Utilizing Hydrogel for Improving Irrigation Management

By

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Abstract

The major goal of the present day agriculture is to maximize land and water productivity without threatening the environment and the natural resources. Irrigation process is improved by using hydrogels. This research demonstrated the possibility of utilizing superabsorbent polymer obtained from baby diapers, to increase water retention in soil, for better management of water used in irrigation. After separation, recovery and cleaning of the recycled hydrogel, experimental parametric study was performed to investigate the swelling ability, and deswelling behavior and kinetics, and investigate parameters including the effects of temperature, saline solution, and pH on the recycled hydrogel performance. Red clay soil was mixed with different percentages of hydrogel in order to investigate water retention ability in soil improved with hydrogel from waste.

The recycled hydrogel had typical kinetic behavior, where it increased slowly with time, until it approached an equilibrium state after about 100 min. The equilibrium swelling capacity reached a maximum value of 235 g water/g hydrogel. The swelling capacity increased with temperature, while it decreased with increasing pH or salt concentration in saline solution. With samples of soil and hydrogel, the addition of the recycled hydrogel decreased the water loss by infiltration.

Hydrogel was used in an agricultural experiment through the preparation five of treatments of soil with different percentages of hydrogel, along with control. The behavior of tomato seedlings grown in different percentages of hydrogel and control length, number of leaves and girth as well as the amount of water losses by infiltration from each replicate in each treatment over 30 days. The ratio of 2%,3% of hydrogel was the best in all samples in terms of the efficiency of growth and the reduction of water quantities of irrigation and prevention of infiltration. The treatments 4% and 5% were less efficient growth, but it has able to resist the conditions of drought reached 21days, but they were able to resist dehydration due to contains hydrogel.

Keywords: Hydrogel, Irrigation, Swelling, Superabsorbent polymer, Agriculture.

Dedication

"Say: 'Allah will see your works and so will His Messenger and the believers; then you shall be returned to the Knower of the unseen and the visible، and He will inform you of what you were doing. '"[9.105]

Praise be to Allah in the beginning and in the end

To our true, source of hope, to the people who keep us going through struggles and hardships, our parents.

To our dearest friends, your big hearts and pure souls only match your encouragement and continuous support.

Thank you from the depths of our hearts.

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Chapter One

Research Concept

1.1 Introduction

Palestine is one of the countries that suffer from water decrease due to the shortage of water resources, which is complete control by the Israeli occupation authority, through a set of measures like confiscation of wells, prevent drilling of new wells and if licensed a new well, they limit its depth not lower than 140 m and, the pumping rates not more than 100 m^3/hr. In addition to these facts, the excessive consumption by the settlements of groundwater wells, as well as the increase in population by 3.5% [1] per year and the fluctuation of rainfall as a result of climate change, all are factors negatively affected the Palestinian water security and subsequently the economy, including the agricultural sector, which led to the decline of agricultural land and Lack of productivity[2].

The agricultural sector is one of the important economic sectors in Palestine. It provides employment for 11% of the total labor force in the West Bank and 10% in the Gaza Strip. The agricultural sector is the largest consumer of water extracted from underground wells, where about 90% of the extracted groundwater is consumed. The allocated water budget for the agricultural sector is relatively small compared to the irrigated area covered by this quantity of water which is 843 Km^2 in the West Bank and about 88 km2 in the Gaza Strip, and pumping water is estimated at 123.8 million cubic meters from groundwater wells used by the agricultural sector [3]. In view of the continuing shortage of water resources and the lack of the level of underground wells contributed significantly to the weak agricultural production and the relationship of many workers in this sector from work and direction and other professions where statistics shown the decline in the contribution of agriculture to GDP, contributing in 2015 by 3.8% compared to 4.5% the previous year [4].

In the past, the method of irrigation was based on direct casting on the plant, and this method is still common, but there are other methods more efficient and effective also used e.g. Drip and spray irrigations as well as Flood (furrow) irrigation. This system is called flood irrigation - water is pumped or brought into the fields and allowed to flow on the ground between crops. This method is simple and cheap [5].

The water used in irrigation is not fully absorbed by the plants but a fraction of it is consumed and the remaining amount part of evaporates and the other part infiltration .301 used in irrigation is great at the time. In which farmers are in dire need of this water in view of the scarcity of water and from here we began to think about how we can use water in the best way, and keep the water content of the soil as long as possible, is it possible to keep this water close to the roots zone of plants.

With this context, polymers play important role in agricultural uses as structural materials for creating climate beneficial to plant growth e.g. mulches, shelters or green houses, for fumigation and irrigation, in transporting and controlling water distribution [6]. The objective of this research is to study the performance of hydrogels in soil/agricultural application, will be explored and investigate in the factors that effect on types of polymer such as superabsorbent polymer.

1.2 Problem Statement

This research project will respond to the following main and sub main problems:

- **Main Problem**

Is it possible to reduce the amount of irrigation water by using hydrogel from solid waste that have ability to improve moisture content of the soil and enhance swelling characteristic.

- **Sub Problem**

1. Studying the retention time of water for hydrogel.
2. Studying the performance of the hydrogel in water and soil, and the mixtures.
3. Studying parameters that have effect on hydrogel performance such as superabsorbent polymer.
4. Studying the performance of plant in different percentages of hydrogel with control samples.

1.3 Goals and Objectives

The main goal is to contribute in reducing the amount of water used in irrigation through hydrogel.

The project targets the following specific objectives:

1. Increasing soil water-holding capacity.
2. Increasing water use efficiency.

3. Enhancing soil permeability and infiltration rates.
4. Reducing irrigation frequency.

1.4 Significance of Study

The importance of the study is to recovery the solid waste and used in the agricultural sector, and to improve the methods of water use in the irrigation process in an economically and environmentally efficient. The use of waste as a source, specifically diapers of children in agriculture so that they contain polymers that have the ability to hold water for long periods as well as the importance of time factor. Enhancing soil characteristics, and supplying roots with water without wasting water and reducing water runoff during irrigation.

1.5 Methodology

The project has two main stages. In the first stage, a review report was prepared based on description research approach, In the second stage, the research approach for this project is based on experimental methodology, for confirming and optimizing in irrigation and agricultural application.

- **The main activities are as follows:**

1. Literature review about hydrogels types and sources.
2. Identify potential waste that could be used as source of hydrogel.
3. Preliminary testing on hydrogel as superabsorbent polymer.
4. Investigating the efficiency of different type of hydrogels.
5. Applying different test for superabsorbent performance.
6. Various parameters were studied such as pH and temperature.

- **Research requirement (Materials and Equipment)**

1. Used dippers, fresh hydrogel, clay soil, distilled water.
2. Laboratory equipment (flasks, bottle, funnel, cup, pots, tomato seedling, etc.), thermometer.
3. Chemical materials ($CaCl_2$, NaCl, HCl, and NaOH).

1.6 Budget

The estimated total cost for this project is 2400 NIS as listed in Table1.1.

Table 1.1: Budget of this project.

No.	Item	Cost (NIS)
1	Hydrogels	800
2	Materials	100
3	Furnace	400
4	Lab tools	500
5	Distilled &Tap water	400
7	Other indirect cost	200
Total cost		2400

1.7 Action Plan

The action plan during the first semester as shown in Table 1.2, and the action plan for the next semester is shown in Table 1.3.

Table1.2: Action plan for the first semester (2017).

Task	1st Month				2nd Month				3rd Month				4th Month			
	W 1	W 2	W 3	W 4	W 1	W 2	W 3	W 4	W 1	W 2	W 3	W 4	W 1	W 2	W 3	W 4
Identification of Project Idea																
Literature Review																
Preliminary Testing of Hydrogel																
Writing Proposal																
Social aspect دراسة الناحية الشرعية																
Preliminary Result Analysis																
Documentation																
Presentation																

Table 1.3: Action plan for the second semester (2018).

Task	1^{st} Month				2^{nd} Month				3^{rd} Month				4^{th} Month			
	W 1	W 2	W 3	W 4	W 1	W 2	W 3	W 4	W 1	W 2	W 3	W 4	W 1	W 2	W 3	W 4
Sourcing & purchasing commercial hydrogel																
Preparation of soil samples with different percentage of hydrogel (1-5)%																
Cultivation of samples of tomato seedlings																
Data analysis																
Documentation																
Final Presentation																

Chapter Two

Literature Review

2.1 Introduction

The main emphasis of agricultural development all over the world was the increasing productivity for crop production to feed the ever-increasing population. This was substantially accomplished through over exploitation of natural resources such as water and plant resources and excessive use of fertilizers and pesticides. Although this practice resulted in considerable increase in crop yields in the short-tem, it was not sustainable in the long run. The productive capacity of the arable land was impaired, the natural water resources were depleted and also polluted with hazardous pesticides and chemical fertilizers which threatened the survival and well-being of all life forms on earth [7]. Therefore, the emphasis on agricultural development in the present century has shifted to the sustainable use of land, water and plant resources in agriculture [8]. The major goal of the present day agriculture is to maximize land and water productivity without threatening the environment and the natural resources (Sustainable Development) [9].

Drought stress is one of the major limiting factors that affect crop growth and productivity, also in several key production environmental (soil and ground water) is becoming depleted through compaction, salinization, erosion, net nutrient export and diminishing water supply, and is expected to result in long- term trend towards higher temperatures, greater evapo-transpiration [10]. Hydrophilic polymers may have greater potential in restoration and reclamation project where opportunity for post planting irrigation is limited and thus storing water available for plant establishment and to avoid desiccation is critical. Polymers are classified into 3 groups, starch-polyacrylonitrile graft polymers (starch copolymers), vinyl alcohol-acrylic acid co-polymers and, acrylamide sodium acrylate co-polymers. All of these hydrogels when used correctly and ideal situations will have at least 95% of their stored water available for plant absorption[7].

