Asian Soil Research Journal

2(3): 1-14, 2019; Article no.ASRJ.53036
ISSN: 2582-3973

Impact of Irrigation with Saline Water on the Production of Tomato (*Solanum lycopersicum*) under Soilless and Traditional Techniques

Alaa Ibrahim[1] and Jamal Elfaki[2*]

[1]Developing & Evaluating Irrigation Systems Department, Water Management Research Institute, National Water Research Center, Cairo, Egypt.
[2]Faculty of Agriculture, Nile Valley University, P.O.Box 1843, Atbara, River Nile State, Sudan.

Authors' contributions

This work was carried out in collaboration between both authors. Author AI designed the study, performed the statistical analysis, and wrote the protocol. Author JE wrote the first draft of the manuscript, managed the analyses of the study and approved the final manuscript. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ASRJ/2019/v2i330056
Editor(s):
(1) Dr. Ademir de Oliveira Ferreira, Professor, Dynamics of Organic Matter in Soil, Systems Management, University of Northern Paraná, Rua Tibúrcio Pedro Ferreira, Ponta Grossa, Paraná, Brazil.
(2) Dr. Henry Oppong Tuffour, PhD, Senior Lecturer, Department of Crop and Soil Sciences, Kwame Nkrumah University of Science and Technology (KNUST), PMB, KNUST, Kumasi, Ghana.
(3) Dr. Alessandro Buccolieri, Department of Biological and Environmental Sciences and Technologies (DiSTeBA), Università del Salento, Italy.
Reviewers:
(1) Elżbieta Szczepankiewicz, Poznan University of Economics, Poland.
(2) R. K. Lal, India.
Complete Peer Review History: http://www.sdiarticle4.com/review-history/53036

Original Research Article

Received 08 October 2019
Accepted 16 December 2019
Published 07 January 2020

ABSTRACT

A greenhouse experiment was carried out to evaluate the response of tomato (*Solanum lycopersicum*) to saline water irrigation under soilless and traditional techniques. A special fertigation technique with two different salinity levels (1dS m^{-1} and 4dS m^{-1}) of water was used under different soilless media, namely, perlite, gravel, and pozzolana as inert media, in addition to traditional techniques. Results showed that among the three soilless substrates, perlite medium produced the highest total yields with larger fruit sizes. Furthermore, the perlite medium enabled significant savings in water, compared to gravel (-15%) and pozzolana (-20%). Moreover, the results corroborated the existing knowledge on the tolerance of tomato to brackish water irrigation, since there was no significant difference in yield of plants grown in the soil irrigated with water with salinity levels of 1.1 dSm^{-1} and 4-5 dS m^{-1}. Plant biometric data revealed a better and quicker development of plants grown in the soilless media compared to those grown in the soil, even in the case of freshwater irrigation.

**Corresponding author: E-mail: jamal.elfaki@nilevalley.edu.sd*

Keywords: Fertigation; saline water irrigation; salinity; soilless medium; tomato.

1. INTRODUCTION

As land and water resources become increasingly limited for agriculture in many parts of the world, particularly in urban and peri-urban areas, there has been a rapid upsurge in the production of high-value crops in plastic and glass. Intensive systems are more and more requested to get maximum yields with minimum use of resources.

By the year 2025, it is estimated that 8.5 billion people will have to be fed, and protected agriculture will play an important role in meeting the projected world's food production requirements [1]. It is, therefore, clear that to increase the supply of food in the next century, land resource output must increase.

Soilless culture is possibly the most intensive method of crop production in today's agricultural industry [2]. In combination with greenhouses or protective covers, it is both technology and capital intensive. It is also highly productive, supportive to both land and water conservation, and protective to the environment. During the last two decades, there have been increasing interests in hydroponics or soilless crop production techniques for producing greenhouse horticultural crops [3]. The future growth of hydroponics depends greatly on the development of production systems that are cost-competitive with open-field agriculture.

In the arid and semiarid regions, the demand for water is constantly increasing as freshwater resources are being exhausted. However, more water is needed to meet the future demands of food production. The best solution, thus, is to develop a water-saving management techniques and/or the adoption of non-conventional sources of water for crop production; the best solution would be to promote the use of marginal quality water, especially, saline water for agricultural purpose [4].

However, if saline water is to be used on large scale for irrigation of crops, it is required to be established in proper soil, crop, water management, which is much more complicated than that of the freshwater. Such complexities on the use of saline water for irrigation, and the rapid deterioration of soil productivity evident in irrigated agriculture due to salinity [5], waterlogging and alkalization could be controlled when saline water is applied in soilless media with inert mineral composition. Hence, there is a high potential of employing saline water irrigation in soilless media, particularly for the production of vegetable crops.

In this regard, the main question on which the present study was conducted is: can the soilless media with inert mineral composition coupled with saline water irrigation support the production of crops, including those which are relatively sensitive and less tolerant to salinity? The objectives of the study, therefore, were to (i) evaluate the salinity levels of the investigated substrates, and their impacts on the growth and yield of tomato; (*Solanum lycopersicum*) (ii) assess the growth and yield of tomato in soilless media and conventional growth medium under saline and freshwater irrigation systems (iii) evaluate the physical properties of tomato fruits produced from soilless media and soil under freshwater and saline water irrigation systems.

