Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Investigation of the efficiency of wicks irrigation system for greenhouse crops

Mohammad Reza Nouri Emamzadei
Shahrekord Univ. Shahrekord
Reyhaneh Mohammadi
Shahrekord Univ. Shahrekord
Ahmad Reza Ghasemi
Shahrekord Univ. Shahrekord
Abdolrahman Mohammadkhani
Shahrekord Univ. Shahrekord
Kaveh Ostad-Ali-Askari
kaveh.oaa2000@gmail.com

Isfahan University of Technology
Hamid Raeisi Vanani
Shahrekord Univ. Shahrekord

Short Report

Keywords: Wick Irrigation System, Planting Bed, Greenhouse Plants, Water Consumption, Water Use Efficiency, Root Dry Weight, Bed of Soil

Posted Date: February 25th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-8957663/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Investigation of the efficiency of wicks irrigation system for greenhouse crops

Mohammad Reza Nouri Emamzadei[1], Reyhaneh Mohammadi[2], Ahmad Reza Ghasemi[3], Abdolrahman Mohammadkhani[4], Kaveh Ostad−Ali−Askari[5*], Hamid Raeisi Vanani[6]

[1]Water Engineering Dept., Faculty of Agriculture, Shahrekord Univ. Shahrekord, Iran.

[2]Water Engineering Dept., Faculty of Agriculture, Shahrekord Univ. Shahrekord, Iran.

[3]Water Engineering Dept., Faculty of Agriculture, Shahrekord Univ. Shahrekord, Iran.

[4]Horticulture Dept., Faculty of Agriculture, Shahrekord Univ. Shahrekord, Iran.

[5*]Department of Civil Engineering, School of Engineering, American University in Dubai, Dubai, 28282, United Arab Emirates.

E-mail: kaveh.oaa2000@gmail.com (*Corresponding author) ORCID: 0000-0001-5637-1124

[6]Water Engineering Dept., Faculty of Agriculture, Shahrekord Univ. Shahrekord, Iran.

Abstract

A. Objective

This study was conducted to investigate the efficiency of wick irrigation system for greenhouse crops as a factorial experiment in a completely randomized basic design with two factors wick type and planting medium in four levels and three replications in the research greenhouse of Shahrekord University.

B. Methods

For this purpose, the traits of total fresh and dry weight of shoot, average stem diameter, root dry weight, pH, soluble solids, RWC, vitamin C, fruit dry weight, fruit yield and water use efficiency were measured.

C. Results

The analysis of variance results indicated significant main effects and interaction effects of wick type and planting medium on various plant growth and yield indices. Water consumption was found to be significant at 5% and 1% confidence levels. However, the main effect of wick type on relative water content and substrate type on pH, as well as the interaction effect on several parameters, were not significant. The most favorable outcomes were observed with a specific substrate and wick type combination.

D. Conclusion

Therefore, the use of woven wire and wicks in the soil + cocopeat + fertilizer + perlite substrate increases plant water consumption as well as quantitative and qualitative characteristics of bell pepper.

Keywords

Wick Irrigation System; Planting Bed; Greenhouse Plants; Water Consumption; Water Use Efficiency; Root Dry Weight; Bed of Soil;

List of Abbreviations

RWC: Relative Water Content

WUE: Water Use Efficiency

pH: Potential Hydrogen

FC: Field Capacity

FW: leaf fresh weight

DW: Dry Weight

SAS: Statistical Analysis System

LSD: Least Significant Difference

Introduction

In recent decades, due to the increasing water crisis, it is necessary and necessary to use modern irrigation methods to increase the efficiency of water consumption and preserve water resources. The new wick irrigation technique has the ability to be developed to meet the irrigation needs of plants, especially greenhouse plants. The cultivation environment of ornamental plants or home vegetables is very limited and will definitely have a limited water holding capacity. The existence of these conditions requires that the watering of these plants should be done with short frequency and in a small amount. Continuation of these conditions will require spending a lot of time and energy. The use of wick irrigation system can largely solve the problem of the lack of water storage capacity of the cultivation environment, because in this system, the water storage container required by the plant is separate from the cultivation environment and can have a desired capacity. Therefore, frequent and daily watering operations can be reduced and in one step, the water required for several days can be provided to the plant. In order to support the desired growth of plants, the growth environment should provide nutrients and water to the plant in an appropriate way. In order to provide the required moisture, irrigation is one of the main and important parts of greenhouse management. Improper irrigation in the greenhouse reduces the quality and quantity of the product, so it should be done scientifically and by specialized personnel. It is very necessary to make sure of the appropriate time intervals between each irrigation and the amount of water, and there are many and complicated factors such as the cultivation environment, radiation, plant type, growth period, ventilation and water needs of the plant. The results show that wick irrigation can be useful for smallholder farmers for greenhouse crops and it can be called as a low-cost and highly efficient irrigation system by improving water efficiency (Roonjho et al., 2022). Water use management has become a basic and important issue for improving agriculture. With the correct management of water and soil and the use of advanced techniques, limited water resources can be used optimally. In this regard, in dry

areas, various measures can be taken to preserve and store water in the soil. The amount of water that is lost due to evaporation from the tanks, which have a relatively large surface, is sometimes more than the amount of water that is used to produce the product (Kang et al., 2017). Failure to properly manage the irrigation system in the greenhouse will cause problems. Estimating low water demand and as a result, applying low irrigation causes symptoms such as growth stoppage, smaller leaves, shortening of the distance between nodes, deformity and falling of leaves, burning of leaf margins and reduced yield. to be On the other hand, excessive watering, in addition to increasing the soil moisture and the moisture under the greenhouse cover, also causes a decrease in the passage of light into the greenhouse. As a result, plants suffer from problems such as height increase, the stem becoming watery and soft and brittle, reducing soil oxygen, damaging the roots, and not absorbing water and nutrients, and eventually withering and stopping growth (Nikolaou et al., 2019). Correct and accurate estimation of the water requirement of greenhouse plants in order to have a good and effective management in irrigation under controlled greenhouse conditions is inevitable (Abioye et al., 2020). Considering the arid and semi-arid climate such as Iran, water plays an important role in determining the type and composition of agricultural activities as one of the limiting factors of production (Araya et al., 2017). Lack of water is one of the most important limiting factors for plant growth, which reduces the amount of dry matter and the quality of the product (Zegbe-Domínguez et al., 2003 and Kabir et al., 2021). In the wick irrigation system, water is directed from a reservoir into the cultivation environment by capillary movement. This irrigation system, which can be used mainly for greenhouse and ornamental plants, is more responsive than conventional irrigation systems in terms of saving time, water consumption and cost (Al-Mayahi et al., 2020 and Roonjho et al., 2022). One of the most important advantages of using this system for watering greenhouse plants is that, in addition to saving time and money, this system can increase the productivity of water and nutrients (Chaturvedi et al, 2021 and I.S, 2003). By using the wick irrigation system, the quality of production

products has increased and in terms of controlling direct evaporation and humidity and preventing depth losses, it can cause higher efficiency and productivity (Bainbridge, 2002; Felipe and Bareng, 2022; Bhayo et al, 2018 and Heidari et al, 2022). This system can also be used for semi-hydroponic cultivation, in which case the wick itself can be considered as the cultivation environment and receive water and nutrients from the storage tank associated with it (Ferrarezi, 2012). During a research in Kenya, 5 different species were used for wick irrigation system. The selection of these materials was based on the three criteria of water holding capacity, water absorption pattern and maximum capillary height. Based on the results of this work, the wicks produced from the combination of linen and polyester materials had the best absorption pattern and maximum capillary height. Pure linen and pure polyester wicks were not prioritized for this purpose (Wesonga et al, 2014). During the experiment, the efficiency of wick irrigation system for lettuce production was investigated and compared in three different cultivation environments. Based on the results of their work, wick irrigation in all three environments significantly improved the quality and performance of the production (Ferrarezi & Testezlaf, 2016). The wick irrigation system has been used in clay pots in India. In this way, one or more holes were placed in the buried clay pot and cotton wicks were placed in the holes. The wick provided water from a fixed source slowly to the plant and caused the expansion of root and plant growth (Mari Gowda, 1974). Various factors, such as the amount of water and suitable cultivation substrate, are very important in the relationship between the plant and the physical environment. Cultivation of plants in cultivation beds instead of soil is expanding due to many advantages such as the possibility of optimal control of plant nutrition, reducing the incidence of diseases and pests, and increasing the quantity and quality of the product compared to soil cultivation (Maloupa et al, 2001). For the successful production of vegetables in soilless cultivation in greenhouses, it is necessary to have sufficient food reserves in different cultivation substrates at different stages of growth (FAO, 2013; Savvas and Gruda, 2018; Fussy and Papenbrock, 2022). Cultivation of

greenhouse vegetables in organic substrates is more common. Today, in these systems, different materials are used as planting substrate, each of which has unique characteristics (Colla et al, 2003). These materials include organic, mineral and synthetic materials, which should have high water retention capacity, sufficient ventilation, proper drainage and high cation exchange capacity, and should not have any adverse effects on the plant (Ghasemi et al, 2010). Capsicum with the scientific name (Capsicum annum L.) is an annual plant belonging to the Solonaceae family, whose main habitat is Mexico and South America (Sanatombi and Sharma, 2007). This plant has very valuable medicinal properties and is used in the treatment of many diseases, including heart diseases, high blood pressure, and obesity (Sanati et al, 2018). Capsicum is a herbaceous plant with sympodial stems that grows in small or large form and is useful in terms of economy and consumption and maintaining human health (Mongkolporn and Taylor, 2011; Tripodi and Kumar, 2019). In this research, the effect of wick irrigation on the growth of this plant has been investigated.

