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Applications of Natural Polysaccharide Polymers to Overcome Water Scarcity on the Yield and Quality of Tomato fruits

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ABSTRACT

As a result of water resource crisis, water-saving agriculture is necessary for sustainable development. Natural polysaccharide polymer is gaining great acceptance over synthetic polymers as controlled-release systems due to it is safe for the environment, cost effectiveness, easy availability, and biodegradability. This study is designed to evaluate the potential of natural polymers (cellulose, starch and cellulose/starch composite) to overcome scarcity of water on tomato (*Solanum lycopersicum*). Two different agricultural solid residues (rice straw and potato peels) were used to prepare of natural polymers. Polymer efficiency to water-saving and controlled release sencor herbicide was studied. Greenhouse experiment was conducted during 2017/2018. Four treatments; without polymer as a control and with different polymers (cellulose, starch and cellulose/starch composite) under three different level of irrigation (100, 75, and 50% FC) were used. Data indicated that the maximum swelling ratio of different polymer were in the fowling order, cellulose/starch (6.21 g/g) > Cellulose (4.80 g/g) > Starch (3.01 g/g). The results from the pot experiment showed that the addition of natural polymers to the soil have a positive effect to conserve water and increase the proportion of soil moisture compared to control. The highest increase was recorded at cellulose/starch polymer, this increase reached to 2.7-, 2.2- and 2.1 fold for 100, 75 and 50% FC that control. Natural polymers application with different water stress condition have positively affected on yield and quality of tomatoes especially when polymers were use under full irrigation. The increase of yield was recorded when applied different polymers (cellulose, starch and cellulose/starch) under full irrigation (100% FC), this increase reached to 13.7, 14.7 and 20.5% compared to without polymers and 2.2, 3.8 and 5.4% under irrigation scarcity (75% FC) compared to control without polymers (100% FC). Irrigation scarcity increased proline and phenol content and decrease total chlorophyll. Vitamin C, total soluble solids, pH, lycopene and juice content improved significantly with applies of natural polymers. The use of natural polymers under water scarcity improved the water use efficiency (WUE) of tomatoes.

Keywords: Natural polysaccharide polymers; agricultures residues; cellulose, starch, controlled release systems, soil.

INTRODUCTION

Several countries have not sufficient water resources to face their actual environmental, urban and agricultural requirements. As a result of water resource crisis, water-saving agriculture is necessary for sustainable development. Moreover, drought is portending to become increasingly severe due to climate change (Gornall *et al.,* 2010). The productive capacity of the arable soil was damaged; the natural water resources were minimized and also polluted with hazardous pesticides and chemical fertilizers which threatened the survival of all life types on land. Therefore, the focus on agricultural development in this century has shifted to the sustainable use of soil, water and plant resources in agriculture.

Polymer hydrogels play an important role in agricultural sector and use as structural materials for creating a climate beneficial to plant growth and increasing irrigation water efficiency (Dehkordi 2017). One of the new methods used for managing water in soil is the use of polymer hydrogels as a storage tank to prevent water waste and increase irrigation efficiency (Khodadadi-Dehkordi and Seyyedboveir, 2013). They have been established as a soil conditioner to decrease soil water loss and increase crop yield. Polymer hydrogels are hydrophilic networks with a high capacity for water uptake, which can absorb, swell and retain aqueous solutions up to hundreds of times their own dry weight of sample (Sun *et al*., 2012). It is applied in the soil to make a water supply, near the rhizosphere zone and advantage agriculture (Han *et al*., 2010). Also, it minimized micronutrients from washing out to water tables and causes more efficient water consumption, reduction in irrigation costs (Abedi Koupai and Mesforoush, 2009) and improving plant viability, seed germination, ventilation and root development. Polymers are in three types containing natural, semi-artificial and artificial (Mikkelsen, 1999). Currently, further extension of application domains of polymer was limited because the practically available polymer hydrogels are mainly petroleum-based synthetic polymer with high production cost and poor environmental friendly properties; in addition, there will be an environmental problem with synthetic polymer (Zhang *et al.,* 2007). In order to solve those problem, the tendency for replacing these synthetics with "greener" alternatives is necessary; due to the poor degradability and biocompatibility of synthetic polymer hydrogels (Kiatkamjornwong *et al.*, 2002 and Zohuriaan-Mehr and Kabiri 2008). Recently, the development multi-component Superabsorbents derived from natural polymer and eco-friendly additives such as polysaccharides (Li *et al.*, 2009) it has good commercial and environmental values with the advantages of low cost, renewable and biodegradable polysaccharides for deriving Superabsorbents (Yoshimura *et al.*, 2005; Lanthong *et al.*, 2006; Peng *et al.*, 2008; Ma *et al.*, 2011). Both starch and cellulose are carbohydrate polymers, which most abundant resource in nature, and are biocompatible, biodegradable, non-toxic, low cost and renewable.

Rice straw is the most abundant lignocellulosic agro-residues, in Egypt of about 3.1 million tons are produced annually. Rice straw still a waste till now all over the world and especially in Egypt, since there is no way to turn it to useful products on the wide range. The biochemical composition of rice straw is characterized by a typical composition of an agricultural-based lingocellulosic residue: it contains on average 30 –45% cellulose, 20 –25% hemicellulose, 15 –20 % lignin, as well as a number of minor organic compounds (Abdelhady *et al*. 2014).

Cellulose, which has abundant hydroxyl groups, can be used to prepare superabsorbent hydrogels easily with fascinating structures and properties (Suo *et al.,* 2007; and Li *et al.,* 2009). Compared with the synthetic polymer hydrogels, cellulose-based polymer hydrogels have high absorbency, high strength, good salt resistance, excellent biodegradable ability and biocompatibility.

Potatoes are usually peeled during processing and production losses in a form of potato peel waste can vary from 15 to 40%, depending on the peeling method. Each year huge quantities of peel waste as a by-product remain after industrial potato processing. Raw potato peels is an inexpensive by-product it contains a large quantity of starch (52 g 100 g^{-1} of dry weight), non starch polysaccharides, lignin, polyphenols, protein and small amount of lipids (Wu *et al*., 2012).