2. MATERIALS AND METHODS

The experiment was carried out in a greenhouse at the Mediterranean Agronomic Institute of Bari (MAI Bari), South East of Italy, from October until July (9 months).

About 100 m^2 in a polythene-covered greenhouse of 1000 m^2, was used for tomato production in soilless media. The greenhouse was equipped with automatic heating and aeration systems. The heating system regulated to keep the minimum temperature inside the greenhouse constantly around 20°C. Also, a mini meteorological station comprising class A pan evaporimeter and hygro-thermometer were installed in the greenhouse.

The experimental design included major variables, namely soil and soilless media, and irrigation with brackish and freshwater. The variables included four growth media (perlite, gravel, pozzolana and agricultural soil) irrigated with brackish water (4 to 5 dS m^{-1}) and two different salinity levels in irrigation water (1,1 and 4 to 5 dS m^{-1}) for the plots with the agricultural soil. In all cases, fertigation with a nutrient solution was practiced.

2.1 Plant Materials

Tomato (*Solanum lycopersicum*) is believed to originate from the coastal strip of western South

America where the greatest genetic diversity is found. Tomatoes like warm conditions with temperatures ranging from 24°C to 29°C. Tomatoes need some shading and good aeration [6].

2.2 Life Cycle

Tomato can be planted in short cycle (as “catch” crops) in autumn, and as the main crop in early spring, or with a long cropping cycle (winter-spring, autumn-winter and spring-summer production) [7].

In Mediterranean countries, the tomato production cycles in soilless culture parallel widely those conducted in soil culture, while. on the contrary in northern Europe short cycles are conducted with soilless culture are adopted [8].

2.3 Environmental Requirements

The greenhouse environment has a profound effect on crop productivity and profitability. The main environmental requirements are:

- **a- Temperature**: it is the main environmental component influencing vegetative growth, cluster development, fruit setting, development, ripening & quality. Tomatoes require a carefully determined growing temperature for maximum yield.
- **b- Light:** it is a pre-requisite for plant growth and flowering time, especially in winter when it is in short supply.
- **c- Relative humidity:** growth and fruit set are favored by high relative humidity. However, water condensation can develop serious diseases.
- **d- Air movement:** horizontal air movement is beneficial because it minimizes air temperature gradients in the greenhouse, removes moisture from the lower parts under the foliage, helps the CO_2 from the top of the greenhouse to travel into the leaf canopy where it is taken up and fixed in photosynthesis, and may assist pollination.

Also, the uniformity of the greenhouse environment is improved.

- **e- pH:** its value is the negative logarithm of the hydrogen in concentration. Optimal results are guaranteed at the pH varying between 5.5 and 6.
- **f- EC:** researches show that the optimum growth is realized between at an electrical conductivity of soil saturated paste of 1.5 to 3.5 dS m^{-1} according to the stage of growth.

2.4 Variety

For the present study, a non-commercialized variety, Gabriela F1, produced by the Society “HAZERA; COIS’94, Italia” [9] was used. Gabriela F1 has the following advantages:

i. Adapted for open field and soilless, protected media;
ii. Adapted for fresh consumption and industry market;
iii. Produces big sized fruits (weight 140-180 g)

The duration (in days) of each growth stage of the crop is presented in Table 1.

2.5 Set up of the Soilless Media Experiments

The basic components used in the soilless media system were categorized into three: (i) Benches and troughs; (ii) Fertigation and drainage system; and (iii) Irrigation system control and monitoring equipment (Fig. 1).

2.6 Fertigation and Drainage System

2.6.1 Fertigation unit

The injector is a Priva Nutriflex unit, coupled with a pump powered by a 1 hp electric engine, with a discharge rate of *ca*. 8 m^3/hour at a pressure of 2.5 bar. In detail, the fertigating unit comprised:

Stock nutrient solution tanks: Five set-ups of 100 L plastic tanks were used; two for macronutrient solutions, one each for microelements, seawater, and nitric acid for the automatic control of the nutrient solution pH.

Hydrometers: Before reaching the main distribution network for the nutrient solution to each set-up, a 1½” hydrometer fitted with a transmitter of 10 L impulse was used to regulate the computer system at a maximum delivery volume of 10 L of the nutrient solution to be mixed with 100 L of water.

Injection pump: The five hydrometers were connected to small injection pumps, controlled by a computer, to automatically supply the right amount of stock nutrient solution to the mixing tank.

Nutrient solution mixing tanks: In these tanks, the computer mixed the fixed amount of nutrient solution, saline water with fresh water at the right proportions to obtain the required EC and pH, after which the irrigation nutrient solution was distributed to the irrigation sectors.

2.7 Irrigation Water

Freshwater was used to diluting the nutrient solution as well as the seawater to obtain the desired EC value for saline water irrigation.

