, water meets the soil for the first time with the rains. After that, some of the water leaks into the soil (infiltration) or flows into the surface flow, feeding groundwater, streams and lakes, and some of it is retained in the soil and meets the water needs of plants, agricultural products and other living things. During all these processes, rainfall water is also filtered through the soil and rocks and

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turns into clean water that we drink and use, which is of vital importance for humans.

The spaces in the soil are filled with water or air in certain proportions. The fact that these cavities in the soil are filled with water and its seasonal distribution is very important, especially for agricultural activities, because this is among the most important factors affecting what type of products to grow, when to plant them, and irrigation time and irrigation method. For this reason, different groupings of the water in the soil have been made in terms of both forestry and agriculture. For example; Water in the soil is classified into three groups as "excess water (saturation), saturation", "useful water (field capacity)" and "unuseful (withering point, unusable) water" depending on whether plants can benefit from it or not (Anonymous, 2016; TEMA, 2023).

Soil, which has a close relationship and interaction with the water cycle, also plays a role in providing valuable ecological services. Among these, food and water safety and balancing and filtering of water flows can be listed as the most important ones. In addition, the presence of water in the soil ensures that plant nutrients are used in dissolved form for the growth and development of plants. The presence of sufficient water in the soil also contributes to the soil being more protected and stable, especially against erosion. When viewed on a basin basis, it ensures the continuity of water by slowly feeding the streams in that basin through infiltration of water onto the soil surface and also helps prevent floods and floods. Finally, the movement of water into the lower layers of the soil (percolation) not only feeds groundwater but also can prevent surface waters (streams, lakes) from falling to ecologically critical levels, especially during dry seasons when rainfall decreases (FAO, 2009, 2015).

In this study, it was tried to explain the importance of using water-retaining polymers to ensure water conservation in the soil for a longer period of time in agriculture, especially in crop production, in case of changes in precipitation regimes under the influence of climate change and possible dry periods.

Water conservation in soil

Droughts, which have recently started to increase all over the world, reveal the need to use water more effectively (Figure 1). In Turkiye, as in the world, water is used mostly in the agricultural sector (73%) (KB, 2018; TB, 2024). Since the most water losses occur in agriculture, the most water savings should be made in irrigation. The basic condition in order to obtain the expected benefit from irrigation is to deliver the part of the water needed by the plant that cannot be met by rainfall to the root zone of the plant in the soil at the required time and in the required amount. Preserving soil moisture and keeping water in the plant root zone for longer periods of time make irrigation more effective. One of these applications is the mixing of some organic and inorganic materials with flocculating or adhesive properties into the soil. Adding various forms of organic matter and inorganic soil conditioners, especially to sandy soils with low aggregate stability and water retention capacity, increases the water retention capacity of the soil (Buckman and Brady, 1965). There are many organic and inorganic materials that can be used for this purpose. However, these materials used must be of a quality that will not disrupt the economic and ecological balance.

One of the known properties of water-retaining polymers, a chemical soil conditioner that has been included in many studies on its use in agriculture in recent years, is that it retains water 400-500 times its volume and remains in the soil for about 5-7 years (Buchholz 1998; Kemisol, 2011; Dahri et al., 2019). Studies have shown that the use of polymers especially in sandy soils increases soil water availability and water holding capacity of the soil (El-Rehim et al., 2004; Bhardwaj et al., 2007; Dorraji et al., 2010; Kashkuli and Zahrabi, 2013; Alkhasha et al., 2018).

Figure 1. Drought and cracking soils

What are water retaining polymers?

Water-retaining polymers are cross-linked copolymers of water-insoluble potassium acrylate and acrylamides and are anionic absorbent materials. These materials absorb 500 times their weight of water like a sponge and turn into a gel form. Thanks to their ability to release the water they hold into the environment little by little, they gain the feature of being an ideal product for plant production in areas with limited irrigation facilities and in agricultural areas in hot and arid climates. Polymers can maintain their water absorption and release efficiency for 4-5 years (Figure 2) (Ekebafe et al., 2011; Turkuaz, 2023).