Starch is a natural polymer of hexacarbon monosaccharide–D-glucose which possesses many unique properties. Starch is a biopolymer which possesses many properties. It can be obtained from wheat, tapioca, maize and potatoes. Because it is a biodegradable polymer with well-defined chemical properties, it has a huge potential as a versatile renewable resource for various material applications in various areas (Benabid and Zouai (2016).

Pesticides, the most cost-effective means of pest and weed control in agriculture, are also recognized as a source of potential adverse environmental impact. Polymer hydrogels based on the cellulose series used as carriers for pesticides are of special interest in terms of both economic and sustainable development. Encapsulating herbicides into cellulose-based superabsorbent hydrogels could be used to reduce the release rate of these herbicides (Ekebafe *et al*., 2011).

Tomato (*Solanum lycopersicon L.*) is one of the most important vegetable crops and is one of the most demanding in terms of water use, the yield and quality of tomato are limited by the availability of nutrients and water (Peet, 2005).

The aim of this study is to reuse agricultural waste (rice straw and potato peels) and produce natural hydrogel polymers then application them to overcome the scarcity of water on the productivity of tomato as well as control the release of herbicides.

MATERIALS AND METHODS

Preparation of natural polymer

Preparation of potato peel starch

Potato peels were washed, cut and dried then dispersed in 1% of sodium Meta bi sulphate in 100 ml of distilled water as described by Vasanthan (2001). Suspension was filtered through a muslin cloth. The suspension was centrifuged at 5000 rpm for 20 min. Starch settled at the bottom of centrifuge tube was washed with toluene, oven dried at 30° to 40°C and the dried starch was ground with mortar and pestle into fine powder.

Preparation of cellulose

50 g of rice straw was added to 5% NaOH, and then cooked at 170 °C for 2 h under ultrasonic. The fiber was washing with distilled water then added to 100 ml of distilled water in flask 250 ml with a magnetic stirrer then placed it in a water bath at 95 ° C for 30 min. Potassium persulfate was added to the treated cellulose at 60 °C. The temperature then adjusted to 70-80 °C until the white color gel was obtained. The white gel was washed with methanol for half an hour, followed with ethanol for 5 min. and dried in oven at 60 °C until the fixed weight was obtained.

Preparation of cellulose/starch polymer composite

20 g cellulose was added to 100 ml of ethanol aqueous solution with magnetic stirring for 50 min. 50 ml of NaOH was added at 30 °C. Mono chloroacetic acid was added drop wise at 65 °C and stirred for 3 hr. the solution was then neutralization by HCl and filtrated then dried to obtain carboxy methyl cellulose (CMC). 20 g of CMC was placed in distilled water and mixed well using a magnetic stirrer. The gelatinized starch was added to the CMC solution and allowed to mix for 1 h. Then varying amounts of aluminum sulfate were added, and the solution was allowed to mix for another 30 min. The solution was then spread on Teflon baking pans and dried at 70°C until a film is formed. The film was shredded with a blender and then ground into a powder with a mortar and pestle.

Swelling measurements of natural polymers

The swelling ability of each natural polymer is determined by the method of Guilherme *et al*., (2015). Initially, dry natural polymer hydrogel is weighed (10 g) and immersed into an excess of water (200 ml) and left for 4 h at room temperature. Hydrogel swelling is performed in different periods of time until the maximum swelling ability is achieved. The amount of water absorbed is determined by weight difference using the following equation:

$$S\ (g/g) = [(M_2 - M_1) / M_1]$$

Where: **M_2 is the weight of natural polymers in swollen state and M_1 is the weight of natural polymers in dry state.**

Incubation experiment for determination of polymer water retention efficiency

A pot was perforated at the base and filled with 1 kg of sandy loam soil. Two gram of each natural polymer hydrogel (cellulose, starch, and starch/cellulose) was added and mixed well then weighted the pot (W_i). Pots were watered with different level of water. The weight of pots were recorded, this weight mean zero time (W_0). All the pots under different treatments were weighted after different periods 2, 4, 6, 9, and 12 day (W_t). The water retention percent is calculated as follows:

$$WR\% = 1- [(W_0 - W_t) / (W_0 - W_i)] \times 100$$

Where, **WR% = water retention capacity; W_t = weight at different time; W_i = initial weight; W_0= zero time**

Polymer efficiency to retain the Sencor herbicide

A pot was filled with 1 Kg of washed sand and the each natural polymer (cellulose, starch, and cellulose/starch,) was added separately at a rate 2.0 gm then mixed well. Soil without any polymer was used as a control. All pots were watered with 60 ml Sencor (1000 ppm) as herbicide. Three replications of each treatment were used. Sencor concentration was determined after different times in the soil sample.

Greenhouse experiment

A greenhouse experiment was carried out during successive season (2017/2018) at the Greenhouse and Experimental Farm, Agricultural Genetic Engineering Research Institute, Agricultural Research Center, Giza, Egypt, to evaluate the potential of natural polymers (cellulose, starch, and cellulose/starch) to overcome scarcity in tomato. Tomato seeds (*Solanum lycopersicon L.*) were germinated on bitmos soil then after 20 days, four seedlings were planted in each pot (20 cm diameter) with three replicates lined with a plastic bag to prevent water drainage, and fill each pot with sandy loam soil with or without natural polymers at rate 2 g / Kg (Aloys, 2010). All pots of plants were watered with water at 100, 75 and 50 % of field capacity (FC) until the trial end. The trial design was a split plot based on randomized complete blocks. Physical and chemical characteristics of the studied soil before planting are presented in Table (1). Soil was fertilized with N, P and K with recommended rates. Samples of soil were regularly collected before irrigations (6 days for without polymer and 10 days for with polymer) until the end experiment for moisture determination. Fruit yield were also recorded as well as the biochemical changes in the leaves and fruits were observed. The experiments consisted of these treatments: soil without polymers as control (T1, T2, and T3); soil with cellulose polymer (T4, T5 and T6); soil with potato peel starch polymer (T7, T8, T9) and soil with cellulose/starch polymer composite (T10, T11 and T12). All treatments were irrigated at 100, 75 and 50% of field capacity, respectively.