2.2 Methodology – Literature Review

The methodology of this study is based on the description research approach. The required references were obtained from scientific databases available. The search was made using subject keyword including’’ hydrogels ‘‘,’’ soil moisturizing ‘‘,’’ super absorbent polymer ‘‘,’’ irrigation ‘‘ , ’’ swelling‘‘ .The increased research interest in these aspects was analysed based on number of scientific papers published appeared in recent years.

The selected papers were screened and classified into groups. The classification was based on the soil-moisturizing, source and type of hydrogel. The obtained results are shown in tables these tables were structured around the experimental methods that have been used by the researchers in order to investigate the efficiency of soil moisturizing. The various experimental parameters, methodology and test, and main result are listed in these tables. Based information, the hydrogel type, composition, and application were analysed to achieve long retention time to soil.

2.3 Experimental Research Approach

Papers in this field focused on the hydrogel performance, application and, on analysing the characteristics of hydrogel, through a unified research approach. The experimental approach for investigating technical feasibility of the various potential hydrogel was mainly based on mixing with soil [6], then observing the plant growth. The performance of these hydrogel was absorbing large amounts of water and increasing soil water-holding capacity, increasing water use efficiency, enhancing soil permeability and infiltration rates, reducing irrigation frequency, stopping erosion and water run-off, in behaviour without hydrogel [11], longs time for plant growth, increase water infiltration and, decreasing water retention.

2.4 Result from Literature

The obtained review results are summarized in tables 2.1, 2.2 ,2.3, the first group of papers are listed and summarized in group is shown in Table 2.1. It summarizes application of different types of hydrogels. Table 2.2 include types of hydrogel, chemical formula, composition, application, and etc. The third group is shown in Table 2.3 which reviews parameters that have effects on hydrogel and results.

2.5 Classification of Hydrogels

Hydrogels are broadly classified into two categories:

1. Permanent or chemical gel: they are called 'permanent' or 'chemical' gels when they are covalently cross-linked (replacing hydrogen bond by a stronger and stable covalent bonds) networks. They attain an equilibrium swelling state which depends on the polymer-water interaction parameter and the crosslink density.
2. Reversible or physical gel: they are called 'reversible' or 'physical' gels when the networks are held together by molecular entanglements, and / or secondary forces including ionic, hydrogen bonding or hydrophobic interactions. In physically cross-linked gels, dissolution is prevented by physical interactions, which exist between different polymer chains. All of these interactions are reversible, and can be disrupted by changes in physical conditions or application of stress[12].

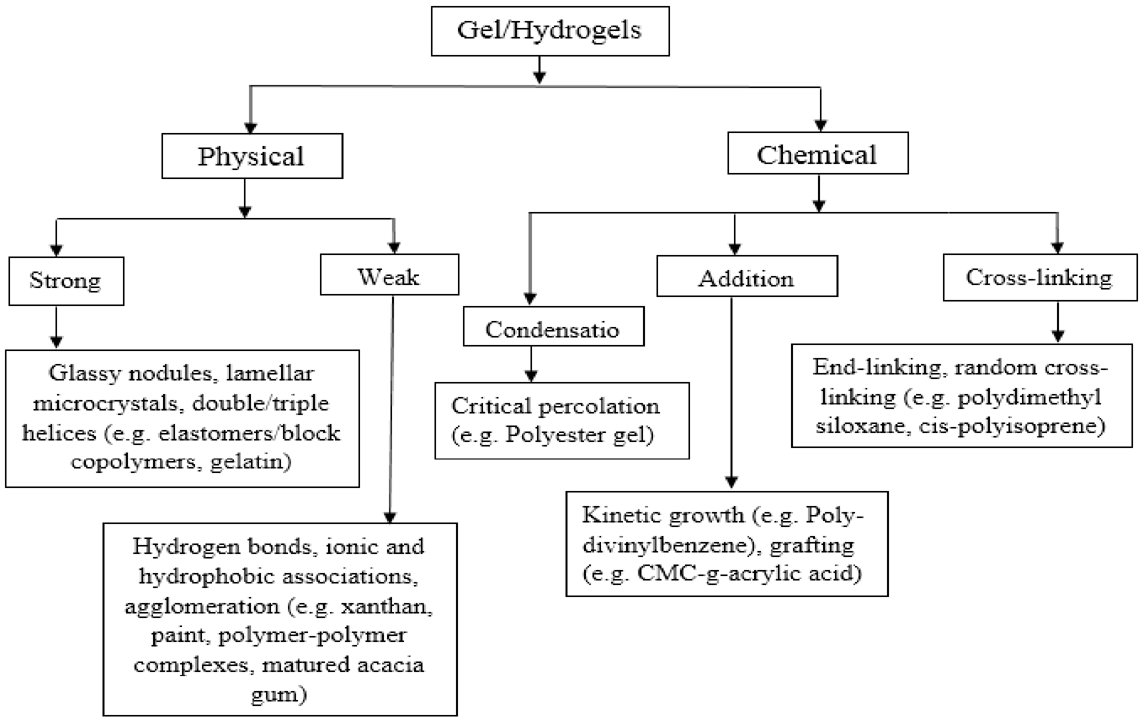

Figure 2.1: Classification of Hydrogels[12].

2.6 Characteristic of Hydrogel

The water holding capacity and permeability are the most important characteristic features of a hydrogel. The polar hydrophilic groups are the first to be hydrated upon contact with water which leads to the formation of primary water bound. As a result, the network swells and exposes the hydrophobic groups, which are also capable of interacting with the water molecules. This leads to the formation of hydrophobically-bound water, also called 'secondary bound water'. Primary and secondary bound water are often combined and called 'total bound water'. The network will absorb additional water, due to the osmotic driving force of the network chains towards infinite dilution. This additional swelling is opposed by the covalent or physical cross-links, leading to an elastic network retraction force. Thus, the hydrogel will reach an equilibrium swelling level. The additional absorbed water is called 'free water' or 'bulk water', and assumed to fill the space between the network chains, and/or the centre of larger pores, macrospores, or voids. Depending on the nature and composition of the hydrogel the next step is the disintegration and/or dissolution if the network chain or cross-links are degradable. Biodegradable hydrogels, containing labile bonds, are therefore advantageous in applications such as tissue engineering, wound healing and drug delivery. These bonds can be present either in the polymer backbone or in the cross-links used to prepare the hydrogel [12].

2.7 Factors Effecting on Hydrogels

Hydrogels can also be stimuli sensitive and respond to surrounding environment like temperature, pH [13]. These are similar to conventional hydrogels except these gels may exhibit significant volume changes in response to small changes in pH, temperature, and light. Temperature sensitive hydrogels are also called as thermo gels These stimuli-sensitive hydrogels can display changes in their swelling behaviour of the network structure according to the external environments. They may exhibit positive thermo-sensitivity of swelling, in which polymers with upper critical solution temperature shrink by cooling of the examples of stimuli sensitive hydrogels are poly (vinyl methyl ether) and poly(N-isopropyl acrylamide) gels [12].

2.8 Application of hydrogel

Hydrogel of many synthetic and natural polymers have been produced with their end use mainly in tissue engineering, pharmaceutical, and biomedical fields Due to their high water absorption capacity and biocompatibility they have been used in wound dressing, drug delivery, agriculture, sanitary pads as well as trans-dermal systems, dental materials, implants, injectable polymeric systems, ophthalmic applications hybrid-type organs. A list of hydrogels with their proposed corresponding applications is shown in Table 2.1.

Table 2.1: Applications of hydrogels.

Application	Polymers	References
Agriculture	Slow Release Fertilizer Hydrogel (SRFH).	[14]
	Pusa Hydrogel.	[15]
	Cross-linked Polyacrylamide Hydrogels (XPAM).	[16]
	Superabsorbent Polymers (SAPs)	[17]
Wound care	Polyurethane,(polyethylene glycol), (polypropylene glycol),	[18]
	(Polyvinyl pyrrolidone), polyethylene glycol and agar	[12]
	Carboxymethyl cellulose, alginate, hyaluronan and other hydrocolloids	[12]
Drug delivery, pharmaceutical	Starch, (polyvinyl pyrrolid one), poly(acrylic acid)	[12]
	Carboxymethyl cellulose, hydroxypropyl methyl cellulose	[12]
	κ-carrageenan, acrylic acid, 2-acrylamido-2-methylpropanesulfonic acid	[7]
Tissue engineering, implants	(Polyvinyl alcohol), poly(acrylic acid)	[19]
	Collagen	[20]
	Hyaluronan	[12]
Technical products (cosmetic, pharmaceutical)	Xanthan, pectin, carrageenan, gellan, welan, guar gum, locust bean gum, alginate, starch, heparin, chitin and chitosan	[20]
Waste treatment, Separation	Starch	[12]
	(Poly vinyl methyl ether), (poly N-isopropyl acrylamide)	[20]

2.9 Agricultural Application with Different Type of Hydrogels

In agricultural applications more than one type of generation was used, some of which were commercial, others were manufactured. Table 2.2 summarizes different type and composition of hydrogels was prepared and used in agricultural application.

Table2.2: Type of hydrogels utilized for agricultural applications.