Materials and Methods

This research was conducted in the research greenhouse of the Faculty of Agriculture of Shahrekord University. The experimental area has a semi-arid climate with a geographical longitude of 50°51' east and latitude of 32°20' north and an altitude of 2061.4 meters above sea level. To investigate the responsiveness of the wick irrigation method, bell pepper plants were grown in different environments and irrigated by wick method in each environment. The mixtures of cultivation medium are given in the introduction section of the design treatments. Plant cultivation in this experiment was done in plastic pots with dimensions of 60×35×40 cm. This research was carried out as a factorial experiment in the form of a completely random basic design. The experimental treatments included four types of soil mixture and two traditional and wick irrigation methods. In the wick method, three different types of wick materials were used, including worsted thread, linen thread and linen-cotton thread with a constant density (Fig. 1).

The selection of wick materials was based on properties such as water holding capacity, water absorption pattern and their maximum capillary height. The specifications of the design treatments are given in Table 1 and are briefly introduced.

In this research, "Lomos" bell pepper plant was used. Cultivation media included a) a combination of soil, sand and animal manure in equal proportions b) a combination of soil, cocopeat, manure and sand in equal proportions c) a combination of soil, cocopeat, manure and perlite c) cocopeat, manure and perlite . Considering three repetitions for each experimental treatment, the number of test pots was 48 pots. The water used in this project was drinking water of Shahrekord University. During the cultivation period, there were all operations and harvesting was done in the same way according to the agricultural recommendations for all treatments (Fig. 2).

In table 2, the humidity limits of different cultivation substrates are given.

How to irrigate and calculate the amount of water used

The water required by the bell pepper plant was measured by volume by humans and was provided to the plant at each turn in the tank installed under each pot (Fig. 3).

The amount of water used in treatments without wicks was measured by measuring the amount of moisture in the soil and in order to meet the water requirement up to the FC moisture limit. Thetaprobe device was used to measure the amount of water in the cultivation environment.

Measurement of Investigated Traits

In order to measure the total dissolved solids, first the fruit extract was prepared by a juicer, and then the amount of dissolved solids was read using a hand-held refractometer in terms of Brix percentage (Burton, 1982; Lieberman, 2012). To measure titratable acid, 0.1 normal sodium titration method was used. First, the fruit extract was prepared and then it was brought to a concentration of 10% with distilled water. 20 cc of 10% fruit juice was poured into Erlenmeyer flask and 2-3 drops of phenolphthalein reagent were added to it and titrated with

the help of soda. The pH was calculated using a pH meter (Tyl and Sadler, 2017). To measure relative water content, the youngest developed leaf from the pepper plant of each treatment was randomly 0.1 gram separated from each leaf was separated and considered as wet weight. Then the samples were placed in distilled water for 6 hours. After that, the samples were dried with a napkin and weighed again (Fig. 4).

The resulting weight was considered as the saturated weight of the leaf. Then the samples were placed in the oven at 75 degrees Celsius for 24 hours and the final weight of the dried samples was measured. The relative water content of leaves was calculated from Equation (1) (Hunt et al, 1987; Yamasaki and Dillenburg, 1999).

$$RWC\% = [(FW - DW)/(TW - DW)] \times 100 \quad \text{Eq. (1)}$$

Where:

RWC: relative leaf water content %

FW: leaf fresh weight (grams) immediately after sampling

DW: dry weight of leaves (grams) after placing in the oven

TW: saturated leaf weight (gram) after exposure to distilled water

In order to measure vitamin C, one bell pepper was randomly picked from each plant. The extract of each treatment was prepared separately with a juicer and passed through a strainer. Vitamin C was determined in potassium iodide in the presence of 1% starch reagent. In this way, 10 ml of 0.01 normal iodine was poured into a 100 ml flask and 1.6 g of potassium iodide was added to it, and the flask was made up to volume with distilled water. To prepare 1% starch, 1 gram of starch powder was poured into a 100 ml flask and a few ml of cold distilled water was added to it and the starch was dissolved in it. Then, 90 ml of boiling distilled water was added to it, and it was stirred until a clear solution was obtained, and finally, it was made up to volume with distilled water. To determine vitamin C, 5 ml of juice was poured into a 250 ml beaker and about 20 ml of distilled water was added to it. In the last step, it was titrated using iodine solution in potassium iodide with 2 ml of 1% starch until the color change of the sample solution was determined to pus blue color. The amount of vitamin

C was calculated from equation (2) (Ballentine, 1941).

$$Ascorbic\ acid\% = \frac{0.88 \times v}{The\ volume\ of\ fruit\ juice} \quad \text{Eq. (2)}$$

Ascorbic acid: the amount of vitamin C in milligrams per 100 ml of juice.

V: volume of iodine in potassium iodide consumed in milliliters.

In calculating the efficiency of water consumption, the performance per unit area is divided by the amount of water consumed and the resulting value is used as an index for prioritization. The obtained value is expressed in kilograms per cubic meter. In most of the completed studies on the efficiency of water consumption, only the relationship between water consumption and production and its value has been discussed, while in a production system, besides the water input, there is a need to use other inputs as well, which in Such studies are ignored. As a result, it is better to have a better view of the efficiency of water consumption by using methods that simultaneously examine other production inputs along with water consumption (Olgarenko et al, 2018). Equation (3) was used to calculate water consumption efficiency.

$$WUE = \frac{D_W}{V} \quad \text{Eq. (3)}$$

WUE = water use efficiency (kg/m3)

D_w = mass of dry matter (kilogram)

V = volume of water used (cubic meters)

Statistics of the data were done with the help of SAS software and the comparison of the average data was done with the LSD test at the 5% level. Excel software was used to draw graphs and tables.

Results and Discussion

The summary of variance analysis results is presented in Table 3.

Wet and dry weight of aerial parts

The results of variance analysis of the data show that the effect of planting beds, wick type

and the interaction of wick type and planting beds on the fresh weight of the entire shoot is significant at the 1% level (Table 3). Fig. 5 shows the highest wet weight of the whole shoot in soil+cocopeat+fertilizer+perlite with wire (F4S3) and braided (F3S3) wicks. The soil+fertilizer+sand substrate with cotton wick (F2S1) had the lowest wet weight of the whole shoot. Fig. 5 shows comparison of the average wet weight of the whole shoot.

In order to evaluate the possibility of using coarse sawdust and the effect of adding bentonite and pumice to it on the vegetative growth of Inspratian red bell pepper, they showed that the highest fresh and dry weight of aerial parts after common peat + perlite was related to sawdust treatment 85 Pumice + 15% and the lowest fresh and dry weight of the shoot was related to sawdust treatment 85% + bentonite 15%. Also, the results showed that the fresh and dry weight of aerial parts of all treatments were not comparable in comparison with common peat + perlite substrate (Barzgarhfashjani et al, 2014). They showed that the culture medium had a significant effect on the fresh weight of aerial parts. The highest and lowest wet weight of the aerial part (11 grams) was observed in the fifth (cocopeat 50%, peat 25%, vermicompost 25%) and sixth (cocopeat 50%, peat 25%, perlite 25%) beds, respectively (Mirabi et al, 2015). In this study, the substrate (S3) with various types of wicks had the highest fresh weight of aerial parts. Based on the results of various researches, the presence of organic materials and high cation exchange capacity has increased the capacity to absorb and retain nutrients and water, and by creating suitable conditions for the growth of plant roots, it has increased the quantitative and qualitative characteristics of the flower, as well as sand or perlite. They are not suitable alone because of their low cation exchange capacity (Tolai, 2001). In addition, sand and perlite, alone or in combination, due to the presence of different salts, increase the salinity of the bed, which will make the bed unsuitable and increase the need for washing and, as a result, increase the cost (Khalaj, 2007). The results of data variance analysis show that the main effects of substrate type and wick type, as well as the first-order interaction effect of substrate and wick at the 1% confidence level, have a significant effect on shoot dry weight

(Table 3). Comparison of the average interaction effect of substrate type in the wick (Fig. 6) showed the highest dry weight of shoot in soil+cocopeat+fertilizer+perlite substrate with wire wick (F4S3) and braided wick (F3S3) with an average of 25.8 and 23.4 grams respectively. It shows the highest dry weight of shoot in the bed of cocopeat + manure + perlite with fiber wick (F4S4) and the average is 1.5 grams.

Fig. 6 shows comparison of the average dry weight of the entire shoot.

In a research, it was reported that the use of peat moss and perlite increases the dry weight of tomato shoots. Also, in planting beds that have a lower percentage of porosity due to the reduction of water holding power, the growth of the aerial organs of the plant decreases in the experiment they conducted on tomatoes (Pill and Goldberger, 2009). In another study, the highest amount of dry weight of the aerial part was observed in the 2.3 and 1.3 vermicompost treatments of Azolla residues, which showed an increase of 82.7% compared to the peat + perlite treatment (Rasouli Sedghiani, 2015). The researchers showed that the dry weight of the aerial part in the bed (peat 50%, cocopit 25%, vermicompost 25%) and (cocopit 50%, peat 25%, vermicompost 25%) had the highest dry weight of the aerial part and in this respect the difference They were significant with other substrates at the probability level of 1% (Mirabi et al, 2015). Studying and investigating the combined effect of particle diameter and amount of perlite in the form of a potted research project on the water holding capacity in the soil and the yield of the wheat crop showed that the use of perlite in the soil increases the dry matter and reduces the water required by wheat (Munsuz, 1987). In this study, the substrate (S3) with braided and yarn wicks increased the dry weight of aerial parts. Since the production of hormones is under the influence of food, perlite, cocopeat and fertilizer mixed with soil can increase growth stimulating hormones and as a result increase the amount of dry matter. Perlite improves the ventilation of the soil due to its properties of accelerating drainage and also reduces the drying rate of the soil (Cook and Dunsby, 1978; Munsuz et al, 1985). The reason for the increase in dry matter is the presence of suitable physical conditions and

nutritional factors in the cultivation environment in the beds (Atiyeh et al, 2002).