2.7.1 Preparation of saline water

Two-sources of water were used to prepare the saline irrigation water: freshwater with EC around 1.1 dS m^{-1} and seawater with EC around 48 dS m^{-1}.

The final EC of irrigation water was between 4 and 5 dS m^{-1} under the hydroponic system.

The estimation of the quantity of seawater to be diluted with the freshwater to achieve the desired EC of 4 dS m^{-1}, was obtained from the Priva Nutnflex computer calculations.

The proportions of nutrient solutions, seawater, and nitric acid used in each irrigation system were automatically calculated with the computer by setting the EC scale 4 to 5 dS m^{-1} and the pH scale at 5 to 6.

Table 1. Cycle length of tomato in days

Init.	Dev.	Mid.	Late	Total	Plant date	Region
30	40	40	25	135	January	Arid region
35	40	50	30	155	Apr/May	Calif. USA
25	40	60	30	155	January	Calif. Desert, USA
35	45	70	30	180	Oct/Nov	Arid region
30	40	45	30	145	April/May	Mediterranean

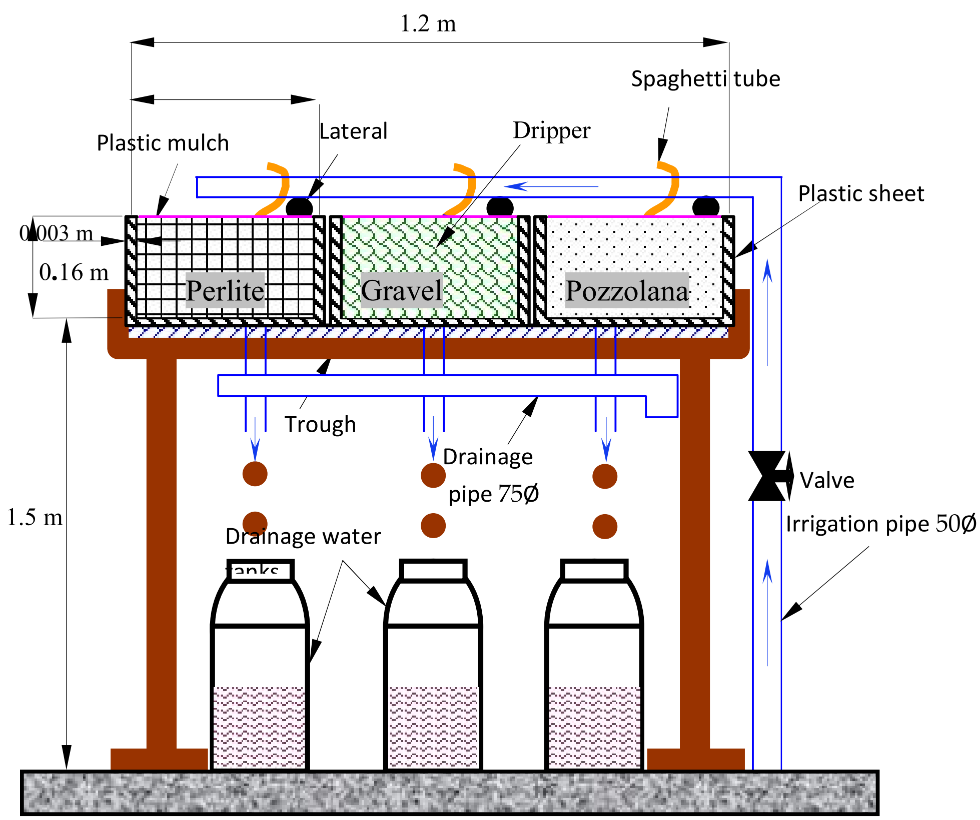

Fig. 1. Frontal view of the cultivation bench

For plants grown in the soil, this was done according to certain ratios predetermined by using the formula developed by Ayers and Westcot [10], however, adjustments were made by iterations. The main components of both freshwater and seawater are presented in Table 2.

2.7.2 Preparation and compositions of nutrient solutions

For fertilizing crops in soilless culture, several formulae have been proposed, however, for the present study, that of Schwarz [11] was employed. The compositions of the nutrient solutions including both macro- and micro-nutrients are presented in Table 3.

2.8 Traditional Cultivation Trial

The experiment was conducted under similar conditions as the soilless media using the natural soil as the growing medium. The experiment was carried out on an area of 75 m^2, divided into two equal parts; each portion was irrigated with one of freshwater or saline water.

Some chemical and physical properties of the soil in the upper and bottom soil layers are presented in Tables 4 and 5.

2.8.1 Irrigation and fertilization

Irrigation was scheduled at 30 to 40% depletion of available soil water to prevent moisture stress in the crops. The volumes of water applied at each irrigation period were estimated from the difference in soil moisture content at the time of irrigation and that of field capacity.

The actual volume of water applied varied with the crop growth stage (between 0.17 and 0.31 L/plant /day). The proportion of saline water to the fresh one was calculated according to Wenten et al. [12].