<table>
<tr><th>Type of Hydrogel</th><th>Chemical Formula</th><th>Composition</th><th>Application</th><th>Type of soil</th><th>Water\ air affinity</th><th colspan="2">Parameters was Study</th><th>Result</th><th>Reference /Year</th></tr>
<tr><td>Cellulose Hydrogel</td><td>–</td><td>-Acrylic acid (AA).
-N,N-methylenebisacrylamide (MBA).
-potassium persulfate (KPS).</td><td>Use for optimizing water resources in agriculture.</td><td>Sandy soil</td><td>Hydrophilic</td><td colspan="2">-Swelling Ratio.</td><td>Swelling ratio was more than 30g water/g hydrogel</td><td>2015 [21]</td></tr>
<tr><td rowspan="2">Superabsorbent Polymers</td><td rowspan="2">SAP</td><td rowspan="2">-Carboxymethyl cellulose.
- Acrylic acid.
- Potassium hydroxide.
- methanol.
- acetone.</td><td rowspan="2">In Agriculture by Using Gamma Radiation</td><td rowspan="2">Sandy Soil</td><td rowspan="2">Hydrophilic</td><td>On Hydrogel</td><td>- Gel Fraction.
- Water Retention.
- Biodegradability.</td><td>- 25 kGy radiation dose.
- 83% for (0.3%SAP) for 13day.
- SAP is biodegradable</td><td rowspan="2">2015 [17]</td></tr>
<tr><td>Mixture of soil and hydrogel</td><td>- Germination percentage (%).</td><td>92% (for (0.3%) SAPs).</td></tr>
</table>

Slow Release Fertilizer Hydrogel (SRFH)	PAA	- Acrylic acid (AA). -Sodium hydroxide (NaOH). - Urea fertilizer. - Ammonium Persulphate (APS). - N'N-Methylenebisacrylamide (NMBA).	Improve water retention of soil and water managing materials for degraded land.	Clay soil	Hydrophilic	Hydrogel	-Swelling Rate.	35 g water /g hydrogel for 300 min.	2016 [14]
						Mixture of soil and hydrogel	-Water Evaporation %. -Plant Growth Performance (for 7 week).	-lost 56.62% of 30th days. -Average Plant Height (cm)= 14.2 Average Leaf Width (cm)= 5.1	
	PAAm	- Acrylamide (AAm). -Sodium hydroxide (NaOH). - Urea fertilizer. - Ammonium Persulphate (APS). - N'N-Methylenebisacrylamide (NMBA)				Hydrogel	-Swelling Rate.	15g water/g hydrogel for 300 min.	
						Mixture of soil and hydrogel	-Water Evaporation %. -Plant Growth Performance (for 7 week).	-lost 44.06% on the 30th days. - Average Plant Height (cm)= 9.4 Average Leaf Width (cm)= 3.8	

	P(AA-co-AAm(	- Acrylamide (AAm). - Acrylic acid (AA). -Sodium hydroxide (NaOH). - Urea fertilizer. - Ammonium Persulphate (APS). - N’N-Methylenebisacrylamide (NMBA).				Hydrogel	-Swelling Rate.	24g water/g hydrogel at 300 min.	
						Mixture of soil and hydrogel	-Water Evaporation %. -Plant Growth Performance(for 7 week).	-loss 51.30% on 30th days. -Average Plant Height (cm)=11.4 Average Leaf Width (cm)=4.0	

2.10 Agricultural Area with Superabsorbent polymer

The use of polymer in agriculture provided solutions to current problems, which is to maximize land and water productivity without threatening the environment and the natural resources. Superabsorbent polymer hydrogels potentially influence soil permeability, density, structure, texture, evaporation and infiltration rates of water through the soils, and indirectly used to protect the environment by reducing pollution and clean-up existing pollutants [6].

2.11 Superabsorbent Polymer

Super-absorbent polymers (SAP, Hydrogel, Polymers) a new water-saving materials and soil conditioners, have been widely adopted in agriculture in the advanced countries of the world. SAP materials are hydrophilic networks that can absorb and retain huge amounts of water [22]. Research evidences suggest that when the soil is treated with SAP, the water volumetric content of the soil increases significantly and as the soil dries, the stored water is released back slowly into soil. Further, fertigation is also possible by the application of SAP to the soil as the same is capable of absorbing the fertilizer and releasing the same with water. Soil moisture can be increased by 6.2–32.8% with SAP application Relative water content, water use efficiency and irrigation intervals also can be increased by application of super absorbent polymer [13]. SAP has a significant effect on plant height and percentage of soil moisture after being harvested [11]. When the SAP is mixed with the soil it can increase grain yield [23]. Water evaporation rate is decreased after the addition of SAP in the soil, it works like a sub-miniature reservoir to retain and supply moisture to crops over time as the soil under-went alternate wetting and drying periods. Repeated water absorbencies in tap water, mixture of distilled water and soil, and mixture of tap water and soil were reduced by 73.4–99.3% relative to those in distilled water. Moreover, water quality had a greater effect on water absorbency from soil. Water absorbency increased with SAP's concentration, and such increase was reduced with repeated utilization. Super-absorbent polymers have the potential to remove water from porous media (soil structure) [24]. After SAPs were mixed in the soil, their capacity of absorbing and desorbing water showed a downward trend with time and outside water condition.

2.11.1 Mechanisms of Swelling in Superabsorbent Polymers

It is necessary to understand the reasons why they swell. There are several mechanisms to the process of swelling, all of which contribute to the final swelling capacity.

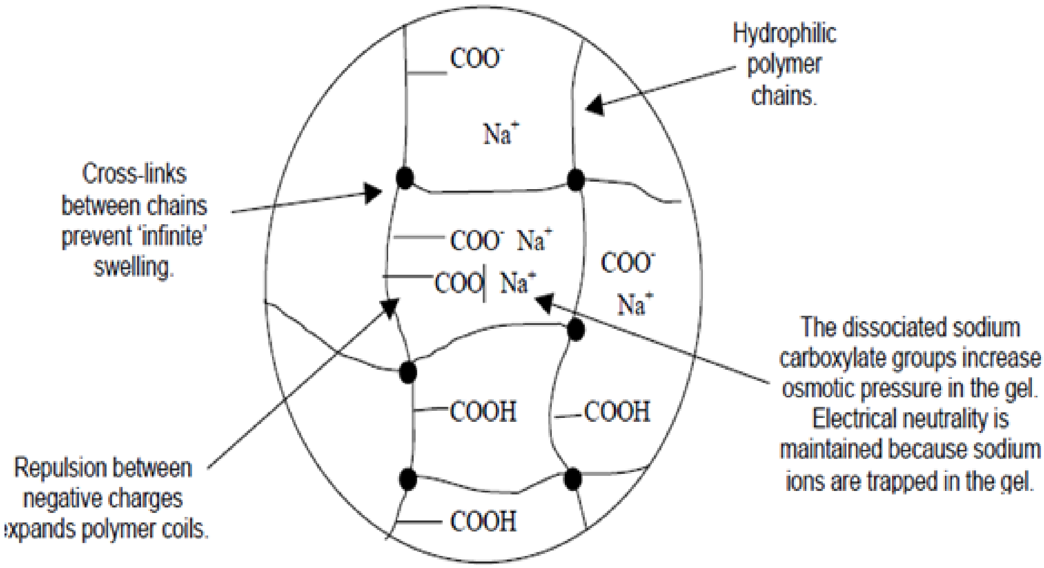

Figure 2.2: Diagram representation of part of the polymer network. The polymer backbone in SAP is hydrophilic i.e. 'water loving' because it contains water loving carboxylic acid groups (–COOH). When water is added to SAP there is a polymer/solvent interaction; hydration and the formation of hydrogen bonds are two of these interactions. [25]

- **Hydration**

This is the interaction of ions of a solute with molecules of a solvent i.e. COO^- and Na^+ ions attract the polar water molecules as shown in Figure 2.2 and Figure 2.3.

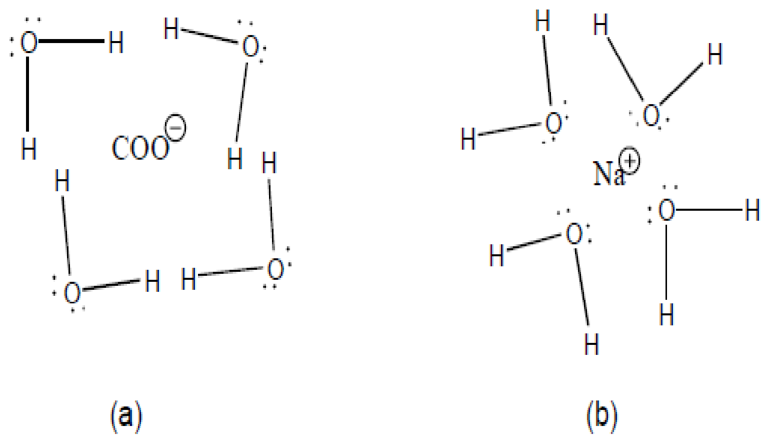

Figure 2.3: Ions interact with molecules of solvent e.g. coo$^-$ and Na$^+$ [25].

➢ Hydrogen Bonds

Hydrogen bonds are electrostatic interactions between molecules, occurring in molecules that have hydrogen atoms attached to small electronegative atoms such as N, F and O. The hydrogen atoms are attracted to the non-bonding electron pairs (lone pairs) on other neighboring electronegative atoms as shown in Figure 2.3.

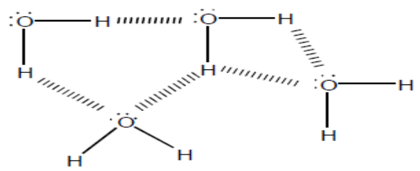

Figure 2.4 : Hydrogen bonds in superabsorbent polymer [25].

2.11.2 The Most Important Variable that Effect on Properties of Superabsorbent Polymer (SAP)

1. Cross-linker type and concentration.
2. Monomers type and concentration.
3. Type, size, and amount of inorganic particles incorporated.
4. Polymerization method.
5. Polymerization temperature.
6. Amount and type of the surfactant used.
7. Porosity generating method or the amount and type of the porogen.

8. Drying; its method, temperature, and time.

Each of the previous variables has an effect on the SAP, so should be taken into consideration [22].

2.11.3 Superabsorbent Polymers are Categorized to Four Groups on the Basis of Electrical Charge located in the Crosslinked Chains

1. Non-ionic.
2. Ionic (including anionic and cationic).
3. Amphoteric electrolyte (ampholytic) containing both acidic and basic groups.
4. Zwitterionic (polybetaines) containing both anionic and cationic groups in each structural repeating unit.

2.12 Super absorbent polymer from waste

Most agricultural applications were used superabsorbent polymer. Table 2.3 Summarize the various parameters that has effect on superabsorbent polymer from waste and experiments as well as equations used to obtain results.

2.13 Social aspect

The social aspect of this research was studied, and was set many questions then sent to a world specialized in Shari'a and prayer. The details are attached in a file at the end of this research as shown in Appendix.