Analytical methods:

Soil analyses were determined according to Page *et al.* (1982). Regarding the plant analysis, total soluble solids (TSS %) was measured in fresh fruit by Erma hand refractrometer. The pH of tomato fruits juice was measured by digital pH meter. The juice was determined as percent of total weight of the fresh fruits. Proline content was colorimetrically measured in plant sample using ninhydrin reagent according to Bates *et al.* (1973). Total phenolics were determined by Folin-Ciocalteu phenol reagent according to Singleton and Rossi (1965). Total chlorophyll was estimated in tomato leave following the method suggested by Lichtenthaler (1987). Lycopene content of fruit was extracted according to Fish *et al.* (2002). Ascorbic acid was determined according to method of Hewitt and Dickes (1961).

Soil moisture content was determined by gravimetric method according to James, (1975) as this equation:

Moisture content = Mass of water/ Mass of dry soil.

At the end of season, all plants were collected, and then number and weight of fruits per pot were recorded.

Water use efficiency (WUE) was calculated from the fresh total fruits yield and total water applied

WUE = Total fresh yield/ Total water used

Table 1. Some physical and chemical properties of the tested soil

Physical	**Value**
Coarse sand%	35.9
Fine sand%	38.6
Silt%	15.5
Clay%	10.0
Texture soil	Sandy loam
Chemical	
pH (1: 2.5, soil suspension)	7.4
SP	30
ECe (dS/ m)	1.86
Soluble cations (me/L)	
Ca^{++}	6.9
Mg^{++}	5.9
Na^{+}	6.6
K^{++}	0.55
Soluble anions (me/L)	
$CO3^{=}$	-
$HCO3^{-}$	0.71
Cl^{-}	18.27
$SO4^{=}$	0.97

RESULTS AND DISCUSSION

Natural polysaccharide polymers that prepared from waste agricultures (rice straw and potato peel were shown in photo 1.

Starch polymer

Cellulose

Cellulose/Starch

Photo 1. Natural Polysaccharide Polymers

The FTIR spectra of different natural polymers

IR spectra of different natural polymers were shown in Figure (1). For Cellulose, the broad band at 3334 cm^{-1} corresponds to the stretching vibration of the OH groups in cellulose molecules, while the peak at 2891 cm^{-1} corresponds to the stretch of aliphatic alkyl compounds HCH. The observed band at 1050 cm^{-1} corresponds to C-O stretching to cellulose and band at 1031cm^{-1} is also confirmed the deformation in the plane C-H aromatic type, the peaks at 1315 and 1103 cm^{-1} might be related to O-H on carboxylic group and C-O-C to the cycle ring respectively. Concerning the IR spectra of potato peel starch, the peak at 992 related to characteristic starch backbone, additionally, the peaks at 1574, 1659 and 2325 cm^{-1} for O-H bending, C-C aromatic ring stretching and C-H stretch, respectively. For the cellulose/starch composite polymer, the FT-IR shows in figure (1) which reveals that the three peaks of cellulose 1031, 1055 and 1103 cm^{-1} become one broad one at 955 cm^{-1} also the small peak at 992 cm^{-1} in potato become more intense and shifted at 955 cm^{-1}. Plus, peaks at 1574 and 2325 cm^{-1} become slightly intense for both peaks and shifted in 2325 peak to 2349 cm^{-1}. The adsorbed water molecules become more boarders.

Swelling and efficiency water retention of natural polymer hydrogels

The perfect water absorbency property of natural polymer hydrogels (cellulose starch, and cellulose/starch) has the ability to store water. Figure 2 indicated that increase in each hydrogel swelling is directly correlated to the time of swelling. In general, water retention is increased with time increased. The tendency of the prepared hydrogel to swell is faster at the first hour then decreased as time tended to 420 minutes. The maximum swelling ratio (g/g) of different polymer were in the following order, cellulose/starch (6.21) > Cellulose (4.80) > Starch (3.01). Also, the results showed in Fig. 3 observed that the natural polymer hydrogels (cellulose, starch and cellulose/starch) had a high retention capacity for a long time. The polymer hydrogels conserved a water percent reached to 40, 34 and 45%, respectively after 6 days of irrigation while reached to 22, 19, and 24% after 9 days compared to control. Generally, in hydrogels, the swelling mechanism occurs by the water diffusion towards the hydrogel polymeric networks due to the hydrophilic capacity of the present functional groups (Guilherme *et al*., 2015).