[EC $_{(seawater)}$ ×proportion used] + [EC $_{(freshwater)}$ × proportion used] = [max. EC $_{mixture)}$]

The calculated and measured ratio of fresh and saline water mixing is given in Table 6.

2.9 Measurements and Observations

2.9.1Soilless system observations

2.9.1.1 Drainage volume

Drainage volume was collected in graduated containers and were measured daily, from which weekly averages were.

Table 2. Selected chemical components in the irrigation water

Source of water	EC (dS m^{-1})	pH	Anions (meq L^{-1})				Cations (meq L^{-1})			
			CO_3^-	HCO_3^-	SO_4^{2-}	CL^-	Ca^{2+}	Mg^{2+}	Na^+	K^+
Freshwater	1.11	7.52	-	4.95	2.12	3.89	6.49	2.13	2.52	0.43
Seawater	47.31	9.22	-	44.98	25.61	427	16.17	72.11	3913	3.97

Table 3. Nutrient solution composition

Solution	Fertilizers	Unit	Weight
A	Calcium nitrate (15.5 N, 20Ca)	Kg	7
	Potassium nitrate (14N; 46 K_2O)	Kg	1
	Iron-Chelate DTPA (4.5 Fe)	g	250
B	Potassium nitrate (14N; 46 K;>0)	Kg	2
	Magnesium sulphate (16.7 MgO; 13 S)	Kg	2.5
	Phosphoric acid	ml	100
	Microelements	g	100
C*	MgO	g	150
	SO_3	g	300
	B	g	5
	Cu	g	5
	Mn	g	24
	Zn	g	2
	Mg	g	0.04

** We used a ready-made fertilizer in form of soluble salts, which contains the desired amount of microelements*

Tables 4. Selected soil chemical characteristic before planting

DEPTH (CM)	PH	EC (DS M^{-1})	Soluble anions (MEQ L^{-1})				Soluble cations (MEQ L^{-1})				CACO$_3$%	O.M%
			$C_2O_3^-$	HCO_3^-	Cl	$S_2O_4^{2-}$	Na^+	K^+	Ca^{2+}	Mg^{2+}		
0-25	7.77	2.13	0	1.23	6.22	13.33	4.75	0.14	13.72	2.51	14.11	1.42
25-50	8.13	0.95	0	1.45	3.11	4.12	2.11	0.06	4.13	1.72	10.87	1.49

Tables 5. Some soil physical characteristics

Depth (CM)	Granulometry %					Bulk density G CM^{-1}	Moisture content in % by weight		
	Clay	Silt	Fine sand	Coarse sand	Texture class		Field capacity	Wilting point	Available water
0-25	49	15	29.55	8.95	Clay	1.21	35	13	22
25-50	52	12	30.22	7.91	CLAY				

Table 6. Calculated and measured the ratio of fresh and saline water mixing

EC DS M^{-1}	Calculated		Measured	
	Freshwater %	Seawater %	Freshwater %	Seawater %
4	93.89	6.11	93.6	6.4

2.9.1.2 Drainage water salinity

Samples of the drainage water collected daily were analyzed for EC with an electrical conductivity meter type CRISON (SCRO CM 2201).

2.9.1.3 Media salinity

Media samples were taken every week for the determination of EC as affected by the source of irrigation water at a ratio of 1:5.

2.9.2 Soil analysis

Total soil analyses were conducted at the beginning of the experiment. This was followed by the determination of EC at a biweekly interval.

2.9.3 Soil physicochemical analysis

The mechanical analysis for soil texture determination was carried out by the hydrometer method using sodium hexametaphosphate as a dispersing agent as described by Elfaki et al. [13].

Soil pH was determined in 1:2.5 (w/v) soil-saturated mixtures using a glass electrode pH meter. Total soluble salts were measured in the soil saturated past extract using electrical conductivity meter to obtain EC in dS m^{-1}at 25°C [14].

Soil organic matter content was analyzed using the Walkley and Black method [15].

In the saturated paste extract, exchangeable cations (Ca^{2+}, Mg^{2+}, K^+, Na^+) and anions (Cl^-, CO_3^{2-}, HCO_3^-, SO_4^{2-}) were determined and analyzed as follows:

- Carbonate and bicarbonate were estimated volumetrically by titration with a standard solution of sulfuric acid, using phenolphthalein and methyl orange as indicators for each, respectively [16].
- Chloride was determined with silver nitrate [14].
- Calcium and magnesium were estimated by titration using the Versenate method with ammonium purporate as an indicator for calcium, and Eriochrome Black T as an indicator for calcium and magnesium [17].
- Sodium and potassium were determined photometrically by a flame photometer (JENWAY PEP7) as described by Rayment and Lyons [14].

2.10 Yield Parameters

The yields were evaluated with quantitative and qualitative parameters.

2.10.1 Quantitative evaluation of yield

Fruits of each plant were collected, counted and weighted. At each harvest period, the following parameters were determined:

- Number of fruits in each plant
- Number of fruits per square meter
- Yield for each plant (kg/plant)
- Yield per square meter
- Fruits diameter

3. RESULTS AND DISCUSSION

As reported by Jones [18], soilless media has proven to be a highly productive technique for crop production. Thus, the trend of the recent horticultural production of major crops will be based entirely on artificial media rather than soil, which has been the common practice [19].

