

Potassium acrylate hydrogel as a substrate in cucumber and tomato cultivation

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Abstract

Agriculture is the basis of food, it develops in soil and hydroponics. Hydroponics is explained as crops without soil, in nutritive solutions, in the case of tomato and cucumber it is in substrate. Substrates have increased productivity, with efficient use of water and fertilizers. If agriculture consumes 70% of water and spending 30% is fertilizers, the objective of this work was to use potassium acrylate hydrogel for its ability to reduce the loss of fertilizers, such as reserving water, allowing to maintain tomato production and cucumber. The research was carried out in Querétaro in 2017. Different saturation capacities of the hydrogel were evaluated for its properties, the mixture of substrate and the yield of tomato and cucumber, finding significant differences.

Keywords: fertilizers, hydroponics, vegetables.

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The constant growth of today's society generates an increasing demand for food and natural resources, which according to Rittmann *et al.* (2011); Dabhi *et al.* (2013), should be doubled to allow this development. Agriculture, the basis of food, the most demanded resources are water, soil and fertilizers, at present they are in short supply and with considerable decrease putting pressure on food security. Hydroponics changed the use of soil for substrate with punctual irrigation to obtain greater yield and control of the crop. There is a large number of hydroponic substrates with which it seeks to maintain and increase production. An alternative is the use of potassium acrylate hydrogel to be used as a substrate in hydroponics.

The hydrogel is a super absorbent polymer of water and other aqueous solutions. Its use has been proposed for 40 years for agriculture due to its ability to increase available water and its absorption property when incorporated into soil or substrate (Montesano *et al.*, 2015).

Some studies show that hydrogels reduce soil erosion, decrease the loss of nutrients and have the ability to gradually release them, allowing plants to have a reserve of nutrients and water, according to the role of absorption-release cycles. Traditional acrylate-derived hydrogels are not biodegradable. According to patent ES2711655A1 potassium acrylate is suitable for agriculture, horticulture and soil care, the hydrogel allows to space the irrigation frequencies, releasing the water as the soil or substrate dries around the polymer, allowing to reduce consumption of water in agriculture.

The objective of this work was to characterize the porosity, water and nutrient absorption of potassium acrylate and to evaluate a mixture of potassium acrylate with coconut fiber in the productivity of tomato and cucumber, under greenhouse conditions.

The experiment was carried out in the first phase with the physical characterization of potassium acrylate and the mixture with coconut fiber, then the cultures were established in the substrate mixture in a 108 m² greenhouse. Characterization of the physical properties of potassium acrylate.

Potassium acrylate was obtained from the Distributor in Hacienda de la Peña, Queretaro, all solutions were prepared using well water with Nitrogen (2.1 ppm), Potassium (25.4 ppm), Calcium (26 ppm) and sulfur (35.5 ppm). Three treatments of 100% (1), 200% (2) Tipanta and Calvache, 2008) and 500% (3) were used in triplicate. The evaluation was carried out in a total time of 3 h with sampling every 30 min. The results were statistically analyzed with Anova and Tukey $\alpha = 0.05$, with MINITAB 2017.

Porosity was determined with bulk density (D_a) and real density (D_r) (Teres *et al.*, 1996), by the equation (Rodríguez-Macías *et al.*, 2010): $Pt(\%) = 100 * 1 - \frac{D_a}{D_r}$; where: $Pt(\%)$ = percentage of porosity; D_a = bulk density (g cm⁻³); D_r = actual density (g cm⁻³).

The water retention capacity of potassium acrylate was calculated with the initial mass of the acrylate (W_x) and the mass of the acrylate in the time after being dried at 30 °C (W_h), is the water absorbed in relation to the mass, using the following equation (Vallejo *et al.*, 2005):

$Q(t) = \frac{Wh(t) - W_x}{W_x}$; where: $Q(t)$ = water holding capacity; Wh = wet weight of potassium acrylate at sampling time (g); W_x = dry weight of potassium acrylate (g).

Absorption of nitrogen (N) by potassium acrylate. The absorption of nitrates (NO_3) and phosphates (PO_4) was determined with the Hanna MultiRangePhotometer HI 83203-02 kit. The organic liquid fertilizer Benefit Pz (Valagro) was used, which was analyzed as a control and the amount was added to the treatments in percentage for its analysis. Determination of the appropriate ratio of mixture of potassium acrylate and coconut fiber.