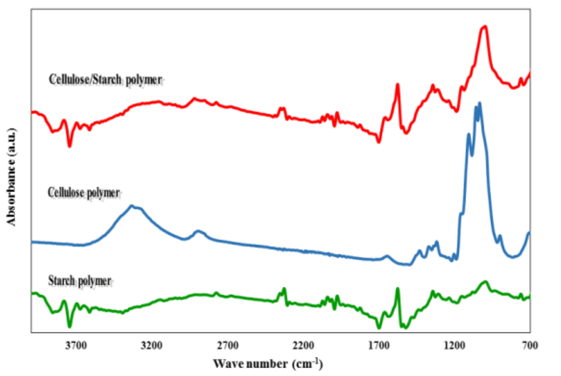

Fig 1: The FTIR spectra of different natural polymers

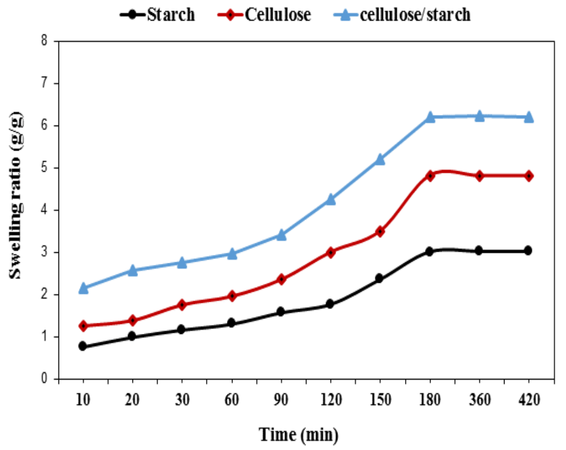

Fig. 2. Swelling capacity of natural polymers in water

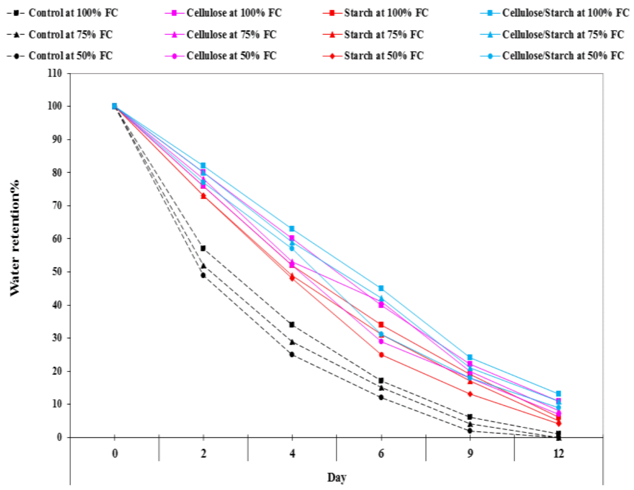

Fig. 3. Water capacity of soil with or without different natural polymers

Herbicide conserve rate of natural polymer

The data confirmed the potential of all polymers to conserve the sencor (Fig. 4). The greatest conserve of sencor herbicide was observed when used starch/cellulose polymer. The conserve of sencor herbicide was in following order starch/cellulose > cellulose > starch. There was a gradual release of sencor from different polymers during the experiment. It was noted that the maximum release was observed at 27 day then decrease until reached the minimum at the end experiment. It worth mention, no change of sencor concentration was noticed in soil without any polymers till the end experiment. The release of herbicides besieged in a hydrogel takes place only after water penetrates the network to swell the polymer and dissolve the chemicals, accompanied with the diffusion alongside the aqueous pathways to the surface of the device. The release of chemicals is closely related to the swelling characteristics of the hydrogels, which in turn is a key function for the chemical architecture of the hydrogels. The active compound is covalently bound to the polymer by a labile bond at the end. Release depends on the rate of chemical of the polymer-active agent bonds. Polymers, especially in the form of hydrogels, are very important in formation of controlled release systems (Rajakumar and Jayasree Sankar, 2016).

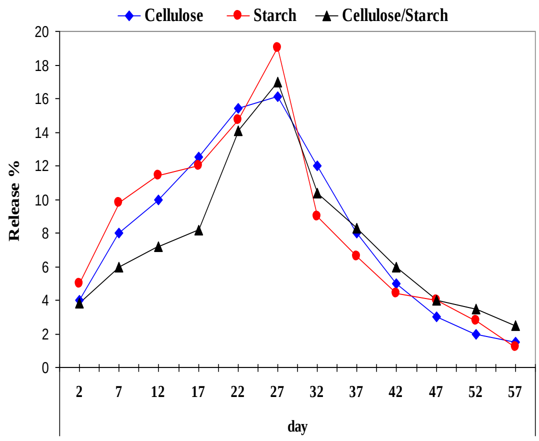

Fig. 4. Release rate of sencor herbicide from natural polymer

Effect of different natural polymers on soil moisture content

Moisture content results of sandy loam soil are given in Fig. 5. The results from the pot experiment showed that, up to 6 days after irrigation, more water was lost from the control than from the polymer treated soils. The mean of lowest moisture content was observed in the untreated soil. It is worth mentioning, that the addition of natural polymers to the soil showed a positive effect to conserve water and increase the proportion of soil moisture compared to control. The increases in moisture content were achieved by using natural polymers and were in the following order: cellulose/starch > cellulose > starch. The highest increase was recorded at cellulose/starch treatment. This increase reached to 1.6-, 1.8- and 2.1 fold for 100, 75 and 50% FC that of the control. These results were agreed with Al-Omran *et al*., (1987) and Vijayalakshmi *et al*., (2012) they reported that mean moisture values were higher in polymer treated soil as compared with those of control. The application of polymer to the soil helped in retaining more moisture in the soil, increased water holding capacity and decreased infiltration rate soil.

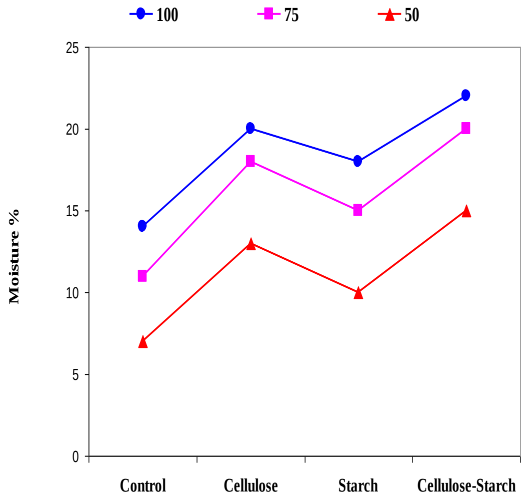

Figure 5. Effect of different natural polymers on soil moisture content

Effect of water stress and natural polymers on **fresh weight and number of fruits**