The present study was conducted to evaluate the response of tomato (var. Gabriela F1) to saline water irrigation in soilless media comprising three inert substrates, namely Pozzolana (Po.), Pelite (Pe.) and Gravel (Gr.).

Generally, the saline water irrigated soilless media produced interesting results as regards water-saving and plant growth enhancement. For the easy and convenient exposition, the following symbols will be used throughout the comments to the results:

Symbol	T1	T2	T3	T4	T5
Treatment	Perlite	Gravel	Pozzolana	Soil-freshwater	Soil-brackish water

3.1 Variations in Substrate Salinity

High EC was recorded in the soilless media at 10 - 12 weeks after planting (Fig. 2), thereafter, it decreased, probably due to lower plant uptake coupled with a high rate of leaching. Interestingly, in T5 (Fig. 3) there was no such decrease in EC, probably due to restrictions to leaching action compared to the soilless media; however, leaching was found to be highly significant in T4.

Another interesting observation was made on the EC values under treatments T1, T2, T3 with those under T4 and T5 at the termination of the experiment, wherein the former had lower EC values (not exceeding 3 dS m^{-1}) than the latter.

When using freshwater (T4) EC values resulted higher than those when brackish water was used in T1, T2 and T3. In the case of T5, an accumulation of salts was evident, with a final EC almost triple than those in T1, T2 and T3.

In drainage water (T1, T2, T3) EC values progressively passed from an average of 1.6 dS m^{-1} in the initial week to a final mean value of 6.55 while pH values remained practically unchanged. It is worthwhile to remark that the peak values of EC were reached by weeks 14-15 and thereafter there was a decrease, paralleling the results obtained with EC in soil paste (Fig. 4).

The above considerations show how dangerous using brackish water is when soils are irrigated without an appropriate drainage system coupled to adequate leaching to avoid salt accumulation, and at the same time shows the high potentiality for sustainably using brackish waters, so far believed unusable, in the irrigation of mildly sensitive plants, provided that the appropriate management is applied.

3.2 Yield

Fruit yield was harvested in five steps, due to its gradual ripening process; accordingly, the total yield is but one factor to be considered, the other being earliness in ripening. (Table 7).

3.2.1 Yield in kg/plant

First considering total yield, no significant difference was found between the five treatments, since they ranged from 2.31 kg/plant to 3.11 kg/plant in T1 and T2, respectively, with intermediate values in the other treatments (2.49 kg/plant in T3 and T4, and 2.54 kg/plant in T5) as presented in Fig. 5.

3.2.2 Yield in kg/m^2

If yield is referred to the unit surface rather than to the plant, the group T1, T2 and T3 is the highest yielding (with 15.55, 11.55 and 12.45 kg/m^2, respectively), significantly distant from T4 and T5 (8.3 and 8.5 kg/m^2, respectively) as presented in Fig. 6.

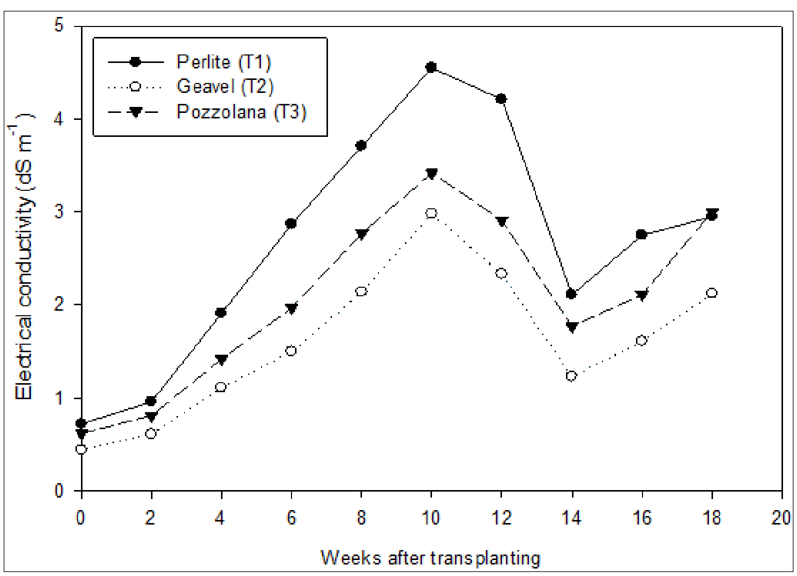

Fig. 2. Electrical conductivity evolution in time in artificial substrates extract (dS m^{-1})