There were two controls for each substrate with 100% coconut fiber (C1) and potassium acrylate (C2); Treatments were: Treatment 1 (TA1) 1 75% AP and 25% FC, Treatment 2 (TA2) 50% AP and 50% FC, and Treatment 3 (TA3) 25% AP and 75% FC, each one in triplicate. The mixtures were saturated in water for 24 h, they were transferred to an ECOSHEL 9162 FCD-2000 oven, at 25, 30, 40 and 50 °C, for 3 h with sampling every 30 min. The same statistical analysis was applied, the treatment with the highest water retention was the one placed in the greenhouse.

Evaluation of water, nutrient and yield consumption in the hydroponic substrate mixture with tomato and cucumber cultures.

The seeds were from Los Molinos farm. A Decagon Devices model MAS-1 soil moisture sensor was placed in the greenhouse, an Arduino microcontroller was programmed when the irrigation pump was turned on. The substrate mixture was placed in 30 x 30 cm bags and the yield was estimated at 6 bunches for the tomato and 6 fruits for the cucumber, the experimental unit consisted of 15 plants.

Physical Properties of Potassium Acrylate

Porosity. The total porosity of potassium acrylate is shown in Figure 1a, where T1 had a higher porosity at 30 minutes, being the highest point of all treatments. The porosity of all the treatments decreased until it remained equal to the 90th minute. The porous space in the soils is of the order of 50%, in the same way Rente-Martí *et al.* (2018) reported a soil porosity of 54.7%, similar to that obtained at T1 after 90 min.

The pore fraction is necessary for the health of the root and the availability of nutrients, in the case of potassium acrylate, the porous space allowed the aeration of the root without interference of the water in the empty spaces due to the fact that it is it lodges in the internal matrix of potassium acrylate. Water retention. The result in T1 was 87.83%, in 2 of 125.44% and in 3 of 132% in its water retention capacity (Figure 1b). The significant treatment was T1, which represented having a lower absorption capacity, therefore it was defined for the experimental conditions that potassium acrylate is better in water retention at 200% or greater.

The water retention capacity of the acrylate depends on the physical characteristics of the substrate where the reported values vary from 50 to 77% by volume, being higher with 125%, due to the main characteristic of the acrylate, highlighting that it was below what stipulated by the supplier, this was due to the mineral salts of the well water, which took up space and in the end it was defined that it could absorb about 130 liters of water per kilogram of acrylate.

Nitrogen absorption by potassium acrylate. The T1 only had absorption until minute 60, so it was eliminated from the total statistical analysis, the Ts 2 and 3 had no statistical difference, the highest absorption that the absorption levels presented from 580 to 615 ppm, respectively (Figure 1c) on substrates for N: acceptable 40-99 ppm, optimal 100-199 ppm. These results were 5 times more absorption of N, this allowed to have a better management of the nutrients, reducing the risks of losses due to leaching due to the frequent and intense irrigation in hydroponics. On the other hand, plants are ineffective in absorbing supplied N, being under its assimilation and the rest is released to drainage (Cuadrado *et al.*, 2014), where the use of potassium acrylate is an alternative to keep fertilizers in the root for its subsequent absorption, more research is required to determine the retention-release processes at exact times and amounts of nutrients.