Data pertaining to tomato growth (fresh weight and number of fruits) were illustrated graphically in Figure 6. The lowest value of fresh weight and number of fruits was observed in plants that grown under water stress conditions in untreated soil by natural polymers. The maximum decrease was observed at 50% FC. On the contrary, data showed that use of all natural polymers under investigation (cellulose, starch, cellulose/starch) in soil with different water stress condition (100, 75, and 50% FC) increased strongly fresh weight and number of fruits. For fruits weight, the fruits weight increase relative to control (untreated with polymers), reached 1.14, 1.14 and 1.21-fold that control for 100% FC while 1.45, 1.48, and 1.50-fold for 75% FC and also 1.71, 1.83, and 1.93-fold for 50% FC. For fruits numbers, the increase reached to 1.11, 1.33 and 1.50-fold for 100% FC while 1.05, 1.20, and 1.50 for 75% FC and also 1.02, 1.45, and 1.69-fold for 50% FC, respectively compared to control that untreated with polymers. The efficiencies of natural polymers in increased tomato growth characterizes are very different. Improving in tomato growth parameters using different natural polymers was observed in the following increasing order: cellulose < starch < cellulose/starch. In the present study, applying of natural polymers especially cellulose-starch compensated to some extent for tomato growth reduction in plants grown under water stress conditions. These polymers caused to increase the growth parameter of tomato compared with the treatments without polymer. This effect is probably due to the absorption of significant amounts of water in polymer structure, thereafter water absorption via soil around the roots during water stress and removing this stress, so that the seedlings have continued to grow in a suitable condition (Tongo *et al*., 2014).

The present results were similar to that recorded for the increases of growth parameter under natural polymer as reported by Zangooei-Nasab *et al*., (2012) and Li *et al.* (2014), they mentioned that polymer cause an improvement in plant growth by increasing water holding capacity in soil. Natural polymer as a soil conditioner; participate significantly to supply a reservoir of soil water to plant on demand in the surface soil where the root systems normally develop.

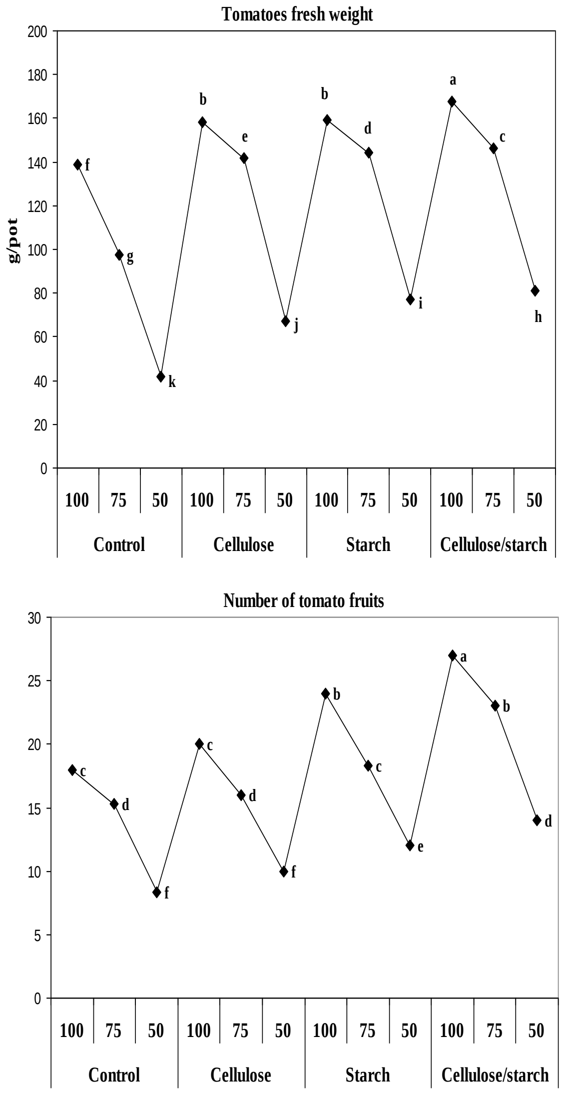

Fig. 6. Effect of natural polymers on tomato growth

Effect of water stress and natural polymers on **chlorophyll**

Data of total chlorophyll of tomato leaves were shown in Fig. 7. The reduction in leaf chlorophyll content of the plants was observed in plants that grown under water stress conditions in untreated soil with natural polymers. The maximum decrease was observed at 50% FC. On the other hand, result showed that use of all natural polymers (cellulose, starch and cellulose/starch) in soil with different water stress condition (100, 75, and 50% FC) increased leaf chlorophyll content. The increment reached to 18, 9 and 30% at 100% FC while 23, 15, and 50% at 75% FC and also 47, 32, and 68% at 50% FC, respectively compared to control that untreated with polymers. The efficiencies of natural polymers in increased total chlorophyll content were observed in the following increasing order: cellulose < starch < cellulose/starch. Generally, water stress caused decrease in the chlorophyll. The decrease of chlorophyll due to water stress is related to the increase of production of free oxygen radicals in the cell. These free radicals cause peroxidation and disintegration and by reduction of photosynthetic pigment, great changes are formed in the plants. The results showed a positive effect on the use of natural polymers to keep photosynthetic pigment content under water stress. Natural polymer has a positive effect by putting water gradually for the plant, the water stress is minimized and it is one of the most important applications of this substance in agriculture (Nazarli *et al*., 2010) and through this increment the growth of plants in stress conditions. Durability of photosynthetic pigment are shown in stress conditions by natural polymers in the sunflower (Nazarli *et al*., 2010) and corn (Khadem *et al*., 2010). Earlier studies mentioned that the reduction in leaves chlorophyll content of the plants grown under stress has been attributed to the destruction of pigments and instability of the pigment protein complex (Jaleel *et al.*, 2008). The decrease in photosynthetic pigment content under stress conditions might be attributed to reduced synthesis of the main pigment complexes (Nikolaeva *et al*., 2010), or to destruction of the pigment protein complexes which protect the photosynthetic apparatus, or to oxidative damage of chloroplast lipids and proteins, therefore formation of photosynthetic pigment decreases. In this regard Akca and Samsunlu (2012) reported that the negative effects of abiotic stress on photosynthetic pigments could be due to the inhibition of chlorophyll biosynthesis or increase of its degradation by chlorophyllase enzyme. Natural polymers that use have a positive effect on chlorophyll content. There are following mechanisms for the explanations: First, the roots took water retention from polymer during water shortage; Second, the addition of natural polymer has a positive effect on CO_2 assimilation rate and the water use efficiency of plants that grown under water stress condition, thus significantly affecting plant growth and biomass accumulation (Jamnická *et al*., 2013).

