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Greenhouse cultivation of Serrano pepper (*Capsicum annuum* var. *Acuminatum*): dry hydroponics

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ABSTRACT

Objective: To produce Serrano peppers using a new cultivation technique that mixes the best of hydroponic cultivation and traditional cultivation.

Design/methodology/approach: We set up a growing system where the Serrano pepper grew from seedling to its full-fledged state, in a growbag containing sand (as support material), potassium polyacrylate (as water retention material), and a nutrient solution for vegetable gardens, under greenhouse conditions. The humidity level of the growbag is controlled by adding as much water with nutrient solution as needed. This technique has generated 100% harvestable plants (total: 20 plants); more than 90% of the water can be saved in comparison to regular and hydroponic cultivation.

Results: Once the harvest began, at least 22.857 kg of Serrano pepper were obtained in 3 m² of soil in a system with a pyramidal structure in which the 20 plants were placed. If we extrapolated this data, approximately 93,000 kg of Serrano pepper could be harvested from a 1 ha system.

Study Limitations/implications: This technique tries to tackle the water access limitations that may exist in some areas of Mexico. However, it does not mitigate the initial costs of a greenhouse system. Nevertheless, this technique can be reused up to 10 times without requiring maintenance.

Findings/conclusions: Experience has shown that hydroponic crops are truly profitable, despite their vast water requirements, which is precisely what prevents their global expansion. However, our modification of this method saves more than 90% of the water, using potassium polyacrylate as a retention agent and sand as a support material. Therefore, this technique could be implemented even in places where water is scarce.

Citation: Velázquez-Carmona, M. Á., Méndez-Arenas, R., Valerio Cárdenas, C., De la Cruz-Burelo, P., & Silíceo-Rodríguez M. L. (2021). Greenhouse cultivation of Serrano pepper (*Capsicum annuum* var. *Acuminatum*): dry hydroponics. *Agro Productividad*. <https://doi.org/10.32854/agrop.v14i11.2018>

Editor in Chief: Dr. Jorge Cadena
Iñiguez

Received: April 30, 2021.

Accepted: October 21, 2021.

Published on-line: December 02, 2021.

Agro Productividad, 14(11). November 2021, pp: 115-121.

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INTRODUCTION

Hydrogels are cross-linked macromolecular hydrophilic polymer chains capable of absorbing water or aqueous fluids. The most commercially successful hydrogels are superabsorbent polymers, also known as SAP (Zhouriaan-Mehr *et al.*, 2010), which generally can absorb around 200-350 times their weight in distilled water, increasing proportionally in size.



An osmosis process delivers up to 95% of the retained water to the plant; its benefits include: a notable delay in wilting under hostile conditions; a greater growth of the species; and a tendency to decrease the volume of water required to maintain a crop. Hydrogels are being used in some crops, to provide plants with the water that their development requires during dry seasons —reducing up to 75% of the water used for irrigation— and to obtain other benefits —such as increasing the productivity and quality of the crops (Anonymous, 2008). The application of hydrogels in agricultural crops was first studied in Mexico by the agronomist Sergio Rico, who realized that, if water was added to a polymer powder, the resulting gel would be capable of absorbing up to 500 times its weight. This gel could be deposited next to the root of the plants, providing them the water they need for their development (Anonymous, 2021).

Competition for natural resources (soil and water) is intensifying. Climate change reduces the resistance of production systems and contributes to the degradation of natural resources. The expansion of the agricultural frontier for food production has a high environmental impact, as a result of the deforestation of forests, contributing significantly to climate change, as well as to the loss of soil fertility and production potential. From a sustainability perspective, controlled spaces influence the enhancement of plant production, contributing to the conservation of the soil and natural resources (FAO, 2020).

The objective of this research was to evaluate the water retention capacity of hydrogel in greenhouse cultivation, seeking an alternative that reduces the use of irrigation water in horticultural crops and offering a solution to grow crops in semi-arid, arid or infertile areas, as well as generating crops in confined spaces to make the most of small areas.

MATERIALS AND METHODS

The study site is located in La Venta, Huimanguillo, Tabasco, Mexico ($18^{\circ} 06' 43''$ N, $94^{\circ} 02' 24''$ W), at the Instituto Tecnológico Superior de Villa La Venta, which has a hot-humid climate, a 30°C average temperature, and a 2000-3000 mm annual precipitation (Climatología, 2021). The dry hydroponics technique proposed in this work was developed under greenhouse conditions. Temperatures were taken inside and outside the greenhouse with high precision Hanna Checktemp®1 thermometers. Moisture was measured with a CONDUCTRONIC PC18 hygro-thermometer. A Hanna potentiometer was used to measure the pH. The nutrient solution and potassium polyacrylate were used without modifications —just as they were received from the commercial provider—; recycling materials were used to complement commercially available materials.