Average Diameters

The results of data variance analysis (Table 3) show that different planting beds, wick type have a significant effect at the 1% probability level on the average stem diameter. The interaction effect of substrate type with wick had no significant effect on the average diameters. Considering that the variance of the interaction effect of the diameter of the beginning of the stem was not significant in the type of wick and the planting beds, but the highest average diameters in the bed of soil + cocopeat + fertilizer + perlite with braided wick (F3S3) and wire (F4S3) with an average of 7.8 and 7.4 mm and the lowest average diameters in the bed of soil+fertilizer+sand and cotton wick (F4S4) with an average of 5.001 mm was obtained (Fig. 7).

In the comparison of different planting media on the performance and quantitative and qualitative characteristics of Puma chrysanthemum in two hydroponic and aquaponic systems in cocopeat: perlite planting media with ratios of 0:100, 25:75, 75:25, 0:10, they reported that The highest diameter of the chrysanthemum stem was observed in the mixture of cocopeat and perlite and the lowest diameter was observed in the 100% perlite (Alaei et al, 2013). In evaluating the effect of different organic and mineral substrates and determining the most suitable substrate in soilless cultivation on the vegetative characteristics of two lily varieties in greenhouse conditions, ten different types of organic and mineral substrates, cocopeat, sand, vermiculite, perlite and two-to-some composite substrates Two with ratios (50:50) from each of them reported that planting beds had a significant effect on stem diameter. The maximum stem diameter was recorded for both Sabdazel and Berini cultivars in cocopeat and perlite + cocopeat substrates and the lowest in vermiculite and vermiculite + sand (Nik-Razm et al, 2018).

Root Dry Weight

The results of variance analysis data (Table 3) show that the main effect of substrate type and wick type, as well as the interaction effect of substrate and wick at the 1% probability level,

have a significant effect on root dry weight. Comparison of the average interaction effect (Fig. 8) of the highest and lowest root dry weight in soil+cocopeat+fertilizer+perlite with cotton wick (F2S3) and soil+fertilizer+sand with cotton wick (F2S1) with wick cotton (F2) and showed an average of 11.1 and 4.5 grams. In evaluating the effects of planting bed and irrigation cycle on seedling growth indicators of tomato cultivars in greenhouse conditions in planting beds (peat, cocopeat and garden soil), they stated that the three planting beds are not significantly different from each other. In this case, seedlings obtained from hybrid seeds and planted in porous beds had better conditions (Aghavani-Shajari et al, 2013). In the study of perlite, perlite and peat moss in the ratio (1:1), perlite and vermiculite in the ratio (1:1) on the growth and yield of tomato, it was observed that the culture medium had a significant effect on the root dry weight has had (Hajiaghaei-Kamrani et al, 2013). Cultivation substrate as a plant holder and root protector plays an important role and provides food and oxygen for plant activities, so that it has a direct effect on the production of the root system, therefore, the water and mineral nutrition of the plant it affects and then the metabolic activities of the whole plant are affected. It seems that a bed that has a greater capacity to hold water provides better growth conditions for the plant by providing water and nutrients until the next irrigation. The use of wick has increased the dry weight of bell peppers by maintaining soil moisture, keeping the root environment cool and creating favorable conditions for growth. Root growth is less affected than shoot growth in dry conditions. It has been reported that in the conditions of drought stress, the nutrients obtained from photosynthesis are more available to the roots, and it causes an increase in the dry weight ratio of the root to the shoot, which is due to a greater decrease in the growth of the shoot compared to the root (Gruda, 2019; Krishnamurthy et al, 2003). In response to drought, some plants increase the amount of water absorption by preserving the roots (Ghorbanli et al, 2001).

pH

The results of variance analysis data in table (3) show that only the main effect of wick type

has a significant effect on pH at the 1% probability level. The type of substrate and substrate interaction in the wick had no significant effect on pH. pH is one of the important quality parameters of fruit. Fig. 9 showed the highest and lowest pH in the cocopit+fertilizer+perlite substrate with braided wick (F3S4) and the soil+fertilizer+sand substrate (F1S1). Increasing the pH of the substrate will cause more acid consumption to regulate the pH in the appropriate range for the plant.

They reported that different cultivation substrates have no effect on the quality characteristics of cucumber fruit (Shaw et al, 2004). In order to determine a suitable alternative substrate for peat, an experiment was conducted using different plant wastes in four 100% peat treatments as a control, peat + dry pine leaves (1:1 by volume), peat + carbonized rice husk (1:1 by volume) and peat + Sawdust (1:1 by volume) that different substrates did not show any significant effect on vitamin C and fruit acidity. The researchers related the reason for this to the low cation exchange capacity of the substrate (Mami et al, 2008). With the aim of investigating the effect of different cultivation substrates on the absorption of nutrients and the quantitative and qualitative performance of greenhouse strawberries in perlite-cocopeat mixed substrates with volume ratios of 25-75% and 50-50%, they showed that the planting substrate affects the pH of the fruit. Strawberries were not significant (Dilmaghani-Hasanloui and Hemmati, 2011).

Soluble Solids

The results of table (3) analysis of the variance of dissolved solids show that only the main effect of the type of wick has an effect on the amount of dissolved solids at the probability level of 1%. The effect of planting beds and the mutual effect of planting beds and wick type on dissolved solids had no significant difference.

The results of the research show that in bag cultivation, different cultivation substrates such as soil, perlite, peat, sand, pumice alone and in different combinations have been investigated on the quality and quantity of tomato cultivation without soil and there is a significant difference

between The studied substrates were observed in terms of dissolved solids (Alan et al, 1994). The highest amount of soluble solids was observed in the interaction between the type of wick and substrate (Fig. 10) with an average of 7.467 in the treatment without wick and soil+cocopit+fertilizer+perlite (F1S3) substrate. The researchers stated in the investigation of the effect of several types of nutrient solution and planting medium in the hydroponic system on the quantitative and qualitative characteristics of "Hamra" greenhouse tomato and planting mediums (perlite, perlite + agricultural soil in equal proportions, compost + perlite in equal proportions, agricultural soil) + compost in equal proportions, agricultural soil + compost + perlite in equal proportions, agricultural soil stated that among tomato planting substrates, soil + perlite and soil + perlite + compost had the greatest effect on the soluble solids of the fruit. Beds reduced soluble solids (Javanpour-harvi et al, 2005). It has been reported that the substrate is not effective on the soluble solid matter of tomato fruit (Alan et al, 1994; Tzortzakis and Economakis, 2008).

Relative Leaf Water Content

The results of variance analysis of the data (Table 3) show that only the main effect of different planting beds has a significant effect on the relative leaf water content at the 1% level. The main effect of type of wick and the interaction effect of wick with substrate were not significant. Researches show that the effect of different levels of drought stress, bentonite, superabsorbent and their interaction on relative humidity content was significant (Valizadeh-Qalaebig et al, 2015). Due to the fact that the variance of the interaction effect of the type of wick and planting beds in sweet pepper was not significant, but the highest relative water content (RWC) was observed in soil+fertilizer+sand beds and with braided and cotton wicks. F3S1, F2S1).

Vitamin C

Variance analysis of vitamin C data (Table 3) shows a significant level of 5% in the main effect of wick and 1% in the main effect of planting beds and the interaction between the type of wick and planting beds in sweet pepper. to give

390 The highest and the lowest amount of vitamin C among the main effects and interaction
391 effects in soil + cocopit + fertilizer + perlite and braided wick (F3S3) with an average of
392 579.5 and cocopit + fertilizer + perlite with cotton wick (F2S3) and an average of 5 /13 was
393 observed (Fig. 11).
394 Some reports indicate the effect of bedding on the level of vitamin C (Simitchiev and
395 Kanarziska, 1983; Premuzic et al, 1998). In this study, the planting substrate had a positive
396 effect on the amount of vitamin C of bell peppers in the substrate (S3), but in the other study
397 in determining the effect of different substrates on the yield and quality of three bell pepper
398 cultivars in different substrates including palm fiber (100%), peat (100%), palm fiber + peat
399 (50:50 volume percent), palm fiber + peat (75 25% by volume) and palm fiber + peat (25% by
400 volume) with three varieties of yellow Rapido, red Roxcy and green California wonder
401 between the substrates in terms of this trait, they did not observe any significant difference in
402 bell peppers(Shabani et al, 2011) . In the study of several beds on tomatoes, it was reported
403 that there is no significant difference between the irrigation cycles and the studied beds in
404 terms of the amount of vitamin C (Padem and Alan, 1994; Islam et al, 2002). It has been
405 reported that the amount of vitamin C in tomatoes was higher in organic substrates than in
406 mineral substrates (Premuzic et al, 1998). There are a large number of antioxidant compounds
407 including phenolic compounds, vitamin C and carotenoids in pepper fruit. The use of these
408 turkeys in the diet is very useful in maintaining human health. The tendency to consume
409 pepper fruit is increasing because of its vital substances and antioxidant compounds (Howard
410 and Talcott, 2000). Among the changes in plants as a messenger of the presence of stress and
411 coping with it is the increase in the levels of different antioxidants. Ascorbic acid (vitamin C)
412 is one of the antioxidant compounds that prevent the destruction of tissues by free radicals,
413 the amount of which is increased in dry conditions in order to reduce the destructive effects of
414 stress.
415 **Fruit Dry Weight**

The results of the variance analysis table of fruit dry weight (Table 3) show that the main effect of the wick at the 5% probability level and the type of planting substrate and the interaction effect of the wick type and the sweet pepper planting substrates at the 1% probability level on the dry weight. Fruit has a significant effect. Fig. 12 showed the highest and lowest dry weight of the fruit in soil+cocopeat+fertilizer+perlite with braided wick (F3S3) and soil+fertilizer+sand with cotton wick (F2S4).