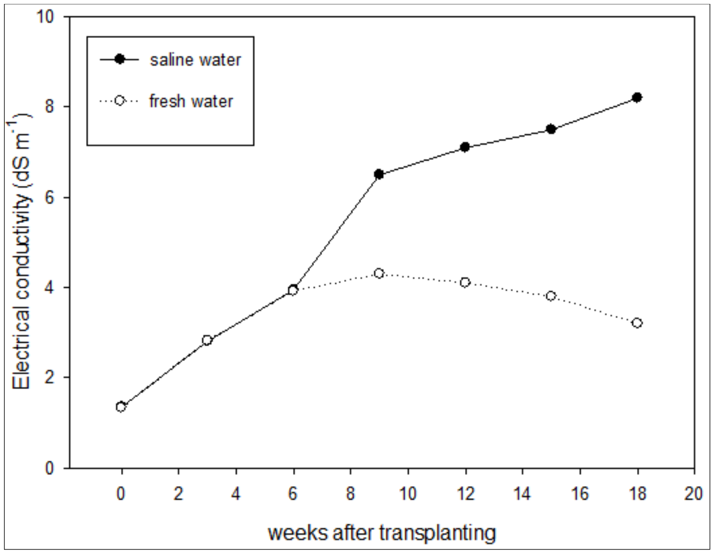

Fig. 3. Electrical conductivity evolution in time in the soil extract (dS m^{-1})

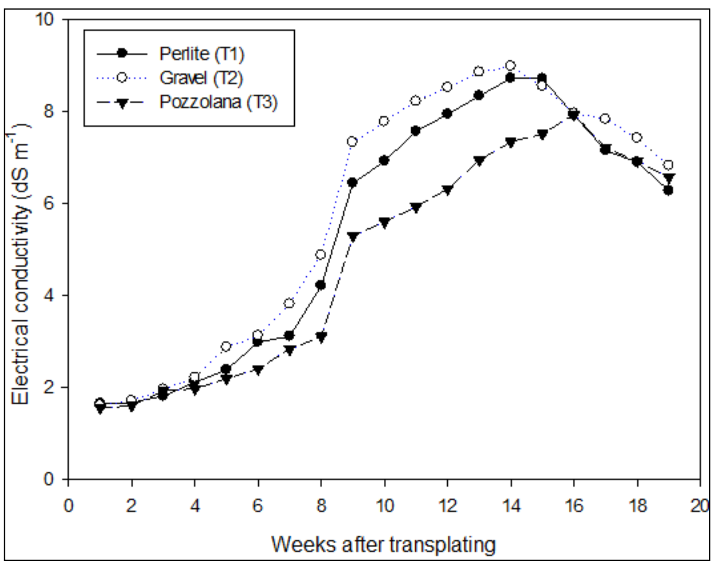

Fig. 4. EC in drained water in artificial substrates (dS m^{-1})

3.3 The Number of Fruits per Plant

The number of fruits per plant showed a different pattern than total yield, since T1, T2 and T3 gave distinctly different results than T4 and T5 (65, 60 and 62 fruits/plant versus 46 and 53 fruits/plant); the lower unit fruit number in T4 and T5 is compensated by a higher unit weight as shown in Fig. 7.

3.4 The Number of Fruits per Area

Considering the number of fruits per unit surface, again the group T1, T2, T3 outnumbered T4 and T5 by 325, 300 and 310 versus 153 and 178 fruits/m^2 as shown in Fig. 8.

If we consider the rate of maturation, we can appreciate that at the second harvest the maturation rate was 21%; 25%; 23% in T1, T2 and T3, respectively, while in T4 and T5 it was only 16% and 18%. At the third harvest, the cumulated maturation rate in T1, T2 and T3 had reached 55%; 47% 45% versus 36% and 33% in T4 and T5. Finally, at the fourth harvest, the cumulated harvest was 99%; 89%; 91% in T1, T2 and T3 whereas in T4 and T5 it was only 87%and 79%, respectively.

Of course, the same rate of maturation applies if we consider the harvest in terms of unit surface (square meter) rather than the unit plant.

3.5 Fruit Physical Characteristics

Considering fruits diameter at the final harvest, the statistical analysis discloses that; the diameter of the fruit in T4 and T5 was significantly higher than in the other treatments (68 and 69 mm versus 64, 61 and 63 mm in T1, T2 and T3, respectively) as shown in Fig. 9.

3.6 Crop Water Consumption

Water consumption was calculated as a difference between the input with irrigation and the output in drainage; consequently, the equipment permitted to reliably conduct such calculations only in bench-grown plants, namely in T1, T2, T3.

The results are reported in Fig. 10 and show not only the obvious increase in water consumption by crops with the growth of their canopies and the progress into the warm season but also the decrease late in the cycle due to senescence.

It is also of interest to underscore that in spite of the well-known reduction in atmospheric demand in greenhouses compared to the open field, the considerable value of 6 mm/day was reached, considerably higher than commonly supposed.