Table 2.3: Parameters that has effect on super absorbent polymer [26].

Test	Material	Quantity		Equation	Conditions		Results
Swelling Ratio	-Dried hydrogel. -Distilled water. -Tea bag.	0.1 g 100 ml 1bag		$Q = \frac{W_s - W_d}{W_d}$ Q: Swelling Ratio. W_s: Swollen hydrogel. W_d: Dry Hydrogel.	Temperature	At room temperature (20 °C±2)	189 g water/g hydrogel.
					Time period	30 min	
Salt Solution Absorbency	-Salts (NaCl, $Ca(NO_3)_2$, CaCl2). -Dried hydrogel. -Distilled water. -Tea bag.	Concentrations Of salt solutions	0-2.5 wt%	$Q = \frac{W_s - W_d}{W_d}$	Temperature	At room temperature (20 °C±2)	When salt concentration increased the swelling capacity decreased
Effect of pH on Swelling Ratios	-Different pH solutions. -Dried hydrogel. -Distilled water. -Tea bag.	pH ranging from 2 to 12		$Q = \frac{W_s - W_d}{W_d}$	Temperature	At room temperature (20 °C±2)	Maximum swelling at pH=10 Minimum swelling at pH= 2
Effect of Temperature on Swelling Ratio of Used Hydrogel	-Dried hydrogel. -Distilled water. -Tea bag.	0.1 g 100 ml 3 bag		$Q = \frac{W_s - W_d}{W_d}$	Temperature	T=25°C T=35°C T=50°C	When the temperature increased the swelling capacity increased

Water Retention Capacity in Soil with Used SAP	-Sandy soil. -Dried hydrogel. - Distilled water.	50 g soil. Used SAP (0.5-2 wt%). 25mL water	$WR\% = \frac{Wo-Wt}{Wt} * 100\%$ WR: Water Retention Capacity. W_o: Initial mixture weight. W_t: Mixture weight at a certain time.	Temperature	At room temperature (20 °C±2)	When adding of hydrogels into soil could obviously improve the water-retention capacity of soil and lessen the amount of water evaporation.
				Time period	12 days	
				Irrigation	uniformly irrigated with 25 mL of distilled water	

Chapter Three

Methodology

3.1 Experimental Work

This research based on experimental work. It started from analysis of hydrogel behavior from waste dippers. These include studying performance of hydrogel with different value of pH, temperature as well as different concentration of salts. Salt solutions are prepared with different concentrations. The pH value analyzed by pH Meter, temperature analyzed by Thermometer. Then soil samples were collected from the university garden, at about 15 cm depth, for further laboratory analysis, including some physical and chemical soil properties likewise (soil organic matter, water content, pH and electrical conductivity (EC)), and study the hydrogel behavior in soil.

3.2 Materials and Equipment

Samples of superabsorbent polymer were extracted from used diapers (Predo Baby Zilan Company/ Turkey). Materials included unused tea bags, distilled water, salts ($CaCl_2$ and NaCl), sulfuric acid (H_2SO_4) and sodium hydroxide (NaOH), and washed clay soil, balance and oven.

A set of materials and equipment were used to study the hydrogel behavior in soil, irrigated with tap water, and planted with tomato seedlings in garden pots. A laboratory glassware including cylinder, weighing balance, caliber, ruler, dishes, and soil Thermometer, Anemometer were also used to register the needed records/variable for this experiment.

3.3 Methods

3.3.1 Investigation of Utilizing Hydrogel from Waste Diapers for Improving Irrigation efficiency

Samples of waste diapers containing only urine were used. The superabsorbent polymer was manually separated from the diaper. They were washed with sufficient water and kept under stirring for two minutes. Then water was removed by filtration on a filter paper. The washing process was repeated twice. Then, the polymer was sterilized to eliminate pathogens, and volatile pollutants. Sterilization was made by placing the sample of superabsorbent polymer in an oven at 125 °C for 15 minutes. Then, it was kept at 60°C for 24 hours, for drying. Red soil clay particles, were washed with sufficient amount of water, to remove the impurities. Then, they were dried in the oven at 60° C for two days.

For swelling and de-swelling kinetic experiments, a known mass 0.1g of recycled polymer samples were used. It was placed in a tea bag and then immersed in 100 ml distilled water in beaker at laboratory temperature 21°C. The bag was then taken out from the beaker, and weighed. Then, the sample was retained to the beaker again. This process was repeated at regular time intervals for kinetic study. The swelling ratio was calculated according to the mass balance equation [14]:

$$\text{Swelling Ratio} = \frac{W_s - W_d}{W_d} \qquad (1)$$

Where W_d is the weight of the dry hydrogel, and Ws is the weight of hydrogel after swelling, at certain time.

In de-swelling kinetic experiments, saturated hydrogel (after equilibrium swelling was achieved) was placed in a dish, at the laboratory conditions. Then it was weighed daily.

The effect of pH on hydrogel swelling ratio was studied by preparing various solutions with pH values of (4,6,10 and 12), through adding the required amounts of acid or alkaline solutions. These solutions replaced water in swelling experiments. The equilibrium swelling ratio was measured after 100 minutes. The effect of salt content on hydrogel swelling ratio was investigated**.** Various solutions of $CaCl_2$, and NaCl (1,2,3,4,5 and 6 wt% contents) were prepared and used in similar experiments as in pH experiment. These tests were run at 17°C.

The effect of temperature on hydrogel was studied by using 0.1g of recycled hydrogel, it was placed in tea bag, and immersed in 100 ml distilled water in an occubater at temperature (17,65) ±2°C, for the required time. The bag was then taken out from the occubater, and weighed. Then, the sample was retained to the occubater again. This process was repeated at regular time intervals for kinetic study. The swelling ratio was calculated according to the mass balance equation (1).

The water retention capacity of gel modified soil was measured by using clay soil, recycled hydrogel in three levels, 4%, 8%, were mixed with washed clay soils. The kinetic behavior was measured over a long period of time: the required samples with various hydrogel contents (in addition to control sample) were prepared with a total mass of 25g. Each sample was placed in a dish, and irrigated by spraying 12ml of distilled water to the top surface, for one time and then weighed. The samples were placed at laboratory conditions (the temperatures were between 16-20°C) and weighed every day for two weeks. Water Retention was calculated according to the following mass balance equation [26]:

$$\text{WR} = \frac{W_o - W_t}{W_t} * 100\% \qquad (2)$$

Where WR water retention capacity W_t mixture weight at a certain time, and W_o initial mixture weight.

Lentils were grown in various samples of hydrogel modified red clay soil containing various ratios of hydrogel (1 and 5wt%) and control (without hydrogel). The effect of hydrogel ratio on plant growth was different. When increase percentage of hydrogel, the increase ability of soil to retain the water and reduce infiltration. but, the best growth rates for plants were obtained at percentage of hydrogel of 1-3%, which provided suitable moisture for the plant as well as suitable ventilation. As for the soil was dry clay, dried at 60°C for two days by using oven.

3.3.2 Application of Hydrogel (Superabsorbent Polymer) in Agricultural

A. Daily Records/Measurements

- The air temperature was checked twice a day at precised time, using Anemometer, and the soil temperature was checked at the same time, using specialized soil Thermometer.
- The seedlings leaf numbers, the girth of seedlings were recorded using Caliber, and the seedlings height from the soil top of the pots were recorded using measuring tape, twice a week.
- After each irrigation installment, the leaked water from each pots in the below/under pot tray was measured using volumetric cylinder and recorded.
- Experiment Design and layout.

A twenty soil samples along with hydrogel were placed in twenty garden pots as shown in table 4.1 , and laid out in five treatments with different hydrogel contents (1, 2, 3, 4 and 5% wt/wt) of the total soil mass placed in the experimental pots. The control pots have 500 gram of soil with no hydrogel. Each treatment has three replicates and one pot as control as shown below in Table 4.1. The completely randomized block, design used in this experiment.

Table 3.1: Experiment Design and layout of pots.

Treatment 1 1%	Treatment 2 2%	Treatment 3 3%	Treatment 4 4%	Treatment 5 5%
 1	 control	 1	 1	 1
 2	 1	 control	 2	 control
 control	 2	 2	 3	 2
 3	 3	 3	 control	 3

B. Planting Tomato seedlings

Ready seedlings of irrigated tomato variety, without any pest and disease problems were obtained from the local market. The seedlings were homogenous in term of the height, the seedlings girth and number of leaves. The Seedlings were transplanted into pots.

Chapter Four

Results and Discussion

4.1 Investigation of Utilizing Hydrogel from Waste Diapers for Improving Irrigation efficiency

4.1.1 Swelling and De-Swelling Kinetics

Figure 3.1 presents the swelling kinetics of recycled hydrogel. It plots swelling ratio as grams of distilled water absorbed per gram of hydrogel versus time. Obviously, rapid water absorption kinetics was observed at initial times to reached 20 min, then it slowed down until reaching the maximum swelling ratio of 235g/g at 90 min, after that the amount of water decreased until it was reached equilibrium at 233g/g. After approximately 100 min as shown in Figure 3.1. This large equilibrium swelling ratio reflects the fact that hydrogel possesses many hydrophilic groups, appropriate crosslinking degree and convenient three-dimensional network structure which generates osmotic pressure, as reported in literature [4].