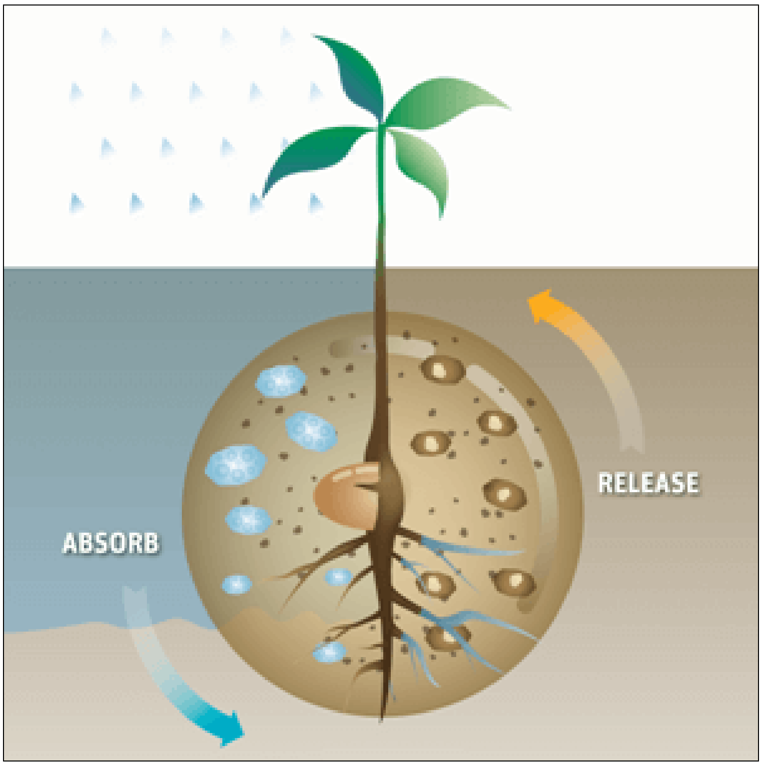

Figure 2. Mechanism of polymers working in plant roots

Polymer types and properties

Polymers are used as soil conditioners with adhesive properties that can aggregate soil grains to give better structure to the soil. Polymers and hydrogels play a role in reducing the amount of water consumption in agriculture, storing rain and irrigation water and gradually releasing it over long periods of time depending on the requirements of agricultural crops. They are compatible with different types of soils and have the effect of improving plant performance and yield.

Polymers are high molecular weight materials formed by chemical bonding of molecules. Nowadays, polymeric materials have a very common usage area. PVC, nylon and Teflon are the simplest examples of polymeric materials. All plastic and rubber materials are polymer based.

Cotton, cellulose, starch, protein, wool, silk, DNA, RNA, natural rubber can be given as examples of natural polymers. Artificial polymers are polymers such as polyethylene, artificial rubber, nylon, polyester, which soften and melt with heat, and these polymers are called thermoplastics (TSE, 2017).

Reduces soil crusting. Reduces the evaporation of water in the soil. Prevents pollution of groundwater and surface water. Reduces water consumption and prevents seeds from dying.

In order to increase the water holding capacity of the soil, organic additives such as sufficient burnt barnyard manure should be given to the soil. When the water holding capacity increases in sandy soils, significant increases in yield can be achieved since the plant roots will receive sufficient water in arid conditions. It is important that the polymers are used completely under the ground without exposure to the sun.

Acrylic Polymers:

Acrylic Polymers (Polymethylmethacrylate) are resins that are highly resistant to abrasion in air, do not lose colour easily, transmit light very well and have good heat properties. Acrylics are thermoplastic materials derived from acrylic and methacrylide acids and are used as adhesives for joining a wide variety of materials. Acrylic polymers are resistant to atmospheric conditions and are not affected by acid and salt water. They have high resistance against many chemical substances (Figure 3).

Since acrylic polymers can hold 600 times their volume of water, they keep the soil moist and reduce the crusting of the soil surface. They also prevent pollution of groundwater and surface water resources. It is an important material in agricultural applications due to its high water retention capacity. It also reduces sediment and nutrient losses from the soil by reducing erosion and helps to regulate salt concentration (Sharma, 2004; Narjary et al., 2012).