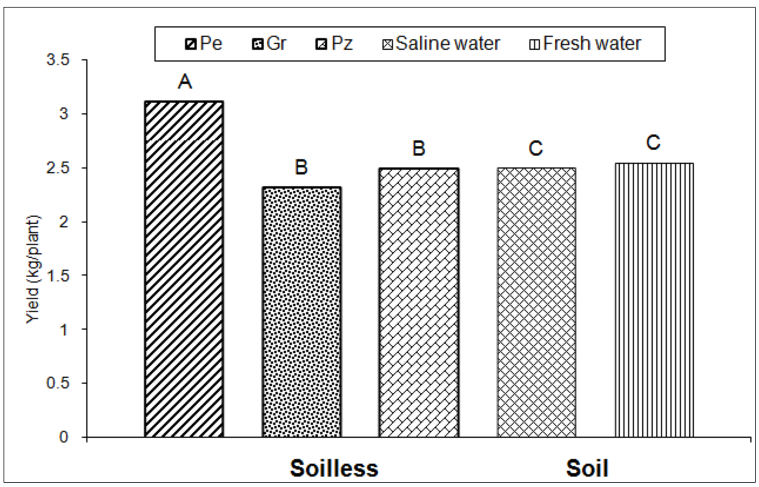

Fig. 5. Comparison of total yield (kg/plant) between the soilless and traditional cultivation

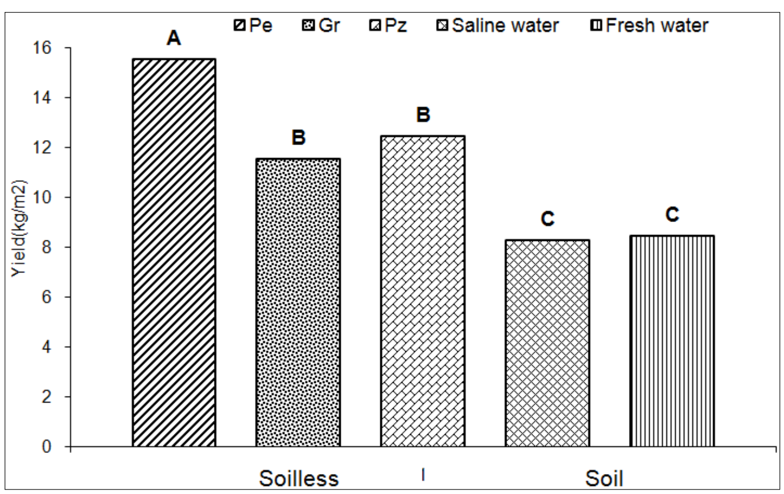

Fig. 6. Comparison of total yield (kg/m^2) between the soilless and traditional greenhouse cultivation

Table 7. Yield - quantitative data

Harvest No	Parameters	Perlite	Gravel	Pozzolana	Soil saline water	Soil freshwater
1	Fruit/plant	2	2	2	1	1
	Fruit/m^2	10	10	10	3	3
	Yield/plant(kg/p)	0,2	0,16	0,23	0,1	0,1
	Yield/m^2 (kg/m^2)	1	0,8	1,15	0,33	0,33
2	Fruit/plant	5	4	5	2	3
	Fruit/m^2	25	20	25	7	10
	Yield/plant(kg/p)	0,49	0,41	0,34	0,38	0,42
	Yield/m^2 (kg/m^2)	2,45	2,05	1,7	1,27	1,4
3	Fruit/plant	15	8	8	5	5
	Fruit/m^2	75	40	40	17	18
	Yield/plant(kg/p)	0,96	0,51	0,65	0,47	0,39
	Yield/m^2(kg/m^2)	4,8	2,55	3,25	2	1,3
4	Fruit/plant	21	22	22	17	19
	Fruit/m^2	105	110	110	57	63
	Yield/plant(kg/p)	1,16	0,98	1,05	1,22	1,11
	Yield/m^2(kg/m^2)	5,8	4,9	5,25	4,07	3,7
5	Fruit/plant	22	24	25	21	25
	Fruit/m^2	110	120	125	70	83
	Yield/plant(kg/p)	0,3	0,25	0,22	0,32	0,52
	Yield/m^2(kg/m^2)	1,5	1,25	1,1	1,07	1,7
Total	Fruit/plant	65	60	62	46	53
	Fruit/m^2	325	300	310	153	178
	Yield/plant(kg/p)	3,11	2,31	2,49	2,49	2,54
	Yield/m^2(kg/m^2)	15,55	11,55	12,45	8,3	8,5

T1 = Perlite T2 = Gravel T3 = Pozzolana T4 = Soil freshwater T5 = Soil saline water