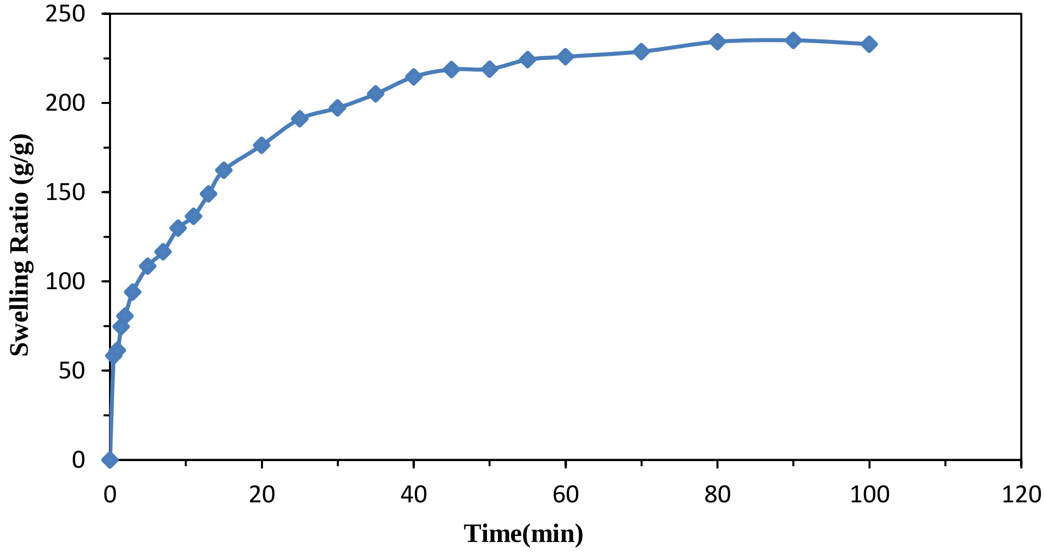

Figure 4.1: Swelling kinetics of recycled hydrogel, as a plot of swelling ratio (g distilled water absorbed/g hydrogel) versus time.

Similar kinetic behavior was reported in literature for hydrogel from waste diapers. The reported time to approach equilibrium was 30 min and was absorbed 189 g/g at this time [26], but in this study recycled hydrogel was absorbed 197 g distilled water at 30 min, then it was continued to absorb water and grow more until reached equilibrium state at 100 min, and absorbed 233 g/g at this time. In literature review hydrogel was reached equilibrium at 30 minutes. However, a lower equilibrium swelling ratio of the used hydrogel (189g/g) was reported. Nearly, 25% increase in equilibrium swelling ratio is obtained in our recycled hydrogel.

Figure 3.2 shows the de-swelling kinetics of the recycled superabsorbent polymer, as a plot of swelling ratio (g water/g hydrogel) versus time. The experiment was made on the recycled hydrogel after it had reach equilibrium. Initially on the first day in saturation zone, the hydrogel was saturated with water, where the loss of water from hydrogel was little, then it begins to lose water significantly in translation zone until reached to the stage that the amount of water remaining very little amount of water in hydrogel. This stage isknown as residual zone.

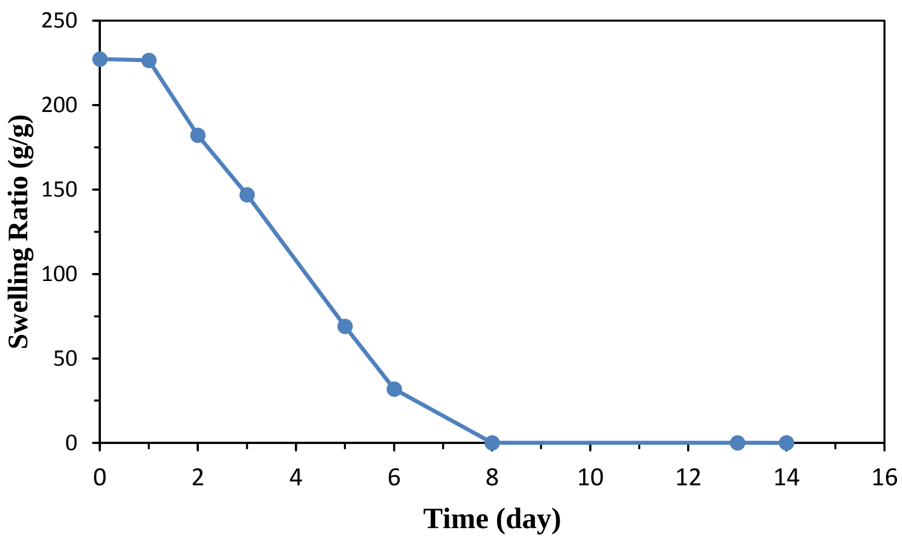

Figure 4.2: De-swelling kinetics of recycled hydrogel, as a plot of swelling ratio (g water/g hydrogel) versus time (after removing the hydrogel from distilled water).

Obviously, our recycled hydrogel has a high capacity to absorb and retain water, and thus suitable to be used for agricultural applications. It has a technical feasibility of increasing water hold capacity of soil. These results indicate that hydrogel has a reversible behavior: it releases its water to soil, when irrigation is stopped. When farming with hydrogel, hydrogel will enhance soil permeability, and stopping erosion runoff.

4.1.2 Effect of Salt Content on the Equilibrium Swelling Ratio of the Recycled Hydrogel

Figure 3.3 shows the effect of salt concentration on swelling ratio for two types of salts: NaCl and $CaCl_2$. The swelling ratio of NaCl solution larger than $CaCl_2$ solution as shown in figure 3.3. The swelling ratio would be lower at higher ion concentrations and decreased because of decreasing ion concentration difference between the concentration of dissociated ions inside the hydrogels and ion concentration in the solution [26]. It is attributed to a screening effect of the additional cations causing a non-efficient anion–anion electrostatic repulsion. This is also associated with a decrease in the osmotic pressure difference between the superabsorbent polymer network and the external solution resulting from the difference in the mobile ion concentration between the gel and aqueous phases decrease and, consequently, the absorbency amounts are diminished. These findings are in agreement with previous studies [28], the decrease in swelling is strongly dependent on the type and concentration of salt added to the swelling medium.

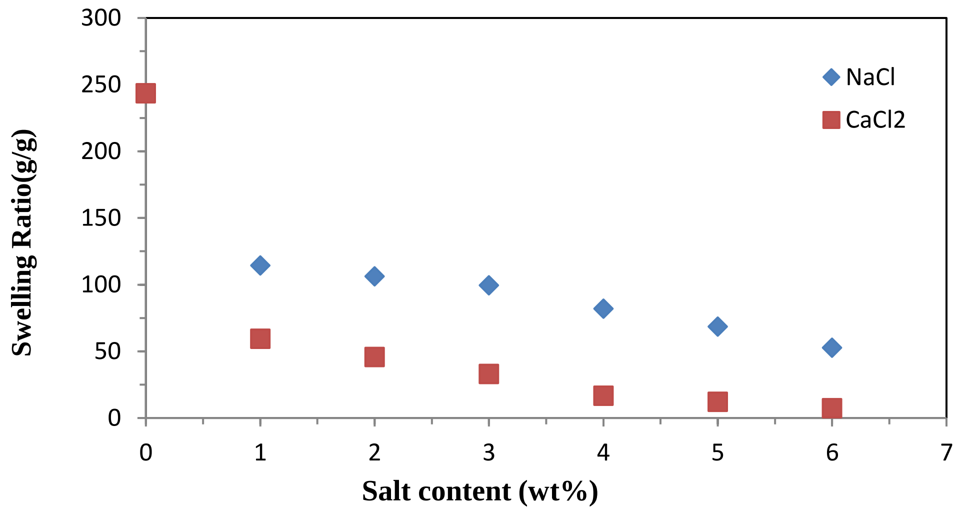

Figure 4.3: The obtained equilibrium swelling ratio of hydrogel versus salt content in water for two types of salts indicated on the figure.

According to studying the behavior of hydrogel in saline solutions in agriculture, and when mixing hydrogel with soil, salinity ratio in the soil should be low to create good conditions for hydrogel to absorb water in soil.

4.1.3 Effect of Temperature on the Equilibrium Swelling Ratio of the Recycled Hydrogel

Figure 3.4 show the effect of environmental temperature on kinetic and equilibrium swelling of hydrogel. Obviously, the swelling ratio increased with temperature.

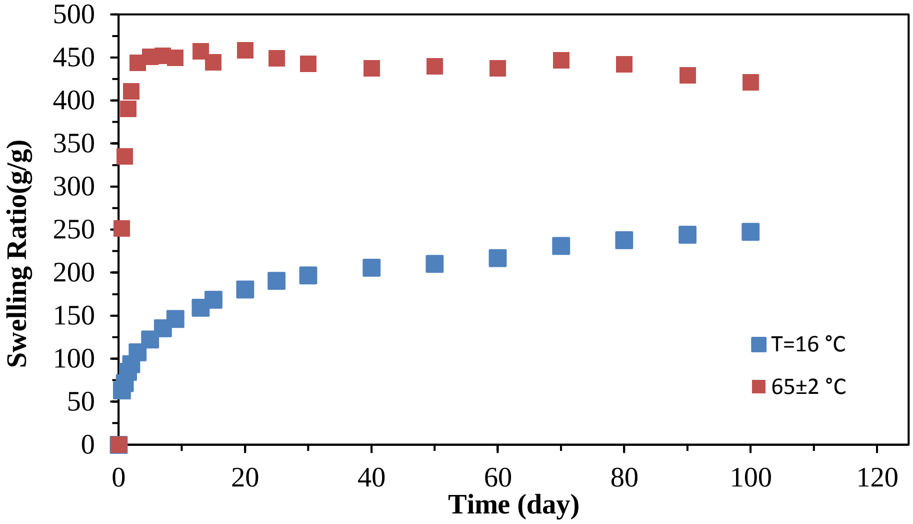

Figure 4.4: Swelling ratio of hydrogel at different temperature.

These results indicated that the swelling ratio increased with increasing temperature. This is explained by the fact that at high temperature (65±2 °C), the hydrogel is thermally more favorable for water molecules to form hydrogen bonds with polar groups in the superabsorbent polymer chains, allowing the hydrogel to exhibit maximum swell ability, because the hot water caused change in structure and thermal properties of hydrogel. When the temperature was increased from 25 to 65±2 °C, the water absorption capacity increased significantly due to an increase in the segmental mobility of the hydrogel chains. At above 65 °C the swelling is drastically reduced. Therefore, the decrease in swelling capacity is induced by the breakdown of the hydrogen bonds between the water molecules and the chains of the three-dimensional hydrogel network [26].