In the investigation of the effect of several types of nutrient solution and planting medium in the hydroponic system on the quantitative and qualitative characteristics of "Hamra" greenhouse tomato and planting mediums (perlite, perlite + agricultural soil in equal proportions, compost + perlite in equal proportions, agricultural soil) + compost in equal proportion, agricultural soil + compost + perlite in equal proportion, agricultural soil stated that soil + perlite and compost + perlite had the highest dry weight of tomato fruit and perlite had the lowest amount (Javanpour-harvi et al, 2005). In the study of the effect of different cultivation media on the absorption of nutrients and the quantitative and qualitative yield of greenhouse strawberries in perlite and cocopit media in volume ratios of 0-100, 25-75, 50-50, 75-25, 0-100 that the dry weight of strawberry fruit was affected by the substrates and their difference was significant. So that the highest percentage of fruit dry matter was obtained in perlite-cocopeat treatment with a volume ratio of 0-100 (Dilmaghani-Hasanloui and Hemmati, 2011). In the present study, the highest percentage of dry matter in the bed (S3) was obtained with braided wick. The percentage of fruit dry matter is an important factor in quality, which depends on the amount of water in the plant. In addition, there is a direct relationship between sugar concentration and nitrogen content of fruits (Lacertosa et al, 1999).

Fruit Yield

The data of variance analysis results (Table 3) of fruit yield showed a significant level of 5% in the main effect of wick type and the interaction effect of wick type in planting beds and 1%

in the main effect of planting beds. The comparison of the interaction between the type of wick and the planting substrate, the highest and the lowest yield of bell pepper fruit in soil + cocopit + fertilizer + perlite and braided wick (F3S3) and cocopit + fertilizer + perlite with cotton wick (F2S4) are shown in the Fig. 13 shows.

A high yield has been observed in the hydroponic cultivation of tomatoes in a mixture of cocopeat and perlite (Djedidi et al, 1997; Maloupa et al, 1999). In the investigation of the effect of the type of cultivation substrate on the yield and absorption of some nutrients by greenhouse cucumbers in cultivation without pure cocopeat soil, perlite-cocopeat (in a volume ratio of 50-50), perlite-cocopeat-peat moss with two volume ratios (50 20-30-20 and 30-50-50) and perlite-peat moss (50-50 volume ratio), it was stated that the highest yield was obtained from perlite-cocopit and pure cocopit beds of greenhouse cucumber among the investigated treatments (Alifar et al, 2008). At the same time, the research indicates that the cultivation bed has significantly changed the yield of tomatoes and cucumbers in the greenhouse (Lee et al, 2000; Tabatabai and Mohammad-Rezaei, 2006). In a research on different greenhouse cucumber cultivation substrates, peat moss was mentioned as the best substrate in terms of performance, the reasons for this superiority are its high moisture retention capacity and high cation exchange capacity (about 100 milliequivalents per 100 grams) (Nourizadeh et al, 2003).

Water Efficiency

The results of variance analysis of the data in table (3) show that the type of wick at the 5% level and the planting beds and the interaction effect of the planting beds and the type of wick at the 1% probability level have a significant effect on the efficiency of water consumption.

In order to investigate the effect of different amounts of perlite mixed with soil on the yield and water consumption efficiency of blue wheat, seven treatments of perlite use P0, P1, P2, P3, P4, P5, P6, including 0, 75, 150, 300, 600, 1200, 2400 respectively kg of perlite per hectare reported that the efficiency of water consumption in different treatments of consumed

perlite shows that the consumption of perlite has caused a significant increase in the water consumption efficiency of blue wheat crop compared to the control treatment (Moghimi et al, 2011). They stated that the use of hydrogel increased the yield and by reducing the water consumption, it improved the efficiency of water consumption (JIN-cheng and JiJinng, 1999). In another research, it was reported that the addition of hydrogel to the peat + perlite + vermiculite bed increased the water holding capacity, but due to the conditions of limited surface absorption in comparison with the artificial bed, it had no effect on preventing nitrogen nitrate leaching (Bres and Weston, 1993). In a research that was conducted on greenhouse cucumbers planted in perlite bed mixed with hydrogel, it was found that the use of 1.5% of hydrogel can help to improve the efficiency of water and fertilizer consumption (Ahrar and Delshad, 2009). Fig. 14 shows comparison of average efficiency of water consumption. In the study of the efficiency of water and fertilizer consumption in the soilless cultivation of greenhouse tomatoes by drying a part of the root and using a superabsorbent in the base bed (control) including coarse perlite mixed with 1 and 2% by weight of hydrogel powder, it was reported that between There is a significant difference between the irrigation treatments and the cultivation beds in terms of the efficiency of water consumption by the plant at the probability level of 1%. Plants grown in substrates containing 2% by weight of hydrogel had the highest efficiency of water and fertilizer consumption compared to the other two substrates (Mousavi-Rahimi et al, 2014). In this study, the highest efficiency of water consumption was observed in the bed (S3). It seems that the physical characteristics and the type of components of the mixed beds are the influencing factors on the efficiency of irrigation water consumption. Root suffocation affects the efficiency of water consumption in soilless crops in two ways: a) disturbance in the activity of the root system (by reducing water absorption and absorption of mineral substances and increasing the harmful secretions of the roots in the cultivation beds) and b) disturbance in the metabolism of aerial organs (by closing the stomata and reducing transpiration and thus reducing light production). Due to the

physical characteristics of the perlite bed, water absorption does not take place in the form of granules in the bed. By increasing the amount of water available to the plant and also creating adaptation conditions in the plant through stomatal control and leaf hormonal activities, it optimizes water consumption in the plant. Reduction of evaporation and transpiration in the plant has its direct effect in the form of reduction of vegetative growth in the plant. Reducing surface evaporation from soil and water and also reducing deep infiltration can increase the efficiency of water consumption (Abuarab et al, 2013; Paterson, 2002).

Conclusions

In this research, the effect of different cultivation media and type of wick on the vegetative and reproductive characteristics of bell pepper in the greenhouse was investigated. The general conclusion shows that most of the quantitative and qualitative characteristics of bell peppers depend on the composition of the substrate and the type of wick used in it, so that the best quantitative and qualitative characteristics of bell pepper are obtained from the mixed substrate of soil + cocopeat + Fertilizer + perlite was obtained with braided wick and yarn. The use of wick and the type of substrate can be effective in increasing the yield and improving the growth characteristics of sweet pepper. According to the results obtained from this research, it can be seen that using wick and adding perlite and cocopeat to the soil in conditions where there is a forced shortage of irrigation water can play a significant role in the efficiency of water consumption. Of course, due to the novelty of using the wick, this technique needs more investigation and more applied research to be used in specific cases. The use of materials such as perlite and cocopeat in combination with soil and fertilizer, as well as braided and cotton wicks, are among the options that can be effective in improving plant growth conditions and optimal use of water resources.

Data Availability Statement

All the data, including the experimental measurements, the data used for formulating empirical relations, and the code processing the data that support the findings of this study, are available from the corresponding author upon reasonable request.

Conflict of Interest Statement

There is no conflict of interest.

Funding

Funding information is not applicable. No funding was received. No grants were received.

Ethical Approval

The present Study and ethical aspect was approved by Department of Irrigation, College of Agriculture.

Consent to Publish

All authors agree to publish this manuscript. There is no conflict of interest.

Author's Contributions

All authors designed the study, collected data, wrote the manuscript and revised it.

Acknowledgment

Not applicable.

References

[1] Abioye E.A, M.S.Z Abidin, M.S.A Mahmud, S Buyamin, M.H.I Izran, M.K.I.A Rahman, A.O Otuoze, P Onotu, M.S.A Ramli. 2020. A review on monitoring and advanced control strategies for precision irrigation, Comput. Electron. Agric, Volume 173, 2020, 105441, ISSN 0168-1699, https://doi.org/10.1016/j.compag.2020.105441.

[2] Abuarab M. Mostafa E. and Ibrahim M. 2013. Effect of air injection under subsurface drip irrigation on yield and water use efficiency of corn in a sandy clay loam soil. J. Adv. Res. 4: 493-499.

[3] Aghavani-Shajari M., H. Nemati, M Mohammad-Bakhsh, J Falahi and F Haghighi-Tajoor. 2013. Evaluation of the effects of planting bed and irrigation cycle on seedling growth indicators of tomato cultivars under greenhouse conditions. J. Hortic. Sci. (1) 26. Pages 95-87. In Persian.

[4] Ahrar M. and Delshad M. 2009. Improving water/fertilizer use efficiency of hydroponically culture greenhouse cucumber by grafting and hydrogel amendment. J. Hortic. Sci. 23: 69-77.

[5] Alaei M. H.R. Roosta, S.N.D Mortazavi and H. Alaei. 2013. Comparison of different planting media on the performance and quantitative and qualitative characteristics of Puma chrysanthemum in two hydroponic and aquaponic systems. Plant Prod. (Sci. J. Agri.). 37 page 3. In Persian.

[6] Al-Mayahi, A., S. Al-Ismaily, A. Al-Maktoumi, H. Al-Busaidi, A. Kacimov, R. Janke, J. Bouma & J. Šimůnek. 2020. A smart capillary barrier-wick irrigation system for home gardens in arid zones. Irrig Sci. 38, 235–250 (2020). https://doi.org/10.1007/s00271-020-00666-3.