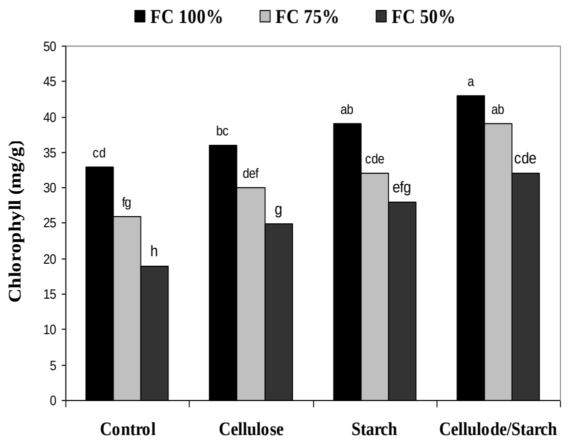

Fig. 7. Effect of water stress and natural polymers on chlorophyll content

Effect of water stress and natural polymers on proline content

Data of proline content of tomato leaves were illustrated in Fig. 8. The increment in proline content of the plants was observed in plants that grown under water stress conditions in soil without natural polymers. The maximum increase was observed at 50% FC. The results showed no significant change in the proline content of the plant that grown in soil with or without polymers at 100% FC. On the other hand, result showed that apply of all natural polymers (cellulose, starch, cellulose-starch) in soil with different water stress condition (75, and 50% FC) decreased proline content. Decrease reached to 29, 34 and 39% at 75% FC while 28, 31, and 51% at 50% FC, respectively compared to control that untreated with polymers. The efficiencies of natural polymers in decreased proline content were observed in the following increasing order: cellulose < starch < cellulose/starch. Generally, High levels from proline enabled the plant to maintain low water potentials. Proline accumulation in drought-stressed plants may play a role as osmolyte to maintain the organelles, resulting in the greenish leaf when exposed to water deficit condition (Safarnejad, 2008). Proline via osmosis control, avoiding enzymes destruction and removal of hydroxyl radicals, increased the tolerance of the plants against stresses. Proline improves stress tolerance by protecting and stabilizing membranesand enzymes during stress conditions. From the previous data, proline content was significantly increased as water stress level increased but decreased after the use of natural polymers. It demonstrated possible that natural polymers could provide a protective cover in tomato plants under water stress conditions, preventing them from being severely affected by water stress. Therefore, the level of proline accumulated in natural polymer-treated plants under water stress was not as high as in water-stressed plants without natural polymers. Similarly, by applying of natural polymers, the reduced proline accumulation was found in sunflower (Nazarli *et al*., 2011) and in Tomato (Ullah *et al., 2016).*

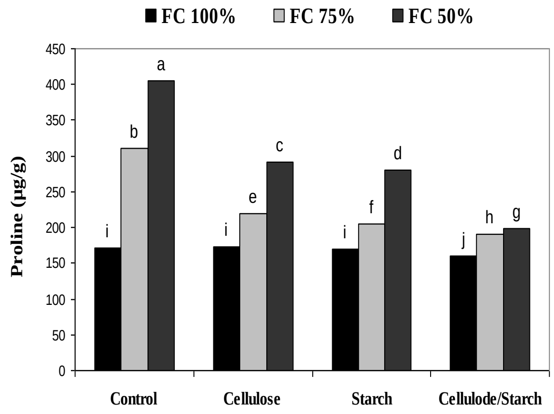

Fig. 8. Effect of water stress and natural polymers on proline content

Effect of water stress and natural polymers on phenol content

Data of total phenol contents of tomato were illustrated in Figure 9. Highest concentration of total phenol was observed in plants that grown under drought stress conditions in soil without natural materials. Total phenol contents increase as the level of drought increases. For plants that grown under different level of drought stress conditions in soil with or without natural materials, the maximum increase was observed at 50% FC. Also, data showed that use of all natural materials (cellulose, starch, and cellulose/starch) in soil with different level of drought condition (75 and 50% FC) decreased phenol content compared to control (without natural materials). Decrease reached to 6, 13, and 16% for 100% FC; 18, 25 and 25% for 75% FC; 24, 26 and 28% for 50% FC. Non-significant effect was observed between different types of natural materials polymers to effect on content of phenol. Generally, total phenol is antioxidant that a series of secondary metabolites synthesized through the pathway of shikimic acid, which exerts cellular signaling functions under conditions of abiotic stress (Michalak, 2006 and Mansori *et al.* 2015) who reported that polyphenols represent a large family of plant secondary metabolites and these may act as antioxidants to protect the plant against oxidative stress. Total phenol content as the functional antioxidant marker has been increased in tomato planted with super water absorbance hydrogel polymer compared to control sample suggesting increased antioxidative ability (Sultana *et al*., 2016). It promotes the synthesis of phenolic compounds such as anthocyanins and flavonoids which may improve the plant.