4.1.4 Effect of pH on the Equilibrium Swelling Ratio of the Recycled Hydrogel

Figure 3.5 shows the equilibrium swelling behavior of the recycled hydrogel with changing pH. It seems that pH has little or no effect on the kinetics of swelling: At all pH values, all curves approach equilibrium within similar time intervals of few minutes. On the other hand, pH has strong effect on equilibrium swelling ratio. Swelling ratio of hydrogel increased with decreasing pH: In acidic media, most of carboxylate groups are protonated. This causes a decrease in repulsion of anionic groups, which leads to a decrease in swelling ratio. In acidic condition, the carboxylic groups of the used superabsorbent polymer are protonated, causing a decrease in the repulsion of anionic groups and also a decrease in the swelling ratio. In neutral medium, the ionic strength is smaller than that in basic media, so it provides higher swelling capacity [26]. This is because the recycled superabsorbent is of anionic-type superabsorbent polymer, which contain a majority of hydrophilic groups, and which plays an important role in swelling behavior and result in water absorbency changes through different interaction species in various pH solution. When the pH is 12, the increase in the ionic strength of the swelling medium causes a rapid decrease in the ionic osmotic pressure, promoting the reduction in swelling ability in the equilibrium. It is important to indicate that the hydrogel can promote high swelling capacity at pH equal 10, which is caused by the buffer action of –COOH and –COO– groups and this is a great advantage for the application of superabsorbent in agricultural fields. Similar conclusions could also be found in other works [28].

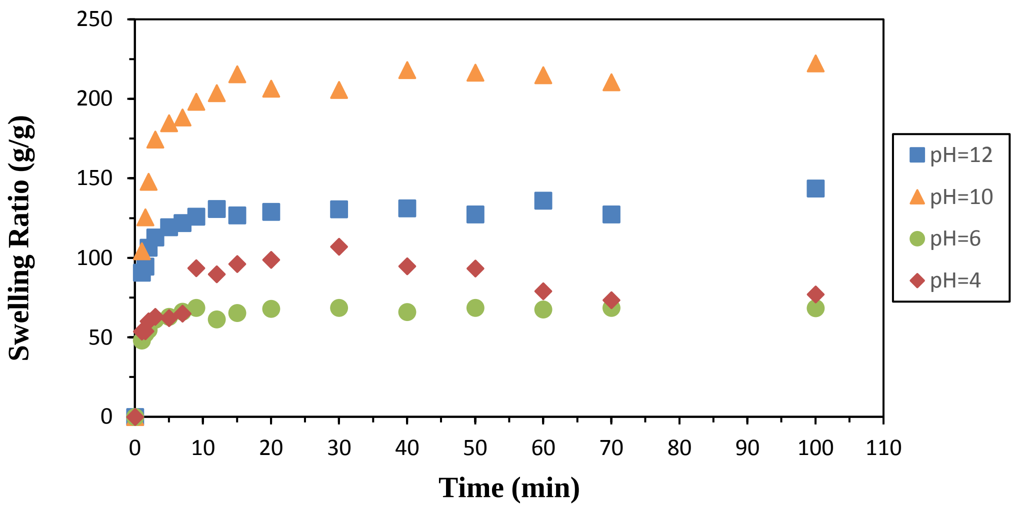

Figure 4.5: The effect of pH on swelling ratio of recycled hydrogel.

4.1.5 Water Retention Capacity of Hydrogel Modified Red Soil

Figure 3.6 shows water retention in soil as a function of time at two mixing ratios of recycled hydrogel with soil (4% and 8%), compared to control soil sample (without hydrogel).

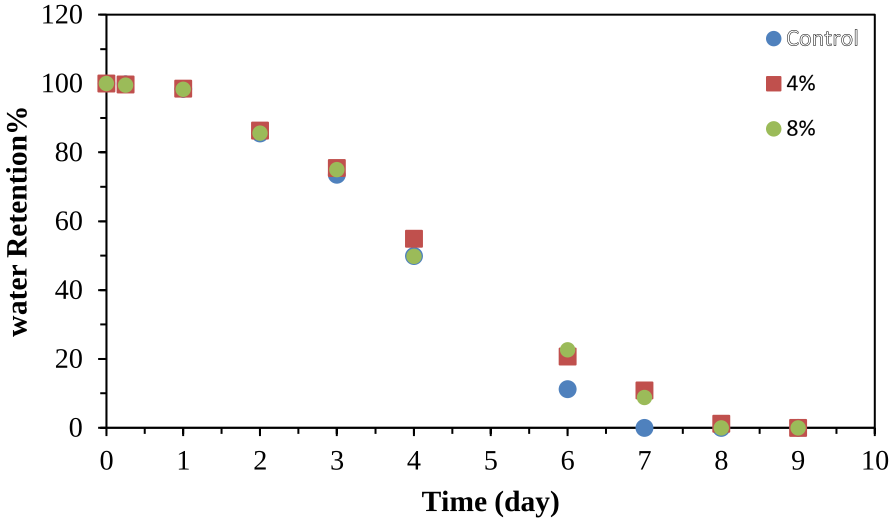

Figure 4.6: Water retention in soil as a function of time at two mixing ratios of recycled hydrogel with soil (4%, 8%), compared to control soil sample.

At early stages, the quantity of water losses from three samples was closed to reached 3 days as shown in figure 3.6, then the difference between three samples begins.

The water retention ratio in the samples containing the hydrogel better than control sample, and the maximum water retention was in sample containing 4% hydrogel. After 7 days the amount of water in control sample reached zero, but the sample 8% needed to 8 days to reached it, and 8.5 for sample 4%.

According to this result, when use the hydrogel in agricultural applications will provide water for longer period than without hydrogel, and it will reduce the amount of water used for irrigation, but when used large amount of hydrogel lead to many problems occurred such as increased evaporation rate and soil disintegration because when irrigated it, hydrogel was swelling and soil cracked leading to increased surface area and voids between soil particles.

4.1.6 Seeds Germination

Seed germination enhanced when used hydrogel, as shown in figure 8 the growth of lentils in mixture hydrogel with clay soil was better than lentils in soil only. The expansion and contraction of SAPs in soil during the cycle of water absorption and evaporation helps to improve air content in the soils, especially in clayey soils [6]. SAPs application in soils greatly reduces irrigation induced erosion and soil water seepage and further increases the uniformity of furrow water applications. Another advantage of amendment of SAP is that it greatly reduces the irrigation frequency particularly in coarse-textured soils. This property could be best utilized for water management practices in arid and semi-arid regions. The SAPs are also biodegradable and further their products do not harm the microbial community present in the soil [23] states that SAP amendment increases yield and water use efficiency of plants that is increase in plant biomass. SAP amendment aides plant growth by increase in plant available water, induce faster growth of plants and also prolong survival of plants under water stress and drought conditions.

Figure 4.7: The growth performances of lentils for various ratio of hydrogel (1,5%wt) and control sample.

4.2 Application of Hydrogel (Superabsorbent Polymer) in Agricultural

4.2.1 Effect of Hydrogel on Plant(Seedlings) Height

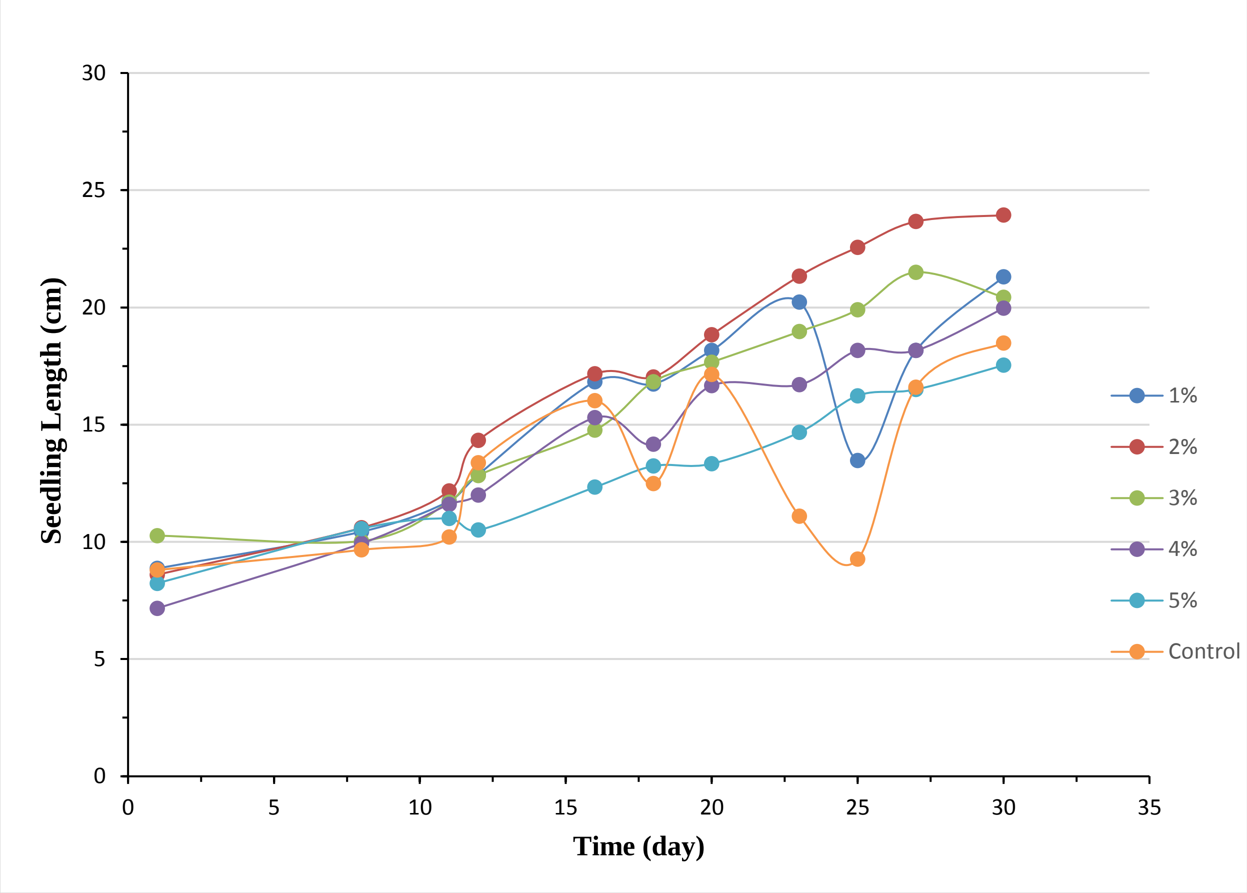

Figure 4.8: A change in the tomato seedlings height grown in a mixture of soil and hydrogel with different percentages of hydrogel ranging from (1,2,3,4 and5%)wt out of 500 gram) and control sample over a time period.