[7] Alan R.A. Zulkadir and H. Padem. 1994. The influence of growing media on growth. Yield and quality of tomato grown under greenhouse condition. Acta Hort. 366: 229-234.

563 [8] Alifar N., A Mohammadi and N Honarjoo. 2008. The effect of cultivation medium on
564 some growth indicators of greenhouse cucumber in soilless cultivation (2) 14 pages 38-
565 45. In Persioan.
566 [9] Araya A, I. Kisekka, P.H. Gowda, P.V.V. Prasad. 2017. Evaluation of water-limited
567 cropping systems in a semi-arid climate using DSSAT-CSM, Agric. Syst, Volume 150,
568 2017, Pages 86-98, ISSN 0308-521X, https://doi.org/10.1016/j.agsy.2016.10.007.
569 [10] Atiyeh R.M. Arancon N. Edwards C.A. and Metzger J.D. 2002. The influence of
570 humic acids derived from earthworm processed organic wastes on plant growth.
571 Bioresour. Technol 84: 7-14.
572 [11] Bainbridge D.A. 2002. Alternative irrigation systems for arid land restoration. Ecol.
573 Restor. 20: 23-30.
574 [12] Ballentine, R. 1941. Determination of ascorbic acid in citrus fruit juices. Ind. Eng.
575 Chem., Anal. Ed, 13(2), 89-89.
576 [13] Barzgarhfashjani Z, M. Mobli, A.H. Khoshgoftarmanesh, J. Abedikopai. 2014. The
577 effect of adding pumice and benomite to sawdust growing medium on the vegetative
578 characteristics of hot pepper. J. Sci. Tech. Greenh. Crops. 21 page 6. In Persian.
579 [14] Bhayo, W. A., Siyal, A. A., Soomro, S. A., & Mashori, A. S. (2018). Water saving and
580 crop yield under pitcher and wick irrigation methods: Khairpur College of Agriculture
581 Engineering and Technology, Khairpur Mir's, Pakistan. Pak. J. Agric. Sci, 34(1), 57–67.
582 Retrieved from https://pjaaevs.sau.edu.pk/index.php/ojs/article/view/256.
583 [15] Bres W. and Weston L.A. 1993. Influence of gel additives on nitrate ammonium and
584 water retention and tomato growth in a soilless medium. Hortscience. 28: 1005-1007.
585 [16] Burton, W. G. 1982. Post-harvest physiology of food crops. Food Res. Inst., Norwich
586 NR4 7UA, UK. 1982 pp.339pp. ref.41pp.
587 [17] Chaturvedi, A.K., Surendran, U., Madhava Chandran, K., Dhanya T. Exploring
588 growth, physiological status, yield and water use efficiency of vegetables grown under

589 wick method of irrigation. 2021. Plant Physiol. Rep. 26, 64–73.
590 https://doi.org/10.1007/s40502-020-00565-x.
591 [18] Colla G. E. Rea F. Pierandrie and Salerno A. 2003. Effects of substrates on yield
592 quality and mineral composition of soilless grown cucumbers. Acta Hort 614: 205-209.
593 [19] Cook C.D. and Dunsby B.L. 1978. Perlite for propagation. Combined Proceedings of
594 the International Plant Propagators Society 28: 224-228.
595 [20] Dilmaghani-Hasanloui M.R., & S Hemmati. (2011). The effect of different cultivation
596 substrates on the amount of nutrients, yield and quality characteristics of Selva
597 strawberry in soilless cultivation. J. Soil Sci. Plant Nutr -Isfahan University of
598 Technology, 2(3), 1-8. In Persion.
599 [21] Djedidi M. Grasopoulos D. and Maloupa E. 1997. The effect of different substrates on
600 the quality of f. Carmello tomatoes (Lycopersicon escullentum MILL) grown under
601 protection in a hydroponic system. Ciheam-Options Mediterraneennes 31: 379-83.
602 [22] FAO. 2013. Good Agricultural Practices for greenhouse vegetable crops Principles for
603 Mediterranean climate areas. Edition: 217Publisher: FAO - PLANT PRODUCTION
604 AND PROTECTION PAPEREditor: Wilfried Baudoin, Remi Nono-Womdim, NeBambi
605 Lutaladio, Alison Hodder, Nicolás Castilla, Cherubino Leonardi, Stefania De Pascale,
606 Muien Qaryouti, Ruth DuffyISBN: 978-92-5-107649-1.
607 [23] Felipe A J B, Bareng J L R. Growth and yield assessment of lettuce (Lactuca
608 sativaL.): an economic feasibility and performance evalua-tion of capillary wick
609 irrigation system. Plant Sci. Today. 2022;9(1):62–69. https://doi.org/10.14719/pst.1460.
610 [24] Ferrarezi R.S. 2012. Water depth filling time and volume of wick irrigation equipment
611 and determination of water distribution uniformity in substrates. Bragantia 71: 1-9.
612 [25] Ferrarezi, R.S & Testezlaf, R. 2016. Performance of wick irrigation system using self-
613 compensating troughs with substrates for lettuce production. J. Plant Nutr. Volume 39,
614 2016 - Issue 1. https://doi.org/10.1080/01904167.2014.983127.

615 [26] Fussy, A.; Papenbrock, J. An Overview of Soil and Soilless Cultivation Techniques—
616 Chances, Challenges and the Neglected Question of Sustainability. Plants 2022, 11,
617 1153. https://doi.org/10.3390/plants11091153.
618 [27] Ghasemi M. Khosh-Khui M. and Abedi-Koupai J. 2010. Effect of superabsorbent
619 polymer on water requirement and growth indices of Ficus benjamin L. starlight. J. Plant
620 Nutr. 33: 785-795. https://doi.org/10.1080/01904161003654030.
621 [28] Ghorbanli. M. Fakerbaher. Z. Mirza. M. and Rezaei. M.B. 2001. The effect of
622 irrigation treatments on some of growth parameters. Quality and quantity of essential oil
623 in Satureja hortensis. Pajouhesh-va-Sazandegi 14: 40-45.
624 [29] Gruda, N.S. 2019. "Increasing Sustainability of Growing Media Constituents and
625 Stand-Alone Substrates in Soilless Culture Systems" Agronomy 9, no. 6: 298.
626 https://doi.org/10.3390/agronomy9060298.
627 [30] Hajiaghaei-Kamrani. M. Khoshvaghti H. and Hosseinniya H. 2013. Effects of salinity
628 and hydroponic growth media on growth parameters in tomato (Lycopersicon
629 esculentum Mill.). Int. J. Agron. Plant Prod. 4: 2694-2698.
630 [31] Heidari, Hassan; Zarei, Zhaleh and Mohammadi, Kazhal. Improving water use
631 efficiency and biomass in maize, foxtail millet and bitter vetch by wick irrigation. Water
632 SA [online]. 2022, vol.48, n.3, pp.264-270. Available from:
633 <http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S1816-
634 79502022000300005&lng=en&nrm=iso>. ISSN 1816-7950.
635 http://dx.doi.org/10.17159/wsa/2022.v48.i3.3913.
636 [32] Howard L.R.S.T. Talcott C. Brenes H. and Villalon B. 2000. Changes in
637 phytochemical and antioxidant activity of selected pepper cultivars as influenced by
638 maturity. J. Agric. Food Chem. 48: 1713-1720.
639 [33] Hunt, E.R., B.N Rock, P.S. Nobel. 1987. Measurement of leaf relative water content
640 by infrared reflectance, Remote Sens. Environ, Volume 22, Issue 3, 1987, Pages 429-

435, ISSN 0034-4257, https://doi.org/10.1016/0034-4257(87)90094-0.

[34] I.S, S. 2003. Production of Cyclamen Using Capillary Wick System: I. Influence of Wick Material and Root Substrate Composition. Journal of Korean Flower Research Society 11: 199-206.

[35] Islam M.D.S. Khan S. Ito T. Maruo T. and Shinohara Y. 2002. Characterization of the physicochemical properties of environmentally friendly organic substrate in relation to rockwool. J HORTIC SCI BIOTECH 77: 143-148.

[36] Javanpour-harvi R., M Babalar, A Kashi, M Mir Abd al-Baghi and M.A Askari. 2005. The effect of several types of nutrient solution and planting medium in water culture system on the quantitative and qualitative characteristics of greenhouse tomato variety "Hamra". Iran. J. Agric. Sci. (4) 36 pages 946-939.

[37] JIN-cheng F. and JiJinng. Q. 1999. Root irrigation with superabsorbent polyacrilamid. Retrieved. May10.

[38] Kabir, M.Y., S.U. Nambeesan, J. Bautista, J.C. Díaz-Pérez. 2021. Effect of irrigation level on plant growth, physiology and fruit yield and quality in bell pepper (Capsicum annuum L.), Sci. Hortic, Volume 281, 2021, 109902, ISSN 0304-4238, https://doi.org/10.1016/j.scienta.2021.109902.

[39] Kang., Sh, X. Hao, T. Du, L. Tong, X. Su, H. Lu, X. Li, Z. Huo, S. Li and R. Ding. 2017. Improving agricultural water productivity to ensure food security in China under changing environment: From research to practice. AGR WATER MANAGE, Volume 179, 2017, Pages 5-17, ISSN 0378-3774, https://doi.org/10.1016/j.agwat.2016.05.007.

[40] Khalaj M.A. 2007. Gerbera breeding. Publications of the National Flower and Ornamental Plant Research Station of Mahalat. Central province. Iran. 86 page 394. In Persian.

[41] Krishnamurthy L. Kashiwagi J. and Upadhyaya H.D. 2003. Genetic diversity of drought avoidance root traits in the mini-core germplasm collection of chickpea.