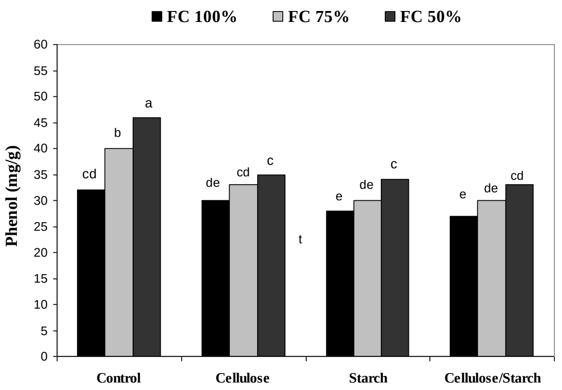

Fig. 9. Effect of drought and natural polymers on phenol content of tomato

Effect of water stress and natural polymers on fruit quality

Effect of water stress and natural polymers on fruit quality of tomato plant was presented in Table 2. Vitamin C, total soluble solids, pH, lycopene and juice content improved significantly with applies of natural polymers. Lowest concentration of vitamin C was observed in plants that grown under water stress conditions in soil without natural polymers. Results showed that use of all natural polymers (cellulose, starch, and cellulose-starch) in soil with different level of water stress condition (100, 75 and 50% FC) increased vitamin C content compared to control without natural polymers. Increase reached to 15, 6, and 24% for 100% FC; 23, 17 and 33% for 75% FC; 44, 36 and 48% for 50% FC. Decrease in vitamin C content under water stress may be attributed to increase in activity of ascorbic acid oxidase enzyme responsible for the destruction of ascorbic acid content in the plants. The application of natural polymers led to reduction in the ascorbic acid oxidase enzyme in the plants might be the reason for enhanced ascorbic acid content in tomato fruit due to supply of sufficient amount of water and nutrients to the plant in water deficit condition. Similarly, Sendur kumaran (2016) also reported an increase in ascorbic acid content, TSS, pH, lycopene content and juice content in tomato due to the application of hydrophilic polymer. Regarding the pH values, lowest value was observed in plants that grown under water stress conditions in soil without natural polymers. Results showed that use of all natural polymers (cellulose, starch, and cellulose-starch) in soil with different level of water stress condition (100, 75 and 50% FC) increased pH value compared to control without natural polymers. Increase reached to 9, 7, and 11% for 100% FC; 8, 7 and 12% for 75% FC; 7, 5 and 16% for 50% FC. These results were conformed to Sendur kumaran (2016) who reported an increase pH in tomato due to the application of hydrophilic polymer. Decrease in the pH of fruits when exposed to water stress may be due to change in the acid content as malic and citric acid (Thybo *et al*., 2006 and Anthon *et al*., 2011). For the TSS content, lowest content was observed in plants that grown under drought stress conditions in soil without natural polymers. Results showed that use of all natural polymers (cellulose, starch, and cellulose/starch) in soil with different level of drought condition (100, 75 and 50% FC) increased TSS content compared to control without natural polymers. Increase reached to 11, 6, and 20% for 100% FC; 13, 4 and 18% for 75% FC; also 30, 17 and 27% for 50% FC. Increases in TSS by polymer may be attributed to improve metabolic and metabolic activities, leading to the synthesis of high amounts of acids, metabolites and glucose. These reserves, which were produced, may have contributed to the original composition of TSS (Sendur Kumaran, 2016). Concerning the lycopene content, lowest value of lycopene content was observed in plants that grown under water stress conditions in soil without natural polymers. Lycopene content decreases as the level of water shortage increases. The maximum decrease was observed at 50% FC. Data showed that apply of all natural polymers (cellulose, starch, cellulose/starch) in soil with different water contents (100, 75, and 50% FC) increased lycopene content. Increase reached to 12, 16, and 24% at full irrigation while 7, 14 and 23% at 75% FC, also 6, 6, and 11% at 50% FC, respectively compared to control that untreated with polymers at the same level irrigation. The efficiencies of natural polymers to increased lycopene content were observed in the cellulose/starch treatment followed with starch then cellulose. Lycopene is known as an important natural antioxidant with anti-carcinogenic properties (Krauss *et al*., 2006). In addition, lycopene is responsible for the red color of tomatoes, aspect of great economic importance (Borghesi *et al*., 2011). Also, an increase in lycopene content was showed in tomato due to the application of hydrophilic polymer (Sendur kumaran 2016). Concerning the juice percent, lowest percent of juice was recorded in plants that grown under water stress conditions in soil without natural polymers. Juice percent decreases as the level of water shortage increases. The maximum decrease was observed at 50% FC. Data showed that apply of all natural polymers (cellulose, starch, cellulose/starch) in soil with different water stress condition (100, 75, and 50% FC) increased juice percent. Increase reached to 9, 5, and 18 at 100% FC; 14, 4, and 20% at 75% FC finely 11, 4, and 22% at 50% FC, respectively compared to control that untreated with polymers at the same level irrigation. Similarly, Sendur kumaran (2016) also reported an increase in juice content in tomato due to the application of hydrophilic polymer.

Water use efficiency

Water use efficiency of tomato as affected by natural polysaccharide polymer under different irrigation levels is presented in Table 3. Significant differences in water use efficiency were observed due to scarcity irrigation rate were detected. Results showed the efficiency of the use of natural polymers in conserving the amount of water used in tomato irrigation compared to non-use. Results showed the polymers efficiency in increasing WUE at different level of irrigation (100, 75 and 50% FC), this increase reached to 2.0-, 2.4- and 3.0-fold, respectively.

Table 2. Effect of water stress and natural polymers on quality of tomato fruits

Treatment	Field capacity	pH	TSS %	Juice %	Vit C (µg/g)	Lycopene (µg/g)
Control	100	3.72^{f}	3.54^{f}	55^{ef}	340^{e}	25.00^{d}
	75	3.62^{gh}	3.28^{h}	51^{g}	300^{f}	22.00^{f}
	50	3.42^{i}	2.72^{j}	46^{h}	250^{g}	20.67^{g}
Cellulose	100	4.04^{b}	3.94^{b}	60^{bc}	390^{bc}	28.00^{bc}
	75	3.92^{de}	3.70^{e}	58^{cd}	370^{cd}	23.67^{e}
	50	3.65^{g}	3.53^{f}	51^{g}	360^{de}	22.00^{f}
Starch	100	3.96^{cd}	3.76^{d}	58^{cd}	360^{de}	29.00^{b}
	75	3.87^{e}	3.41^{g}	53^{fg}	350^{de}	25.00^{d}
	50	3.59^{h}	3.19^{i}	48^{h}	340^{e}	22.00^{f}
Cellulose /starch	100	4.14^{a}	4.25^{a}	65^{a}	420^{a}	31.00^{a}
	75	4.01^{bc}	3.87^{c}	61^{b}	400^{ab}	27.00^{c}
	50	3.98^{c}	3.46^{g}	56^{de}	370^{cd}	23.00^{ef}

Natural polymer can be used as a water conservator in plant production. This data was agreed with Dabhi *et al.* (2013). These results showed that natural polymers had a positive effect on productivity improvement of water irrigation for tomato fruits yield. Therefore, polymers are possible to improve the water use efficiency and conserve water for tomato production under scarcity of water. It can enhance the ratio of yield through the following mechanism reducing water loss; this result is agreed with Mahmoud and Abdulrasoul (2012).