In the beginning the height of all tomato seedlings in all treatments as well as in the control, were equal, as shown in Figure 4.1. After 10 days elapsed, the height of all tomato seedlings remain equal. In the next measurements, the seedlings grown in pots with 2% hydrogel and have reached a height followed by seedlings grown in 1% and have reached a height of 23cm. The Seedlings grown in pots with 3% hydrogel, have reached a height of 21.5cm, in the 23rd days elapsed since the day of sowing. As for treatment with 4% hydrogel, tomato seedlings have average height of 20 cm. Finally, the tomato seedlings in the treatment with 5% hydrogel have average height of 18 cm. The control pots shown fluctuations in their heights. This phenomenon could be explained as a results of water stress experienced by tomato seedlings, followed by leaves wilting. The treatment with 2% hydrogel has shown the best results in term of plant height.

4.2.2 Effect of Hydrogel on Number of Leaves

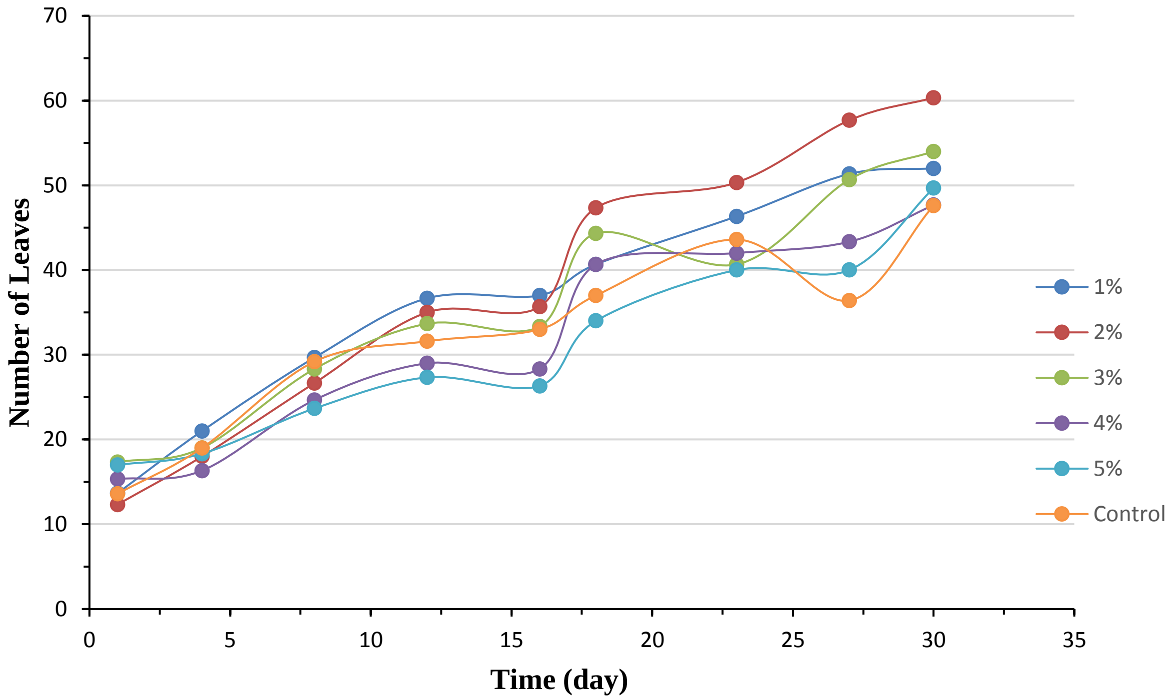

Figure 4.9: Number of leaves of tomato seedling cultivated in mixture of soil and hydrogel (1,2,3,4 and 5%) as well as control sample as a function of time.

Figure 4.2 represents the number of tomato leaves from different treatment over a period of time of 30 days. Figure 4.2 shown the treatment with 2% hydrogel has the best in the number of leaves over a period of 30 days at a rate of 60 leaves, followed treatment 1% and 3% at the rate of 52, 54, respectively. As for the control sample, the leaf growth rate was higher than 4% and 5% until day 23. The effect of water shortage and wetting affects the sample to reduce the number of leaves. The control sample was larger than treatments 4% and 5% until day 23th of planting and then deviated from its path to vice versa. Treatment with 2% hydrogel showed the highest results in term of number of leaves.

4.2.3 Effect of Hydrogel on Girth of Plant

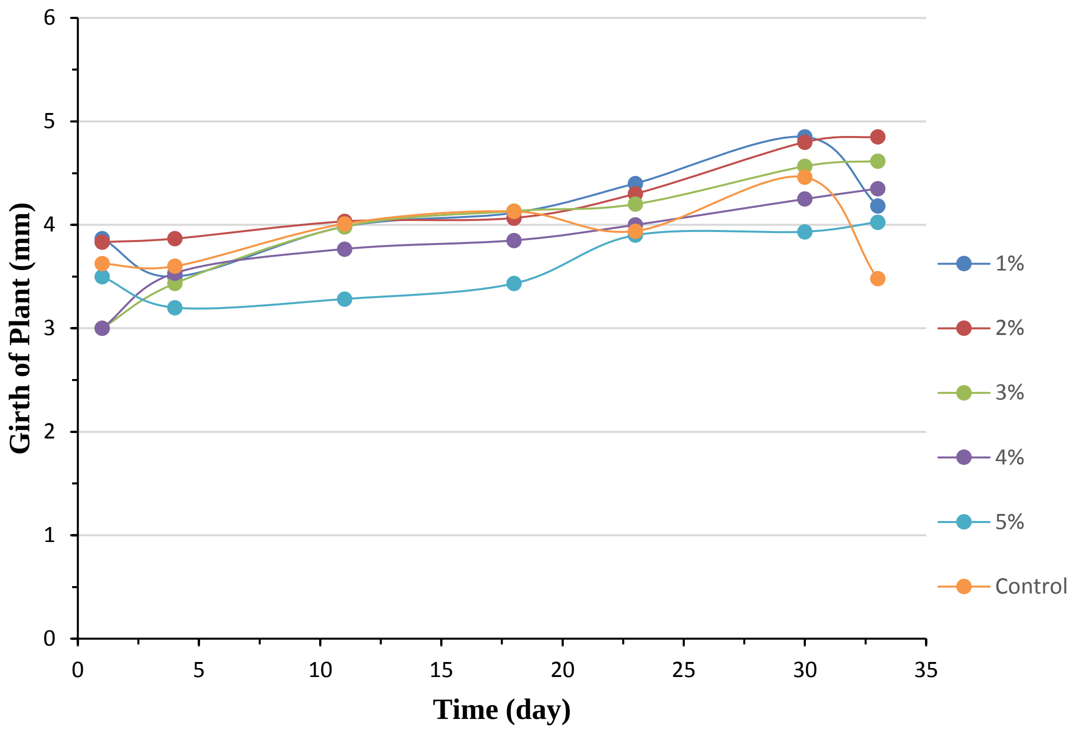

Figure4.10: Girth of tomato seedlings planted in different percentages of hydrogel and soil mixture (1,2,3,4 and 5%) and control sample versus time.

Figure 4.3 shows the girth of tomato seedlings planted in different percentages of hydrogel and soil mixture and control sample. Initially, the different between seedling girth was a slight variation not exceeding 0.8 mm as shown in Figure 4.3. In the next measurements, seedlings grow in pots with 1% hydrogel and reached 4.8 mm girth, followed by 2% processing, which reached the same girth but 1% after 30 days 4.1 mm while treatment 2% continued to 4.85 mm on the last day of readings. Seedlings girth in treatment 3%, 4% reached to 4.6, 4.3 mm respectively on the last day of the experiment. As for the treatment with 5% hydrogel, the tomato seedlings have an average girth of 4 mm. Finally, the control sample showed fluctuations in girth, there was a significant decrease in girth after 18 days, this phenomenon can be explained by the water shortage and losses by infiltration in the control sample.