667 International Chickpea and Pigeonpea Newsletters 10: 21-24.
668 [42] Lacertosa G. Lateana V. Montemurro N. Palazzo D. and Vanadia S. 1999. Soil
669 fertility and plant nutrition status of strawberry in the Basilicata region. Southern Italy.
670 Dev. Plant Soil Sci. 86: 159-62.
671 [43] Lee. B. Lee. J. Chung. S. and Seo. B. 2000. Effects of container and substrate on
672 growth and fruit quality of the hydroponicaly grown cucumber (Cucumis sativus L. cv.
673 Chosaengnakhap) plants. Acta Horticulturae 82: 412-425.
674 [44] Lieberman, M. (2012). Post-harvest physiology and crop preservation (Vol. 46).
675 Springer Sci. Rev.
676 [45] Maloupa E. Samartzidis C. Couloumbis P. and Komnin A. 1999. Yeild quality and
677 photosynthetic activity of greenhouse-grown "Madelom" roses on perlite-zeolite
678 substrate mixtures. Acta Horticulturae 481: 97-99.
679 [46] Maloupa. E.A. Abouhadid. M. Prasad and Kavafakis. C. 2001. Response of cucumber
680 and tomato plants to different substrates mixtures of pumice in substrate culture. Acta
681 Horticulturae 550: 593-599.
682 [47] Mami Y., Gh.Peyvast, D Bakhshi and H Samizadeh. 2008. Determining different
683 tomato planting beds in soilless cultivation system. J. Hortic. Sci. (2) 22 pages 39-48. In
684 Persion.
685 [48] Mari Gowda, M. H. 1974. Dry orcharding. The Lal Baugh 19(1/2):1-85.
686 [49] Mirabi A, S.H. Nemati, M.M. Mehrabakhsh and H. Ebrahimi. 2015. Investigating the
687 effects of cultivation medium and variety on some agronomic and physiological
688 characteristics of melon seedlings. J. Hortic. Sci. (4) 27 pages 375-382. In Persian.
689 [50] Moghimi A., P Fathi, V Toshih and M.M Ardalan 2011. The effect of perlite on the
690 efficiency of irrigation water consumption and some growth components in Zarin wheat.
691 JWIM. (2) 1 pages 31-42. In Persian.
692 [51] Mongkolporn, O., Taylor, P.W.J. (2011). Capsicum. In: Kole, C. (eds) Wild Crop

693 Relatives: Genom. Breed. Res. https://doi.org/10.1007/978-3-642-20450-0_4.
694 [52] Mousavi-Rahimi M., M Dilshad, A.M. Liaqhat and A Rahmatian. 2014. Investigating
695 the efficiency of water and fertilizer consumption in soilless cultivation of greenhouse
696 tomatoes by drying part of the root and using superabsorbent. J. Hortic. Sci of Iran. (2)
697 45 pages 175-184. In Persian.
698 [53] Munsuz N. Ataman Y. and Unver I. 1985. Substrates and Perlite in Agriculture. Perl.
699 Inst. Basic fact about perlite. Pub. No. BF. 76. Perl. Inst. New York. 65 p.
700 [54] Munsuz N. 1987. Perlitin sera ve Tarla Kosullarinda Toprakta Tutulmasi ve Bugday
701 Verimi Uzerine Etkileri. Yayin Agron Report 2: 1-78.
702 [55] Nikolaou G, D. Neocleous, N, Katsoulas, C. Kittas. Irrigation of Greenhouse Crops.
703 Horticulturae. 2019; 5(1):7. https://doi.org/10.3390/horticulturae5010007.
704 [56] Nik-Razm R., S. Alizadeh-Ajirlou, A. Khalighi and S.J Tabatabai 2018. The effect of
705 different substrates on vegetative growth of two lily cultivars in soilless cultivation
706 system. J. Sci. Technol. Greenhouse Cult. (6) 2 pages 52-60. In Persian.
707 [57] Nourizadeh M., Gh Peyvast and M Layegh. 2003. The effect of different cultivation
708 substrates on growth. Yield and quality of greenhouse cucumber in soilless cultivation.
709 New Find. Agric. (2) 4 pages 157 to 166. In Persian.
710 [58] Olgarenko, V. I., Olgarenko, G. V., & Olgarenko, I. V. (2018). A method of integral
711 efficiency evaluation of water use on irrigation systems. International Multidisciplinary
712 Scientific GeoConference: SGEM, 18(3.1), 3-9. DOI:10.5593/sgem2018/3.1/S12.001.
713 [59] Padem H. and Alan R. 1994. The effect of some substrates on yield and chemical
714 composition of pepper under greenhouse conditions. Acta Horticulturae 366: 445–451.
715 [60] Paterson B. 2002. Food production. Poverty alleviation and enviromental challenges
716 as influence by limited water resources and population growth. Proceeding of 18th
717 Congress on Irrigation and Drainage. General Reports 1: 1-23.
718 [61] Pill W.G. and B.C. Goldberger. 2009. Growth of Tomato in Biosolids-Woodchip Co-

719 compost with Varying Proportions of Peat Moss and Perlite Subjected to Two
720 Fertilization Regimes. Commun. Soil Sci. Plant Anal. 40: 2440–2459.
721 [62] Premuzic Z. Bargiela M. Garcia A. Rendina A. and Iorio A. 1998. Calcium, iron.
722 Potassium, phosphorous and vitamin C content of organic and hydroponic tomatoes.
723 Hort Science 33: 255-257.
724 [63] Rasouli Sedghiani M.H, N Moradi. and R. HamzeNejad. 2015. Effect of type and ratio
725 of vermicompost on some growth indicators and concentration of nutrients in tomato
726 under greenhouse conditions. Sci. Tech. Greenh. Crops. 24 page 6. In Pesian.
727 [64] Roonjho S.J, R.Md Kamal and A.R Roonjho. 2022. Modeling capillary wick irrigation
728 system for greenhouse crop production. AGR WATER MANAGE, Volume 274, 2022,
729 107927, ISSN 0378-3774, https://doi.org/10.1016/j.agwat.2022.107927.
730 [65] Sanati S, Razavi BM, Hosseinzadeh H. A review of the effects of Capsicum annuum
731 L. and its constituent, capsaicin, in metabolic syndrome. Iran J Basic Med Sci. 2018
732 May;21(5):439-448. doi: 10.22038/IJBMS.2018.25200.6238. PMID: 29922422;
733 PMCID: PMC6000222.
734 [66] Sanatombi, K., & Sharma, G. J. (2007). Micropropagation of Capsicum annuum L.
735 Not. Bot. Horti Agrobot. Cluj-Na, 35(1), 57.
736 [67] Savvas D, N Gruda. 2018. Application of soilless culture technologies in the modern
737 greenhouse industry – A review. Eur. J. Hortic. Sci.
738 https://doi.org/10.17660/eJHS.2018/83.5.2.
739 [68] Shabani T., Gh Peyvast and J Olfati. 2011. Investigating the effect of cultivation
740 media on quantitative and qualitative traits of three varieties of bell pepper in soilless
741 cultivation system. Sci. Tech. Green. Crops. (6)2 pages 11-20. In Persioan.
742 [69] Shaw N.L. Cantliffe D.J. Funes J. and Shine C. 2004. Success al Beit Alpha cucumber
743 production in the greenhouse using pine bark as an alternative soilless media. Hort
744 Technology 14: 289-294.

745 [70] Simitchiev H. Kanarziska V. Popove I. and Atanasov N. 1983. Biological effect of
746 greenhouse tomatoes grown on rockwool. Acta Horticulturae 133: 59-66.
747 [71] Tabatabai J. and R Mohammad-Rezaei. 2006. The effect of different planting beds on
748 the growth and yield of greenhouse cucumber in water culture system. Agric. Knowl. (2)
749 16 pages 35-44. In Persian.
750 [72] Tolai M. 2001. Guide to growing greenhouse plants by hydroponic method.
751 Publication of agricultural education. Karaj Iran. In Persian.
752 [73] Tripodi, P., Kumar, S. (2019). The Capsicum Crop: An Introduction. In: Ramchiary,
753 N., Kole, C. (eds) The Capsicum Genome. Comp. Plant Genome. Springer, Cham.
754 https://doi.org/10.1007/978-3-319-97217-6_1.
755 [74] Tyl, C., Sadler, G.D. (2017). pH and Titratable Acidity. In: Nielsen, S.S. (eds) Food
756 Analysis. Food Sci. Text Ser. Springer, Cham. https://doi.org/10.1007/978-3-319-45776-
757 5_22.
758 [75] Tzortzakis N.G. and Economakis C.D. 2008. Impacts of the substrate medium on
759 tomato yield and fruit quality in soilless cultivation. Hort Science 35: 83–89.
760 [76] Valizadeh-Qalaebig A., S.H Nemati, A Tehranifar and H Emami. 2015. The effect of
761 A200 superabsorbent. Benomit and drought stress on physiological traits and vitamin C
762 of lettuce under greenhouse conditions. Sci. Tech. Greenh. Crops. (21) 6 pages 79-89. In
763 Persion.
764 [77] Wesonga J.M. Wainaina C. Ombwara F.K. Masinde P.W. and Home P.G. 2014. Wick
765 Material and Media for Capillary Wick Based Irrigation System in Kenya. Int. J. Sci.
766 Res. 23(19): 7059-7064.
767 [78] Yamasaki, S., & Dillenburg, L. R. (1999). Measurements of leaf relative water content
768 in Araucaria angustifolia. Revista Brasilleira de fisiologia vegetal, 11(2), 69-75.
769 [79] Zegbe-Domínguez J.A, M.H Behboudian, A Lang, B.E Clothier. 2003. Deficit
770 irrigation and partial rootzone drying maintain fruit dry mass and enhance fruit quality in

'Petopride' processing tomato (Lycopersicon esculentum, Mill.), Sci. Hortic, Volume 98, Issue 4, 2003, Pages 505-510, ISSN 0304-4238, https://doi.org/10.1016/S0304-4238(03)00036-0.