The structure of the hydroponics technique was modified for this research. Traditionally large amounts of water are used regardless of the variation of the method used, but emphasis is made on flooding and drainage techniques, as well as root-in-water techniques —such as Nutrient Film Technique (NFT) and Deep Water Culture (DWC), described by Gravital Agency (2021). The technique was developed in a greenhouse with a curved roof and mesh walls; this type of greenhouse has a high solar energy transmittance (Agrovit, 2021).

A 3-m² pyramidal structure (1.5 m wide × 2 m long) was built to place 20 growbags with one Serrano pepper plant per bag. Each growbag contained 50% of sand that had been previously mixed with potassium polyacrylate (4g of SAP with 5Kg of sand and 1Kg of gravel). The seeds were extracted from a commercially available stock and were prepared for germination in agricultural foam. Once the seedlings were obtained, they were integrated into the dry hydroponics system, as part of which they were watered with a nutrient solution for vegetable gardens, the same solution used in traditional hydroponic systems. As a reference system, 20 Serrano pepper seedlings were placed in 20-L jugs with a nutrient solution that was renewed every week (1 seedling per jug).

The first tests were carried out in the experimental area of the Universidad Popular de la Chontalpa (UPCH), where 150 Serrano pepper seeds were sown in three different agricultural foam systems (Figure 1a, b). We decided not to buy standard seeds, because ideally this project should be applied in all the socioeconomic scales in the area, which include small households and little or no investment.

The germination of the seeds was 100% successful. This allowed us to establish a seedling management protocol, because an extremely hot climate can be very aggressive if the control system is neglected.

Structure of the dry hydroponics system

The experimental design was installed in 4 spatial distribution lines, on a 1.5 m (h) × 2 m (l) × 1.5 m (w) pyramidal structure (Figure 2a). The experimental system included a total of 20 plants (Figure 2b).

Hydroponic system structure (reference system)

Recyclable materials (20-L jugs) were used for the hydroponic system. A 10-cm hole was cut on one side to introduce water and plants. They were previously disinfected with chlorine, detergent, and tap water. Subsequently, 20 L of water were poured in each jug. Twenty ml of nutrients for vegetable gardens were used per jug. A 3-L bottle cut in half—in

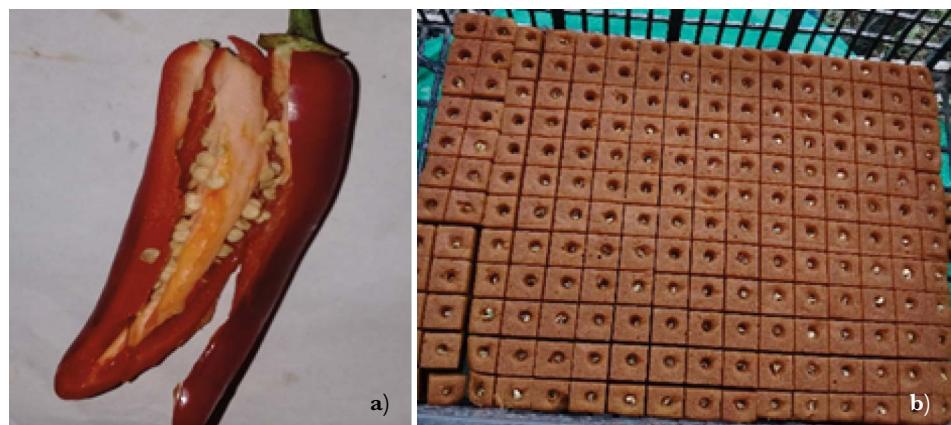


Figure 1. a) Seeds obtained from commercially-available fruits, b) Seed germination.

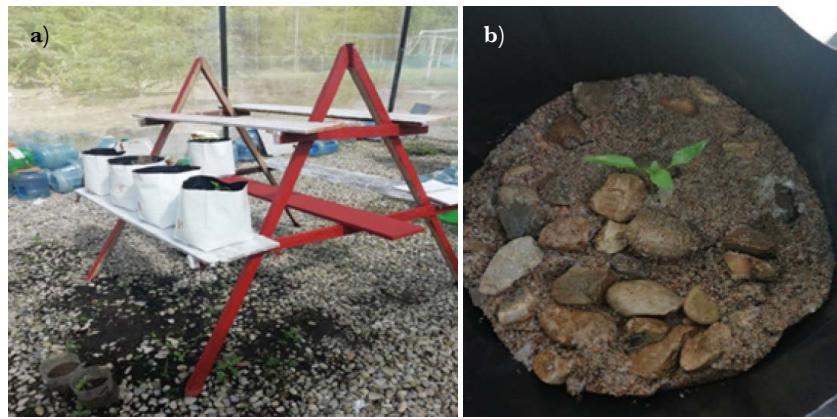


Figure 2. a) Pyramidal structure, b) Transplanted seedlings.

which a small hole was made in the lower part— was used to hold the plant. A total of 20 repetitions were carried out.