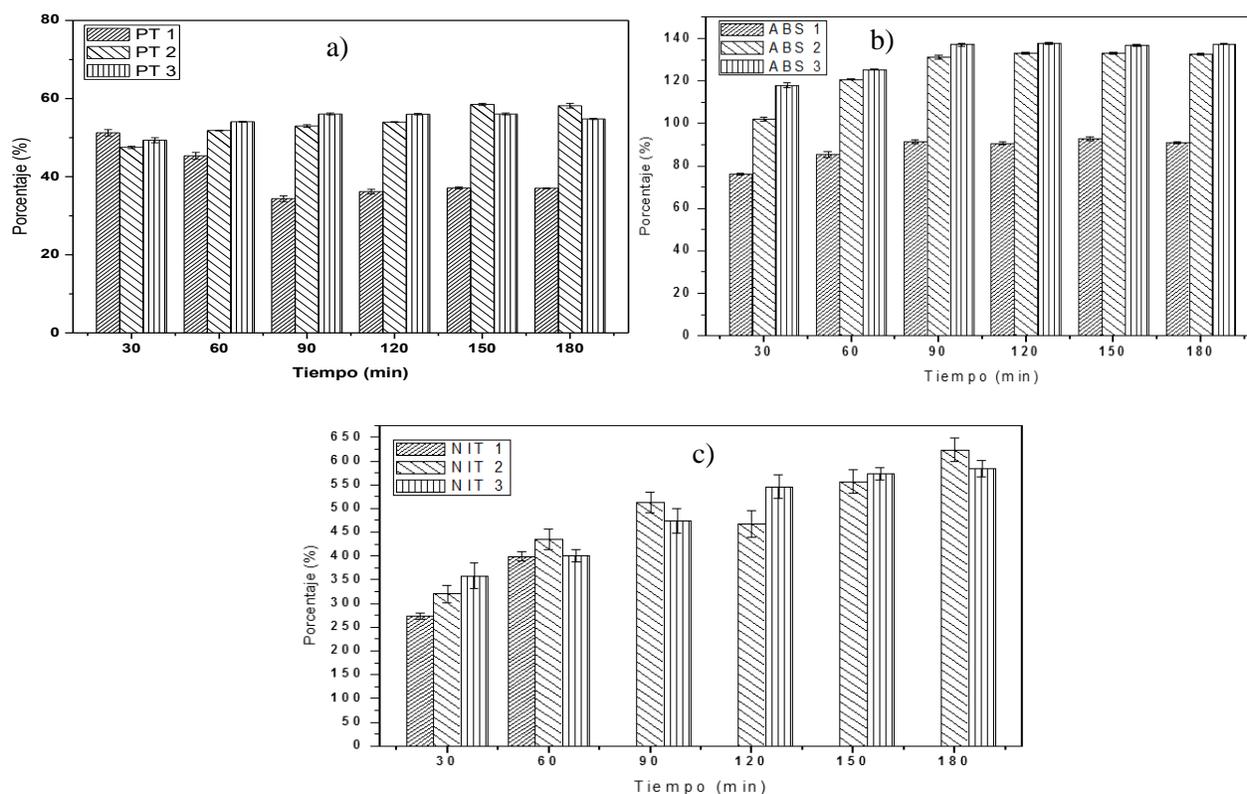


Figure 1. Physical properties of potassium acrylate in the different saturation treatments; a) porosity; b) absorption of well water; and c) nitrate absorption.

Mixture of potassium acrylate and coconut fiber in moisture retention. The result of the treatments was statistically different, which proved to be positive for a higher concentration of potassium acrylate. T1 retained the highest percentage of water and was therefore placed as a substrate in the greenhouse. The variability that existed can be explained by the basic moisture contents and the differences in the water absorption capacity between the mixtures by potassium acrylate.

In this study, the mixture of substrates that held water for the longest time was used under conditions of average temperatures for the semi-arid region of 30 °C. Super absorbent polymers are defined by the ability to absorb aqueous solutions in the presence of carboxylic groups that

allow wide plasticity (Zohuriaan-Mehr and Kabiri, 2008) and because of this they are used as ‘miniature water reservoirs’ (Oksi *et al.*, 2016). The characteristics of the substrates, such as water absorption, must be known before starting a cultivation cycle (Irigoyen *et al.*, 2009).

The union of the substrate mixture exerted a positive synergy because the coconut fiber at the beginning of the cultivation had a greater loss of water that is compensated by the absorption of potassium acrylate; This is explained in the reduction of the porosity that potassium acrylate had when it swelled due to its water absorption characteristic and the coconut fiber has adequate porous spaces for the cultivation to develop, this allowed the root to have the water buffer to its development.

Tomato and cucumber cultures in the mixture of potassium acrylate and coconut fiber

Water consumption. Good water management begins with the correct determination of the crop’s water needs. Water consumption for tomato cultivation was 86% and for cucumber 47%, this reported in literature for the same period (Figure 2) (Cajamar, 2006).