Fig. 1. Cotton, worsted and braided wicking threads from the left respectively



Fig. 2. Seedling tray for transferring seedlings to the main culture bed



Fig. 3. Water tank placed under each pot

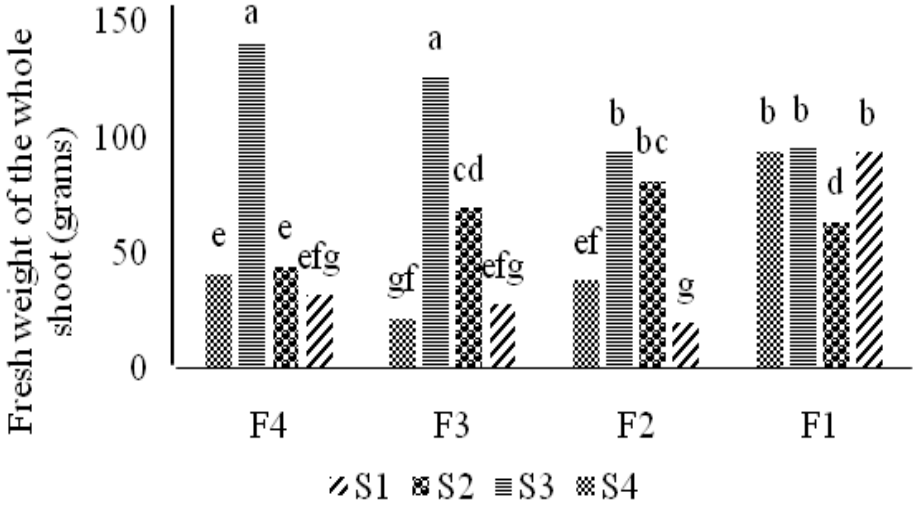


797

798 Fig. 4. Measurement of relative leaf water content

799

800

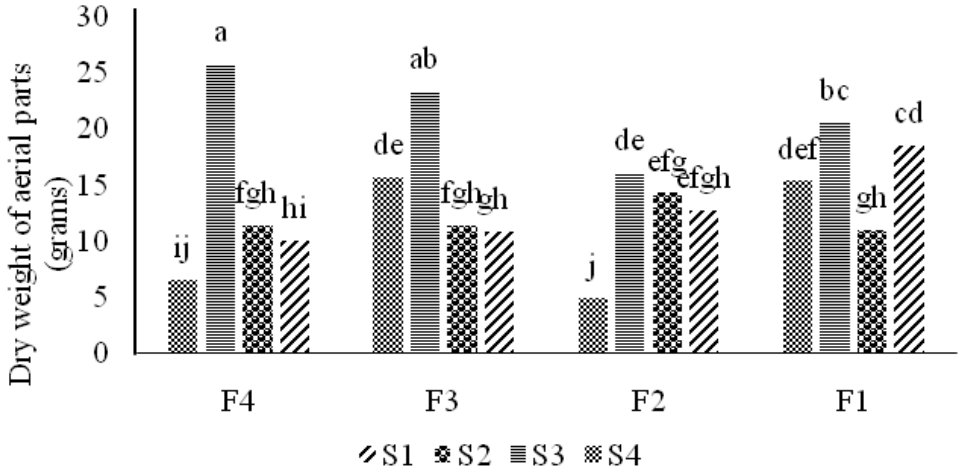


801

802 Fig. 5. Comparison of the average wet weight of the whole shoot

803

804

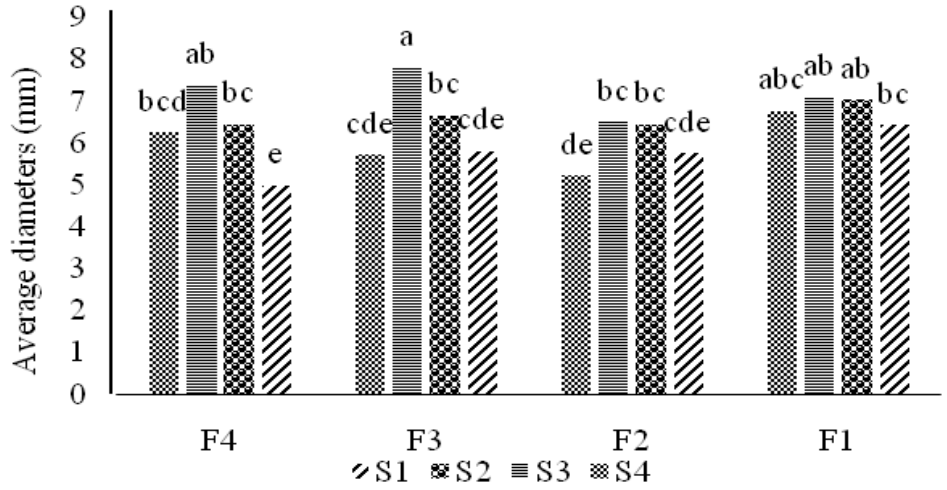


805

806 Fig. 6. Comparison of the average dry weight of the entire shoot

807

808



809

810 Fig. 7. Comparison of mean diameters

811

812

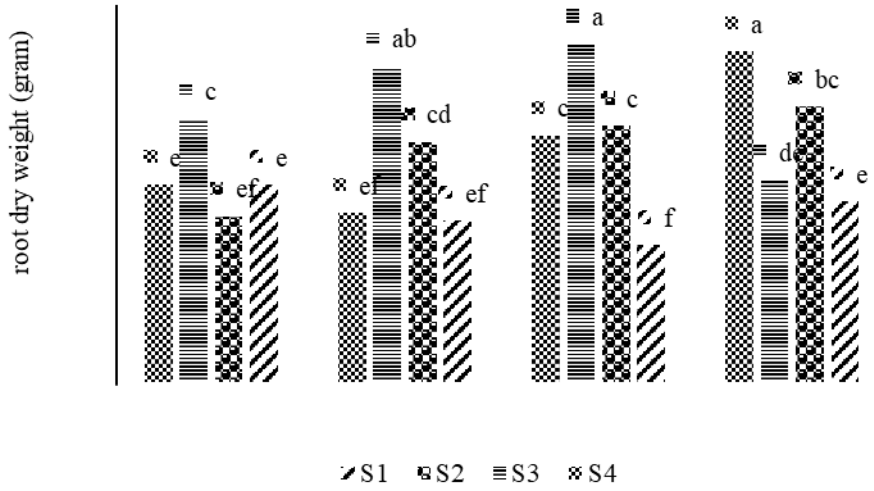


Fig. 8. Comparison of average root dry weight

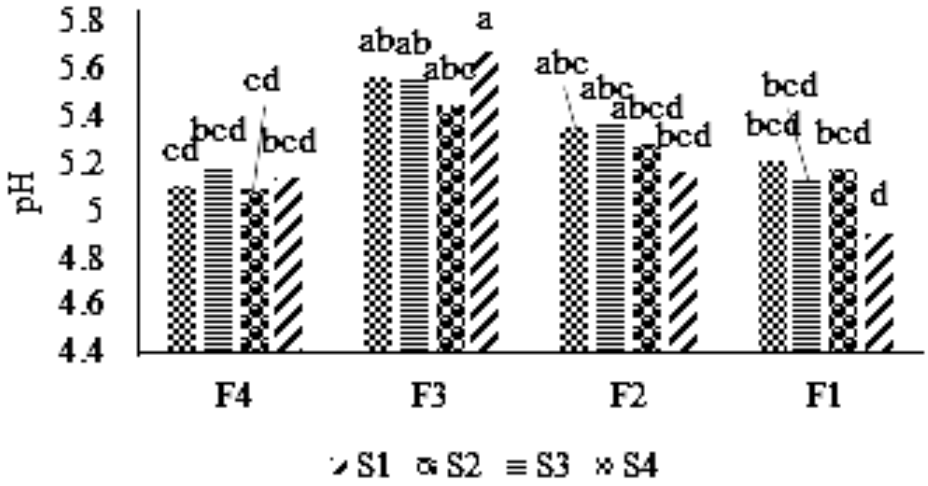
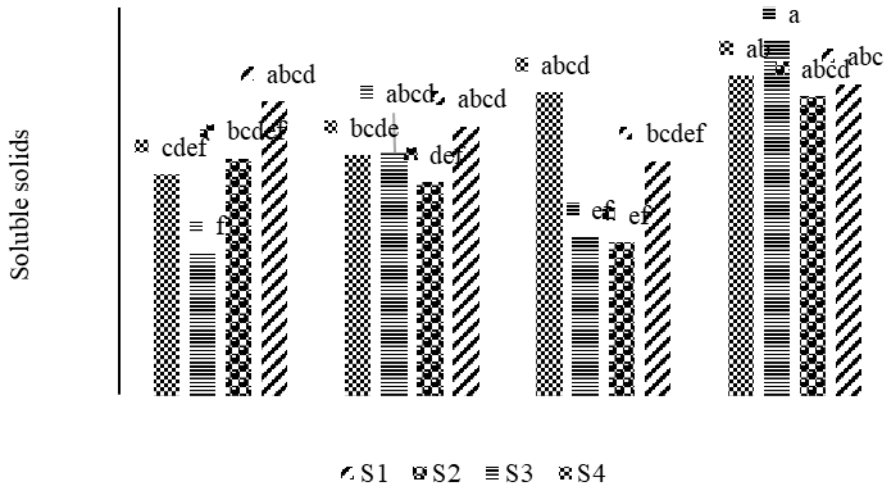