Figure 3. Appearance of acrylic polymers

Hydrogel Polymers:

Hydrogel is the name given to cross-linked polymers that can hold high amounts of water in their structure (Ahmed, 2015; Peppas and Hoffman, 2020). Due to its crosslink structure, it dissolves in water and aqueous solutions (Wang et al., 2020; Kemeç, 2023).

Because of their high water holding capacity, hydrojels support plant growth and vigour in soils of arid and semi-arid zones where water shortage is a major problem for agricultural production (Johnson and Piper, 1997; Lobo et al., 2006). Since hydrogels can hold up to 500 times their weight in water, they can double the water holding capacity of soils (Kazanskii and Dubrovskii, 1992; Esposito et al., 1996; Raju et al., 2003; Bhardwaj et al., 2007; Karimi et al., 2009).

It has been determined by studies that the water stress of plants can be reduced with the use of hydrogel polymer, the water holding capacity of the soil increases, and the time interval between irrigations can be extended (Zhouriaan-Mehr et al., 2010; Yakupoğlu et al., 2019). When used in the soil and in the lower layers of the plants, water and nutrient intake is provided at the desired times of the plant during the absorption and release periods due to the high amounts of water and nutrients (Figure 4).

Figure 4. Appearance of Hydrogel Polymers

Considering the physical and chemical properties of the polymer, the approximate amounts that can be used in natural agricultural applications are shown in Table 1, although they vary according to environmental conditions such as pH and temperature (Bairwa et al., 2020).

Table 1. Application rates of acrylic and hydrogel polymers

Types of Soil	Polymer quantities
Soil of arid and semi-arid regions	4-5 g/kg soil
Sandy soils	0.3-0.5 g/kg soil
Loamy soils	3-5 g/kg soil
Under the drought stress	0.3-0.6% of soil
Under the water stress	5% by weight

Method of use and doses of polymers

Polymer water traps can be easily used in arid and semi-arid agricultural areas for potted plants, vegetable and fruit cultivation, lawn, garden plants and fruit saplings.

Sampling farming: A hole about three times the size of the plant root system is dug and 20-30 grams of polymer is placed. It should be mixed evenly with the soil. The plant root is placed at the bottom of the pit and then filled with soil mixed with polymer. On top of the soil not mixed with polymer is placed 5 cm thick and the seedling pit is closed (Figure 5).

In normally developed trees, a 20 cm wide circular hole is dug from the crown projection to the depth of the root zone, the soil mixed with the base polymer is placed and the soil is filled with normal soil and irrigation is carried out (Figure 6).

Figure 5. Use of polymers in planting seedlings

Figure 6. Irrigation and use of polymers in planting seedlings

Grass cultivation: Polymer water retainers can be easily used in all development stages of grass. It provides a good germination, rapid root development and a uniform grass growth. After the soil to be sown is processed, polymers are spread on the soil surface and then approximately 10 cm of soil is laid on it.

Root dipping: It can be used in root dipping to prevent crumpling and water loss, especially during the transplantation or transport of the roots of seedlings and saplings to a longer distance. 1 kg of water-retaining polymer per 2 litres of water is sufficient to use 1 kg of water-retaining polymer. Keeping the plant roots in the prepared mixture for 15 minutes is sufficient for maximum tendency (Figure 7).