In other words, 10 3-L PET bottles were reused; they were cut in half (Figure 3a); a 2-cm hole was made in the lower part of the bottle to introduce the plant and to function as its support; finally, it was inserted in the jug that contained the abovementioned mixture (Figure 3b); the root floated on its surface.

RESULTS AND DISCUSSION

Irrigation is the most important part of the dry hydroponics technique. Table 1 shows that 20 L of the nutrient solution were added to the entire system every 4 weeks (1 L per growbag).

The results were encouraging after the end of the growing and irrigation period, up to 98% of the water was saved. Only 60 L of nutrient solution were used to grow 20 plants, while the traditional hydroponics reference system spent an average of 264 L per week for 13 weeks (total: 3440 L). One concern at this point is that, to maintain enough humidity



Figure 3. a) Section of the seedling support and b) Seedling in the support.

Table 1. Irrigation plan for the dry hydroponics system and the reference system.

Week	Dry hydroponic	Hydroponic
	Irrigation (L)	
1	20	400
2		400
3		400
4		360
5	20	360
6		320
7		300
8		260
9		200
10	20	160
11		140
12		100
13		40
	Total: 60	Total: 3440 L

for the healthy development of the plants, the average humidity measure should be 80% from the first day to the harvest. This is a major concern, since a hectare of traditional cultivation requires about 24,000 liters of water in a drip system—which is one of the most efficient systems (Horacio *et al.*, 2010).

In this work, in addition to temperature and humidity, the pH of different parts of the growbag was measured. Both systems maintained a practically neutral pH of 6.73 and 6.77 for dry hydroponics and for the reference system, respectively. This is significant, because the Serrano pepper has a 5.5 and 7.5 pH range in which it can develop without any problem (Robinson, 2014). Additionally, the color, leaf size, and stem of each plant were recorded in order to determine if water control had had any kind of impact on the plants. These measurements did not show any impact, only completely healthy plants. However, the reference system had yellowish leaves before the water changes. Therefore, we concluded that water control should be carried out in shorter periods, thus causing a greater water expenditure.

Before discussing harvest yield, we must mention that the harvest fruit seemed to be ready a couple of weeks before the average harvest time. Table 2 shows that three important harvest exercises took place: 22.85 kg of Serrano pepper were obtained.

The production in the dry hydroponics system obtained the expected result: implementing potassium polyacrylate in the inert system as a water retention agent provided the plants with the humidity they required for their development and production. Additionally, 100% of the plants achieved a successful development; this is a much better result than the one obtained by the plants of the hydroponic system of reference —of which only 2 out of 20 bore fruits, at the time of harvest.

Table 2. Serrano pepper harvest record in a dry hydroponics system.

Number	HS1 harvest	HS2 harvest	HS3 harvest
	Weight (g)		
1	612	340	329
2	488	460	321
3	700	315	356
4	601	235	322
5	597	399	221
6	700	301	335
7	620	220	202
8	650	200	250
9	470	345	307
10	600	205	290
11	500	532	357
12	400	218	283
13	350	430	337
14	220	300	284
15	300	242	263
16	350	398	284
17	180	444	227
18	250	266	243
19	460	609	691
20	322	701	425
Partial	9370	7160	6327
Total	22857		

CONCLUSIONS

According to the results obtained in this greenhouse project with practically constant temperature, pH, and humidity conditions, we conclude that the use of potassium polyacrylate as a water retention agent to grow Serrano pepper, combined with this dry hydroponics technique—which does not require fertile soil, because sand and gravel can be perfectly used as support agents—is an excellent alternative to develop an important agricultural culture in arid and semi-arid areas.

Irrigation water was saved, since only 60 L of water with nutrients for vegetable gardens were applied, providing an excellent humidity, temperature, and pH environment. As a result, 100% of the Serrano pepper plants grew perfectly healthy. We must also highlight that the Serrano pepper was chosen as test plant because it is not locally produced; it is brought from the north of the country, thus increasing its costs. This study will offer local producers an efficient technique in the near future. A 22.85 kg production of Serrano pepper was obtained, representing a competitive production quota in a market that depends on non-local production. This work aims to consolidate the dry hydroponics technique... but there is still much work to be done.

ACKNOWLEDGMENTS

The authors would like to thank Cintya Valerio Cárdenas (ScD) and Patricia de la Cruz Burelo (ScD) for their unconditional support and valuable collaboration in the development of this work. They would also like to thank the Instituto Tecnológico Superior de Villa La Venta for their support for this project.

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