Table 3. Water use efficiency of tomato as affected by natural polysaccharide polymer under different irrigation levels

Treatment	Field capacity	Yield (g/pot	* Water applied (m^3/pot)	WUE (g/ m^3)
Control	100	139	45.00	3.1
	75	98	33.75	2.9
	50	42	22.50	1.9
Cellulose	100	158	27.00	5.9
	75	142	20.25	7.0
	50	72	13.50	5.3
Starch	100	160	27.00	5.9
	75	144	20.25	7.1
	50	77	13.50	5.7
Cellulose/ starch	100	168	27.00	6.2
	75	147	20.25	7.2
	50	81	13.50	6.0

*** Water applied (m^3/pot) for all season**

Natural polymers and conserve water to tomato plant

Natural polymers (cellulose, starch and cellulose/starch) had a positive effect to reduce the amount of water irrigation in tomato planting (fig. 10). The amount of storing water reached 18, 13.5 and 9 m3/ pot at 100, 75 and 50% FC, respectively. Consequently, natural polymers have the ability to reduce irrigation requirements of tomato crop.

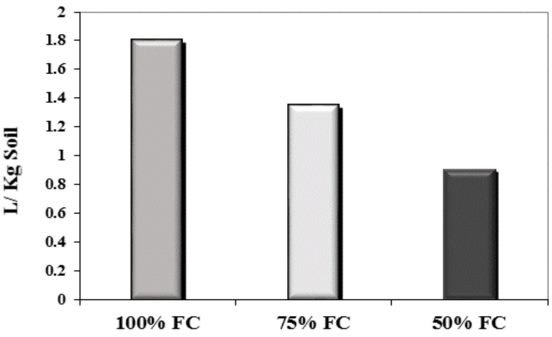

Fig. 10. Natural polymers and conserve water for tomato friuts at different levels irrigation

CONCLUSION

This study recommends that, reuse of some plant residues to produce natural and environmentally safe polymers and their application in agriculture to reduce plant irrigation requirements under this experiment up to 40% while maintaining the productivity of tomato compared to full requirements of irrigation without polymers.

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التغلب على نقص المياه باستخدام بوليمرات البولى سكرايد الطبيعية وأثرها على محصول و جودة الطماطم

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نتيجة لأزمة الموارد المائية ، فإن الزراعة الموفرة للمياه ضرورية للتنمية المستدامة. يكتسب البوليمر الطبيعي (البولى سكرايد) إقبالا كبيرًا على البوليمرات الصناعية كنظمام تيسر بطئ محكوم بسبب كونها آمنة للبيئة ، الفعالية من حيث التكلفة ، وسهولة توفرها ، والقابلية للتحلل الحيوي. أجريت هذه الدراسة لتقييم إمكانية البوليمر الطبيعي (السليلوز ، النشا ، سليلوز/ نشا) للتغلب على الآثار السلبية لندرة الماء على نمو الطماطم. تم استخدام اثنين من المخلفات الصلبة الزراعية المختلفة (قش الأرز وقشور البطاطس) لتحضير البوليمرات الطبيعية. كما تم دراسة كفاءة البوليمر في توفير المياه وكذلك التحكم والاطلاق البطئ لمبيد الحشائش السينكور. أجريت تجربة داخل الصوبة خلال 2017-2018. تم استخدام أربعة معاملات: بدون إضافة البوليمر ، وبإضافة البوليمر (السليلوز ، النشا ، سليلوز/نشا المركب) تحت ثلاثة مستويات مختلفة من الري (100 ، 75 ، و 50٪ من السعة الحقلية). أشارت النتائج إلى أن نسبة التشرب القصوى في البوليميرات المختلفة كانت في الترتيب التصاعدى التالى: بوليمر نشا/سليلوز (6.21 جم / جم) > بوليمر السليلوز (4.80 جم / جم) > بوليمرالنشا (3.01جم / جم). أظهرت نتائج تجربة الصوبة الزراعية أن إضافة البوليمرات الطبيعية إلى التربة كان له تأثيراً إيجابياً للحفاظ على المياه وزيادة نسبة رطوبة التربة مقارنة بالكونترول (بدون بوليمر). سجلت أعلى زيادة في بوليمر النشا/السليلوز حيث وصلت هذه الزيادة إلى 2.7 و 2.2 و 2.1 مرة لـ 100 و 75 و 50٪ نسبة الى الكونترول. أثر استخدام البوليمرات الطبيعية مع حالة الإجهاد المائي المختلفة بشكل إيجابي على محصول وجودة الطماطم خاصة عندما كانت البوليمرات تستخدم تحت الري الكامل. تم تسجيل زيادة في المحصول عند تطبيق البوليمرات المختلفة (السليلوز والنشا والسليلوز / النشا) تحت نظام الري الكامل (100 ٪ من السعة الحقلية) ، وصلت هذه الزيادة إلى 13.7 ، 14.7 ، و 20.5 ٪ مقارنة بدون استخدام البوليمرات وكذلك 2.2 و 3.8 و 5.4 ٪ مع نقص مياه الري بنسبة 25 ٪ مقارنة مع الكونترول بدون البوليمرات (100 ٪ من السعة الحقلية). أدى نقص الري إلى زيادة محتوى البرولين والفينول وتقليل الكلوروفيل الكلي .كما اظهرت النتائج تحسن فى قيم فيتامين (ج) ، والمواد الصلبة الذائبة الكلية ، ودرجة الحموضة ، والليكوبين ، ومحتوى العصير بشكل كبير مع تطبيق البوليمرات الطبيعية .أدى استخدام البوليمرات الطبيعية في ظل ندرة المياه إلى تحسين كفاءة استخدام المياه (WUE) في الطماطم.