4.2.4 Effect of Hydrogel on Decreasing Water Losses by Infiltration

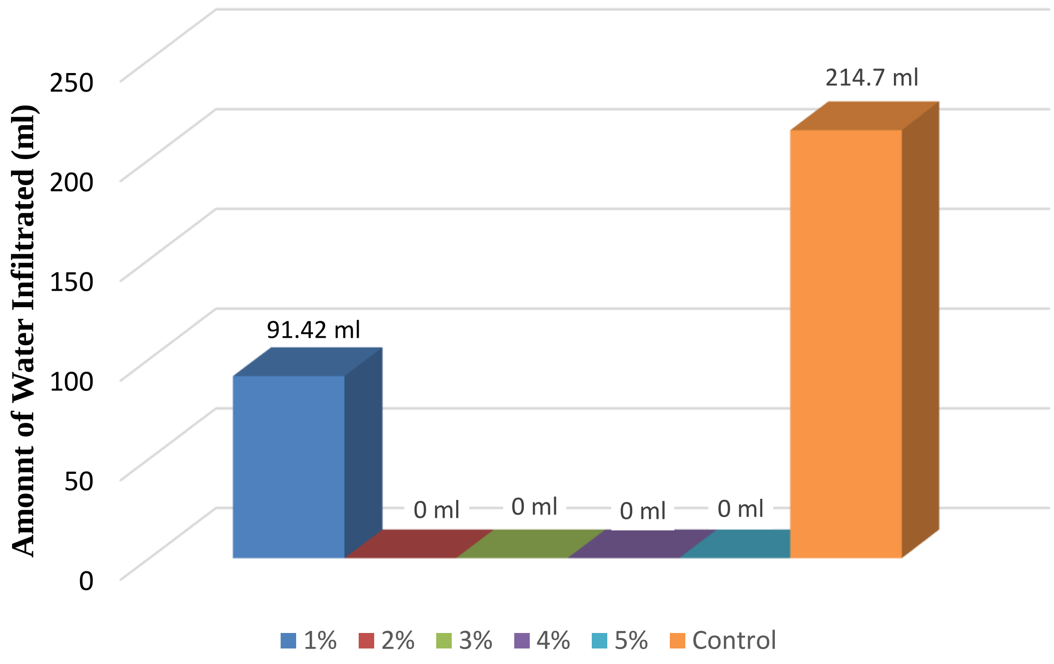

Figure 4.11: The total amount of water discharged from each treatment (1,2,3,4 and 5%) and the control sample after irrigation over four weeks.

Figure 4.4 shows the total amount of water infiltrated from each treatment of the six samples after irrigation with 250 ml and repeat the process over four weeks. The total water volume given to each sample during this period was 1000 ml (1L /sample). In the control sample and the sample with 1%, which contained the lowest percentage of hydrogel as shown in Figure 4, the total amount of water discharged from the sample reached 214.7 over the four weeks, and the treatment was 1% in much smaller quantities totaling 91.42 ml. In reducing water leakage. Treatments that containing higher quantities of hydrogel (2%, 3%, 4%, 5%) did not leak water and the quantity equal zero in all treatments.

4.2.5 Experimental Conditions (Temperature)

Soil temperatures ranged from 17 to 30 ° C in all treatments, and optimal root temperatures of 20 to 30 ° C. A drop below 11 ° C and an elevation of 35 ° C causes the germination to stop .

Tomato plants need a mild warm season, with temperatures ranging from 15 to 30 ° C [27]. Air temperatures ranged from 17 to 30 ° C in all treatments as shown in Table 4.1.

In the period, during which the experiment was conducted, the temperatures were within optimal range for the growth of tomato plants in air and soil.

Table 4.1: Temperature readings of air during the planting reading.

Temperature / No. of Day	T ° C	T_{min} °C	T_{max}° C
1	17	16.9	17.4
2	24.5	24.4	24.5
3	29.7	29.6	29.8
4	23.7	23.7	23.7
5	25.3	25.3	25.3
6	27.9	26	28
7	24.2	24.2	24.2
9	23.6	23.6	23.7
10	27.7	27.4	27.7
11	38.1	39.6	32.3
12	26.4	25.6	26.5
13	22.8	22.7	22.8
17	24.6	24.3	24.7
18	23.9	23.3	23.9
20	25.3	25.3	25.4
23	27.7	25.2	27.7
24	24.4	23.8	24.4
25	20.3	20.1	20.8

26	21.9	21	21.9
27	20.4	20.3	20.5
30	25.9	24	26

4.3 Discussion

The control sample was grown over five days of irrigation with a weekly quota 250 mm water until the soil lost its full water content that was occurring on the fifth day. After the fifth day, signs of wilt appear on the plant, and there is a strong cohesion in the soil and this indicates the need for the sample to re-irrigation. During this period, the plant was exposed to damage in some leaves and a decrease in the number as shown in Figure 4.5, in addition to the decline in the height of the sample as shown in the Figure 4.1 and Figure 4.2. After irrigate control sample returns to the growth and increase in the number of leaves, height and thickness.

On the other hand, the growth in treatment 1% was almost identical to the growth in the control sample. However, the signs of wilt began to appear after 7 days from the time of the weekly irrigation. This affects the height only, so that the plant returns to growth again. The result was that hydrogel was able to provide water for an additional two days from the control sample. But the stem and leaves of the plant was light green color and leaves soft thin and this makes the plant more prone to wilt if exposed to high temperature or lack of water. The soil was less cohesive than the control, allowing the process of ventilation.

Figure 4.12: Changes on control sample. [A] Plant growth in the first week, [B] Sample wilt after five days of irrigation, [C] Return the sample to grow after re-irrigation.

After 4 weeks, all treatment was irrigated for the last time and take necessary readings. All treatments were left under the same conditions to determine the time period each sample will need to wilt as a result of water shortage, loss of soil for its entire water content and determination of the time period in which hydrogels can maintain moisture Soil per ratio.

The result was that the higher hydrogel in samples, increase their ability to retain their weekly water content and the samples were resistant to drought conditions as they continued to grow. The treatment 5% was the most resistant to drought conditions, with slow growth lasting up to 21 days. Followed treatment 4% as the second treatment in terms of water retention and drought resistance for 19 days. Followed treatment 3% to begin wilt signs on day 14. The treatment 2% started to wither after the 8 day. Treatment 1% resistant to drought for a maximum of 7 days to show signs of wilt it is the only sample where there is a leakage of water. The control sample retains water for 5 days.

Finally, the samples 2% and 3% are the best in all samples because they combined good growth and ability to retain water and soil cohesion. The proportions of 4% and 5% is suitable for areas that suffer from severe drought and pressure as they are working to retain the largest amount of water and characterized by the thickness of the leaves and dark color and roughness, making them the largest ability to resist the conditions of drought as shown in Figure 4.6.

Figure 4.13: Hydrogel performance and effect on growth of tomatoes plant during the experiment period.

Conclusions

In the context of climate changes that caused the lack of rainwater, and increased temperature in arid and semi-arid regions is prominent throughout the world which encourages efficient water conservative irrigation technology by using SAP. The technique has a great water absorption capacity by its own weight that helps in improving soil moisture capacity and hence reduces water stress on the plant during prolonged drought stress condition and during irrigation intervals. Quantity of total water required for the irrigation is also reduced by 15 to 50% when the soil conditioning by SAP in different proportion is adopted. SAP is safe, bio degradable, nontoxic in the soil actively. Moreover, better aeration in the root zone enhances germination, root development. Reduced use of fertilizers and pesticides adds to the overall benefits and the quality of yield.

Recommendations

Awareness of the use of hydrogel substances in agricultural applications should be initiated in plants, gardens and playgrounds, since they have many benefits, including the possibility of reducing the water used for irrigation and reducing the problem of water in arid zones. To expand the work, we have done in large agricultural lands to optimize the utilization of water resources.

Future Work

Other sources of waste will be studied to obtain a new hydrogel that has the ability to absorb and retain water as well as the economy and the environment. The study of the possibility of using hydrogel in other applications in the scientific and practical life, preparing courses to convey the idea of using hydrogel in agriculture to the community in general and women especially because this product is present in most homes and women deal with it, as well as to investigate the idea of using waste as a source. Preparing for publishing a scientific paper from this study very soon.

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Appendix

• الناحية الاجتماعية للمشروع

يعد التقبل الاجتماعي لأي مشروع واحد من اهم شروط نجاحه واستدامته لذا كان لابد من التطرق للبحث في الناحية الشرعية للمشروع وذلك لاحتواء النفايات التي سيتم استخدامها على البول الذي يعتبر من النجاسات. تم اعداد عدة اسئلة حول الموضوع وارسالها الى مختص في الشؤون الشرعية الذي وضح ان استخدام بوليمرات فائقة الامتصاص مستخلصة من الحفاضات المستعملة في التطبيق الزراعي غير محرم .

❖ الاسئلة المرسلة

1. ما حكم استعمال حفاظات الأطفال/الفوط المستعملة (المحتوية على نجاسات- بول وبراز) دون غسيل أو تعقيم (علمي).
2. ما حكم السؤال أعلاه، إذا كانت النجاسة تتضمن فقط البول.
3. ما حكم استعمال حفاظات الأطفال المستعملة (التي تحتوي نجاسات) بعد التعقيم بالحرارة (دون الغسيل).
4. ما حكم استعمال حفاظات الأطفال المستعملة (التي تحتوي نجاسات) بعد القيام بغسلها بالماء (شطف).
5. هل يتغير الحكم في حالة حفاظات الأطفال المستعملة لأطفال تقل أعمارهم عن ستة أشهر (كما هي دون غسيل أو تعقيم حراري أو غيره).

❖ الأجوبة على مجموعة الأسئلة كما يلي باختصار:

- (1,2,3,4): الحكم الشرعي في استعمال أو استخدام الأشياء أو المواد التي علقت فيها نجاسات كالبول والبراز والدم ... إلخ هو المبادرة إلى تطهيرها وإزالة ما علق بها من نجاسة، أما قبل تطهيرها فإن استعمالها أو استخدامها يأخذ حكم الكراهة فحسب. ولا تعتبر هذه الأشياء أو المواد طاهرة بمجرد شطفها بالماء أو تعقيمها بالحرارة.
- (5): الثوب أو الشيء الذي أصابه بول الطفل الرضيع قبل أن يأكل غير الحليب يكفي فيه الرشّ إن كان بول رضيع ذكر، ويحتاج إلى غسل إن أصابه بول رضيع أنثى، أما بعد أن يأكل الرضيع طعاماً آخر غير الحليب فإن بوله نجس لا فرق بين الرضيع الذكر والأنثى، ولذا لا عبرة بكون الرضيع أنهى ستة أشهر من عمره.

والمحصلة: هي أن استعمال الفوط أو الحفاظات المحتوية على البول أو الغائط في (استخدام البوليمرات فائقة الامتصاص من حفاظات الأطفال المستعملة لتحسين عملية الري في التطبيقات الزراعية) من أجل التعليم الجامعي يأخذ حكم الكراهة ولا يأخذ حكم التحريم، أي لا إثم فيه.