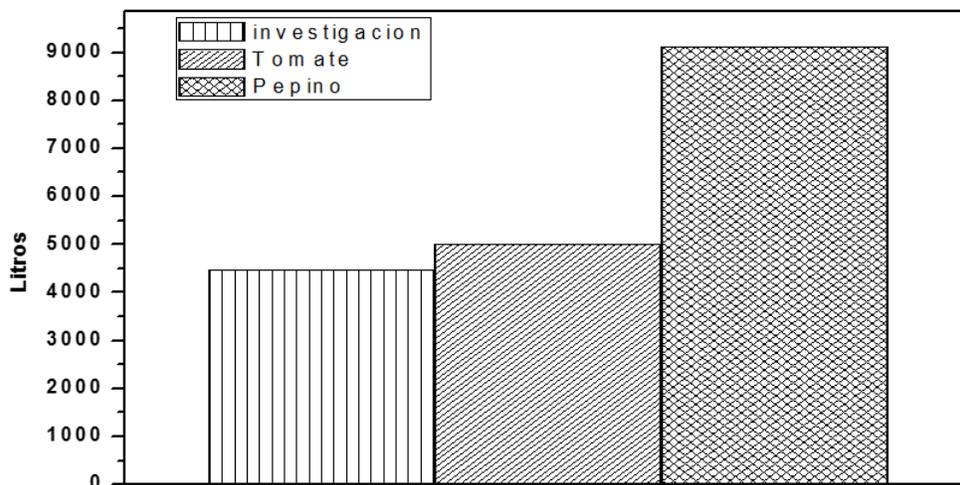


Figure 2. Comparison of water consumption for the cultivation of cucumber and tomato.

The use of the substrate mixture between coconut fiber and potassium acrylate can be considered as a friendly option in saving water; being reported by Montesano *et al.* (2015) used a cellulose-based hydrogel applied in sandy soil and obtained an increase in field capacity of up to 400% compared to normal soil, and the wilting point was similar in both soils, on the other hand, they evaluated a mixing the hydrogel with perlite, achieving an increase in water retention in the container of 28 and 48% more, similar to that obtained in this study. Shahid *et al.* (2012); Hemvichian *et al.* (2014) achieved positive effects in the application of acrylamide-derived hydrogels for plant growth and in reducing water stress, confirming the results of this research.

Nutrient consumption. There is a positive correlation between the consumption of water and fertilizers, a saving of fertilizers is shown, where the results have an average value of 747 ppm of nitrogen and 139 ppm of phosphorus per plant consumed at 105 dds (Figure 3). The greater the water consumption, the greater the fertilizer expenditure (Ortega *et al.*, 2016).

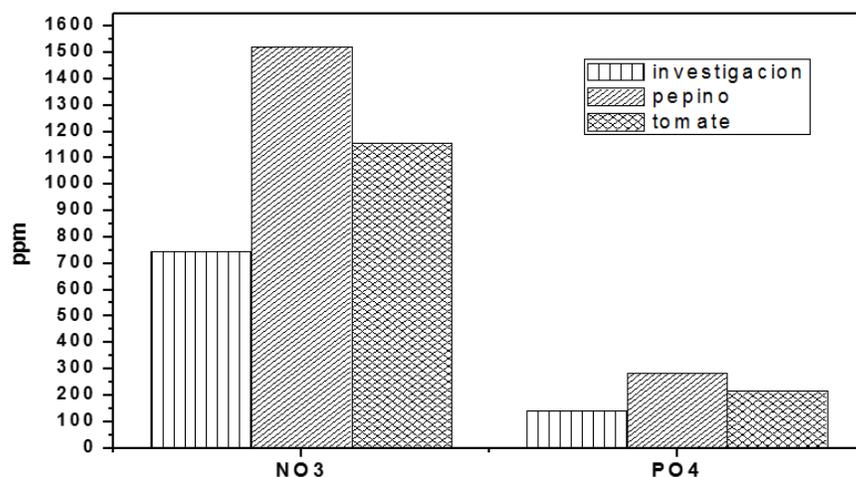


Figure 3. Comparison of the consumption of nitrates and phosphates in the cucumber and tomato culture.