Fig. 9. Comparison of average acidity

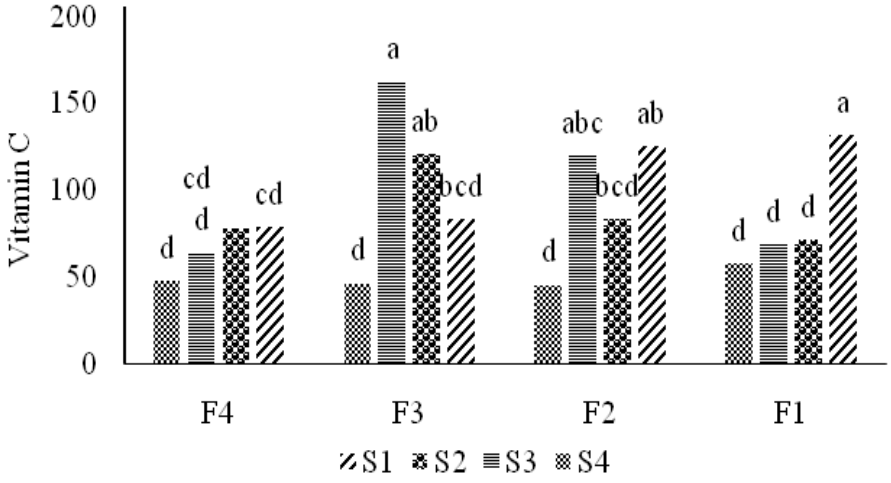


821

822 Fig. 10. Comparison of average dissolved solids

823

824

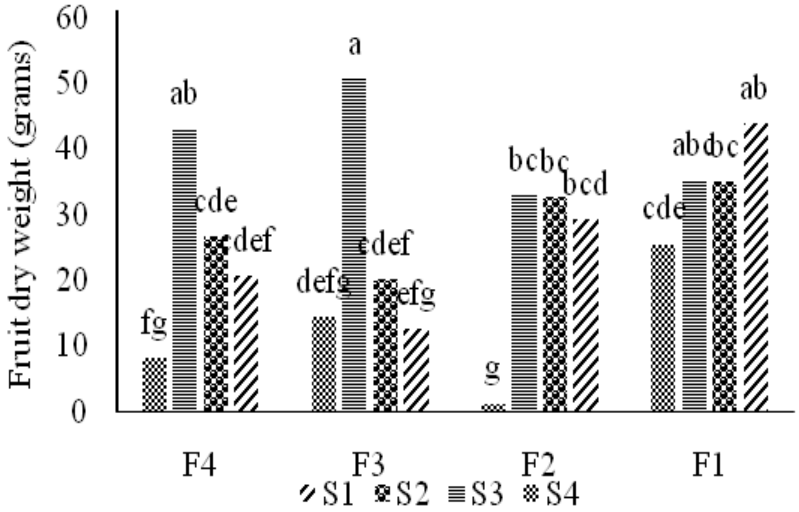


825

826 Fig. 11. Comparison of average vitamin c

827

828

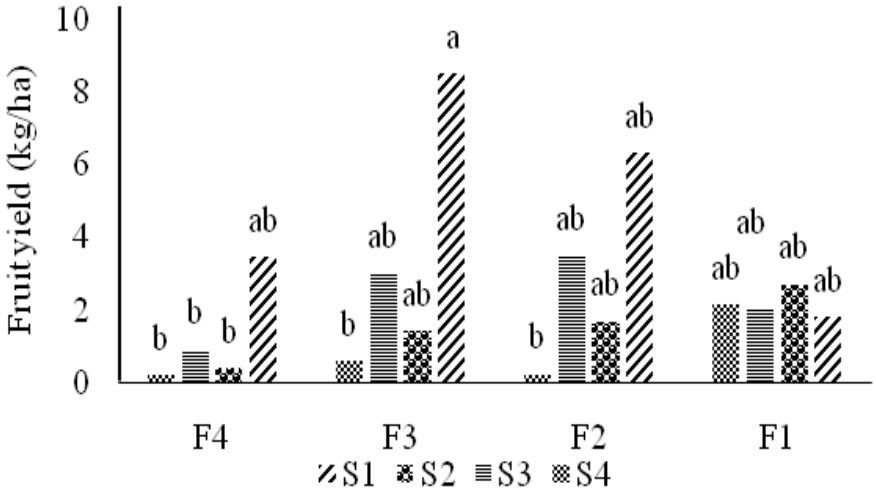


829

830 Fig. 12. Comparison of average fruit dry weight

831

832



833

834 Fig. 13. Comparison of average fruit yield

835

836

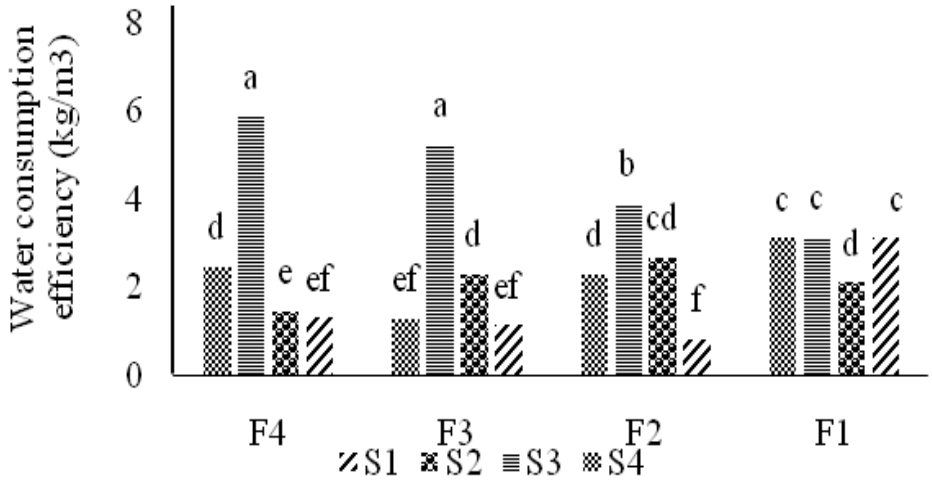


Fig. 14. Comparison of average efficiency of water consumption

Table 1- Specifications of experimental treatments

Row	Description	Symbol
1	Surface irrigation + substrate containing soil + sand + animal manure	F1S1
2	Irrigation with cotton wick + substrate containing soil + sand + animal manure	F2S1
3	Irrigation with braided wick + substrate containing soil + sand + animal manure	F3S1
4	Irrigation with cotton wick + substrate containing soil + sand + animal manure	F4S1
5	Surface irrigation + substrate containing soil + cocopeat + gravel + sand	F1S2
6	Irrigation with cotton wick + substrate containing soil + cocopeat + gravel + sand	F2S2
7	Irrigation with braided wick + substrate containing soil + cocopeat + gravel + sand	F3S2
8	Irrigation with cotton wick + substrate containing soil + cocopeat + gravel + sand	F4S2
9	Surface irrigation + substrate containing soil + cocopeat + fertilizer + perlite	F1S3
10	Cotton wick irrigation + substrate containing soil + cocopeat + fertilizer + perlite	F2S3
11	Irrigation with braided wick + substrate containing soil + cocopeat + fertilizer + perlite	F3S3
12	Irrigation with cotton wick + substrate containing soil + cocopeat + fertilizer + perlite	F4S3
13	Surface irrigation + substrate containing cocopeat + fertilizer + perlite	F1S4
14	Irrigation with cotton wick + substrate containing cocopeat + fertilizer + perlite	F2S4

15	Irrigation with braided wick + substrate containing cocopeat + fertilizer + perlite	F3S4
16	Irrigation with cotton wick + substrate containing cocopeat + fertilizer + perlite	F4S4

Table 2- Humidity ranges of different cultivation beds

Cultivation beds	Mass humidity at the limit of agricultural capacity (%)	Mass moisture at the wilting point (%)
soil, sand, animal manure (S1)	21.9	9.9
soil, cocopeat, fertilizer and sand (S2)	21.3	9.2
soil, cocopeat, fertilizer, perlite (S3)	24.7	11
Cocopeat, fertilizer, perlite (S4)	17.8	6.1

Table 3- Variance analysis of performance components of different treatments

Sources Change
Degrees of freedom
Fresh weight of the whole shoot
Dry weight of aerial parts
Average diameters
Root dry weight
pH
Soluble solids
RWC
Vitamin C
Fruit dry weight
Function Fruit
Water use efficiency
treatment
15
4283.1**

		96.8**
		1.8**
		13**
		0.13^{ns}
5.2**		
		0.03^{ns}
		3679.1**
		557.6**
		11259468**
6.1**		
		wick
		3
		2001.8**
		44.9**
		1.5*
		5**
		0.52**
12.8**		
		0.02^{ns}
		2856.9*
		332.8*
		58515524*
0.57 *		
		bed
		3
		12550.5**
		285.4**
		5.1**
		27**
		0.02^{ns}
4.3ns		
		0.06*
		8098**
		1604.4**

		359834547**
	20.4**	
		wick × bed
		9
		2287.6**
		51.1**
		0.6^{ns}
		10.9**
		0.03^{ns}
	3ns	
		0.02^{ns}
		2480.2**
		283.5**
		48099090*
	3.3**	
		error
		32
		106.1
		5.9
		0.5
		10.9
		0.1
	1.5	
		0.02
		678.1
		87.9
		18091865
	0.14	
		cv
		15.2
		17
		10.6

942		0.7
943		4.9
944	23.6	
945		22.8
946		29.1
947		28.8
948		27.9
949	14.2	
950		
951		
952		
953		
954		
955		
956		
957		
958		
959		