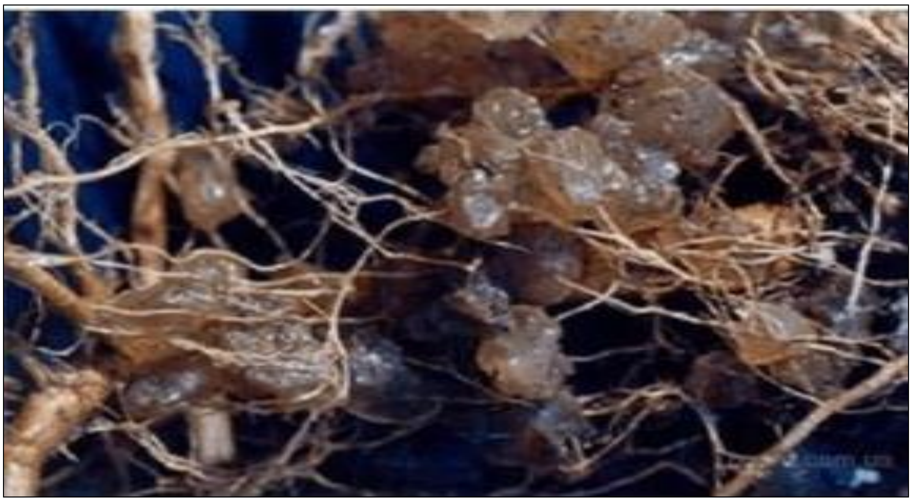

Figure 7. Appearance of hydrogel polymers in plant roots

Floriculture: Hydrogel polymers are used in floriculture to colour the water in glass containers and in containers where cut flowers are placed. 1kg hydrogel polymer is sufficient for 150 litres of water. It is also easily used in the transportation of cut flowers.

The use of water-retaining polymers in agricultural production and their benefits on soil water conservation

Water retaining polymers can be used to meet the water needs of potted plant cultivation, vegetable and field crops, garden plants and fruit saplings.

The pH, lime, mineral matter levels and water hardness of irrigation water affect the water retention performance of polymers. Polymers used in the root zone of the plant increase the utilisation of water and plants suffer less from water stress in dry times (Teyel and El-Hady, 1981; Helalia and Letey, 1989; El-Sayed and Kirkwood, 1992; Chen et al., 2004; Üğlü and Uysal, 2017). For this reason, these factors must be analyzed and determined before use. Water retaining polymers;

- It increases the water retention capacity of the soil and reduces the irrigation period by 50%.
- Prevents water loss caused by evaporation and percolation in the soil.
- Limits water and nutrient loss due to washing. It provides resistance to drought and water stress in the plant.
- It ensures that water and nutrients dissolve in the root area so that the plant can receive nutrients at optimum levels, and increases plant development.
- It improves the physical properties of tight impermeable soils by increasing the aeration capacity of the soil.
- Protects the environment against drought and pollution of groundwater.
- Provides economic benefit by reducing irrigation costs.
- It prevents the roots from drying out and keeps them moist during the transfer of saplings from the greenhouse to open areas and long distances.
- It provides durability against drought and water stress.
- It provides good, uniform and faster germination.
- Reduces evaporation from the soil.
- Reduces death of seedlings due to transport shock.
- Protects the environment against drought and groundwater pollution.
- Prevents the death of germinating seeds in late spring and early autumn frosts down to -60 degrees Celsius.
- It is highly effective in the fight against root pests, menatodes and fungi.

CONCLUSIONS

By using water-retaining polymers in agricultural production, maximum benefit from irrigation can be achieved by preventing the loss of water we put into the soil. This will result in greater efficiency from production.In arid climatic conditions and during the dry agricultural season, the use of water retaining polymers has an impact on water loss from the soil. Polymers can create optimum conditions for plant growth and have a positive effect on product quality and yield. Therefore, they can be widely used in hot and arid climatic conditions.

In the production of agricultural products where water consumption is mandatory, an effective and economical agricultural water use will be realised by saving the amount of irrigation water due to their properties.

Thanks to the use of hydrogel, the safety of the natural environment in agriculture is ensured, soil and water productivity is increased and land erosion can be prevented. At the same time, by improving the structure, permeability and aeration of the soil, drought is combated and crop productivity is increased.

Many researchers predict that the world's water demand is expected to increase by about 50 per cent by 2030, while clean water resources are not sufficient for this demand. For this reason, it will be an important solution to develop and use hydrogels that can hold high amounts of water, release almost all of the absorbed water and can be reused after drying, especially in agricultural activities. As a result, when the literature review is made, it should be taken into consideration that the use of hydrogel in agricultural applications for ‘agricultural sustainability’ and ‘sustainable green nature’ will become increasingly widespread.

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