Obtaining agricultural productivity with reduced nitrogen fertilizers is a great challenge (Bedoya and Salazar, 2014). In what was reported by Ortega *et al.* (2016) there was a low consumption of fertilizers in cultivation in mulched soil and a higher consumption of coconut fiber, this was due to its low nutrient retention. To promote the increase in yields in the use of hydrogel in hydroponics, it is necessary to contribute to changes in production systems, where technology and research must reach farmers to generate sustainability and economic improvements by reducing the cost of fertilizer.

Yield of the cucumber (*Cucumis sativus*) and tomato (*Lycopersum esculentum*) culture.

The results for the cucumber in average plant length was 200 cm, in the fruit a length of 23.0367 cm, with a diameter of 4.22 cm and a yield of 2.3 kg m², these results are according to the type of seed used and the cultivation season, under the semi-arid conditions of the Mexican shoal, the result for the yield variable was 3 plants m² (Figure 4).

The performance obtained was with values higher than that described by Marcano *et al.* (2012) with average weights of 157-201 g and close to the report of values from 271 to 422 g of the Poinsett 76 variety. It can be affirmed that the application of hydrogel in mixture with substrate will decrease the use of fertilizers, will improve the physical properties of substrates, water availability and yield (Ortega and Soto Zarazúa, 2017; Gholamhoseini *et al.*, 2018).

In tomato the results showed homogeneity in plant size, number and size of fruits, with an average yield of 4.7 kg plant, which is close to that reported with sawdust-compost substrate by Ortega-Martínez *et al.* (2016), which was 4 kg per greenhouse plant, the results for the yield were 6 plants m² for a total of 28.3 kg m² (Figure 4).

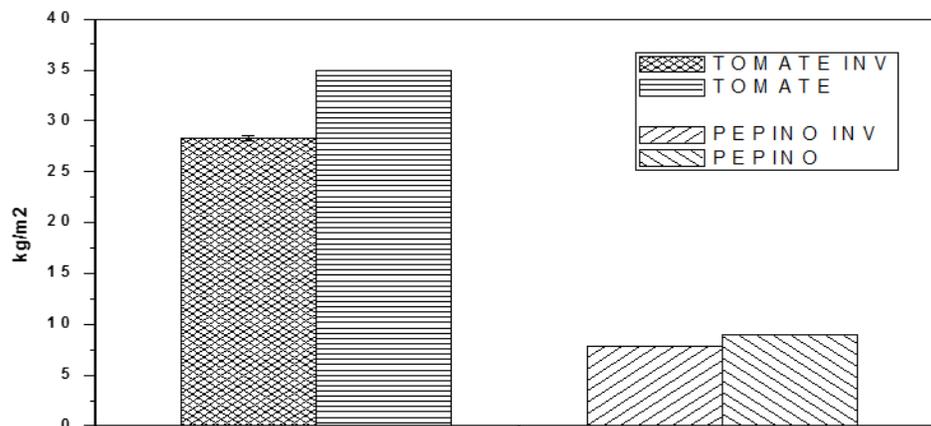


Figure 4. Cucumber and tomato yield.

In a study with hydrogel and cherry tomato under water stress, with the hydrogel they obtained an advantage over water stress due to the gradual release of water and avoided wilting due to water deficit, concluding their potential use in agriculture as water reservoirs (Madaghiele *et al.*, 2013), in the present investigation the performance obtained was achieved with the reduction of water and fertilizers, which translates into environmental economics.

The use of hydrogel in hydroponics and agriculture can be scaled for tomato varieties as in Bres and Veston (1993); Sayyari and Ghanbari (2012); Madaghiele *et al.* (2013) for the quality of the fruit, yield and to withstand the water deficit, aspects for the management of agricultural crops and the alternative of using hydrogels to enhance the use of water.

Conclusions

The application of potassium acrylate on substrate in greenhouse crops as in the case study for tomato and cucumber resulted in savings in water, fertilizers and economy. Substrate cultivation is usually an effective tool to increase crop yield, efficient use of water and reduce environmental impact. This system, which allows increasing the efficiency of water use while maintaining its quality, is an option to be implemented more intensively at any scale to support the economy and agricultural ecology.

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