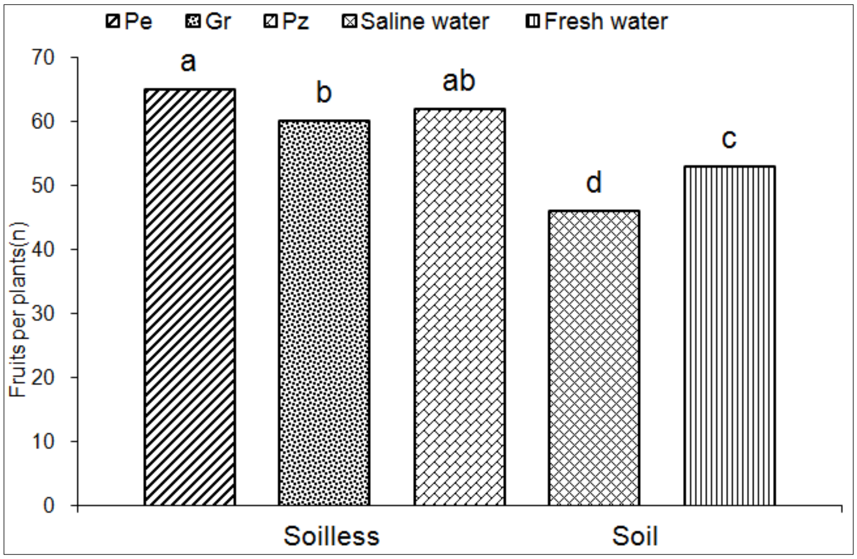

Fig. 7. Comparison of the number of fruits per plant between the soilless and traditional greenhouse cultivation

Finally, the different water consumption in the three substrates (although not statistically significant) must be remarked, with averaging 4.11, 3.81 and 3.25 mm/day for T1, T2 and T3, respectively, (Fig. 11), such differences can be probably explained with the physical characteristics of the substrates bringing about different evaporation rates.

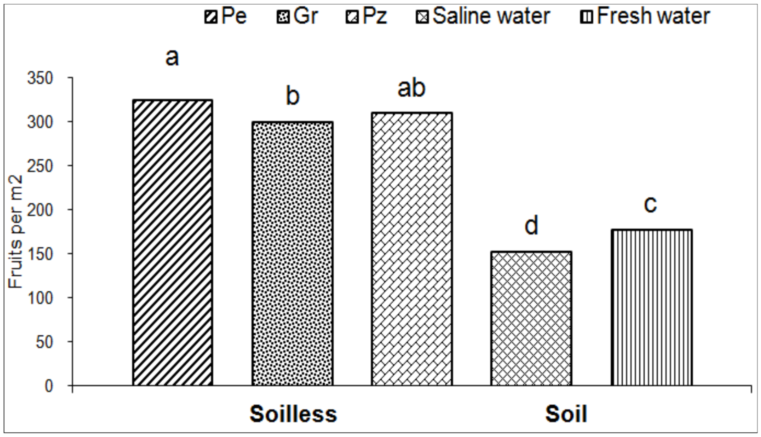

Fig. 8. Comparison of the number of fruits per m^2 between the soilless and traditional greenhouse cultivation

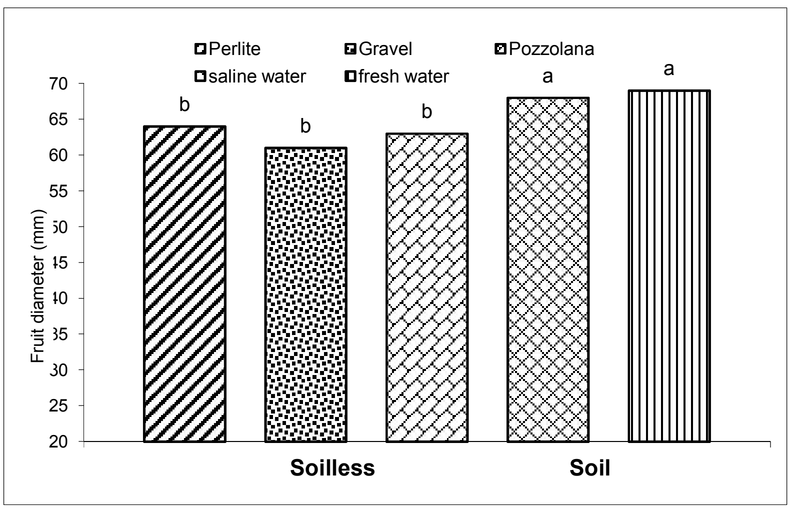

Fig. 9. fruits diameter at the final harvest

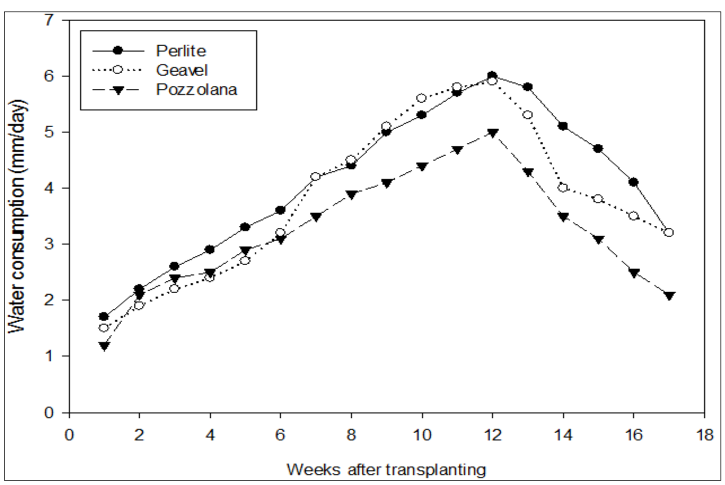

Fig. 10. Water consumption in the artificial substrates (mm/day)

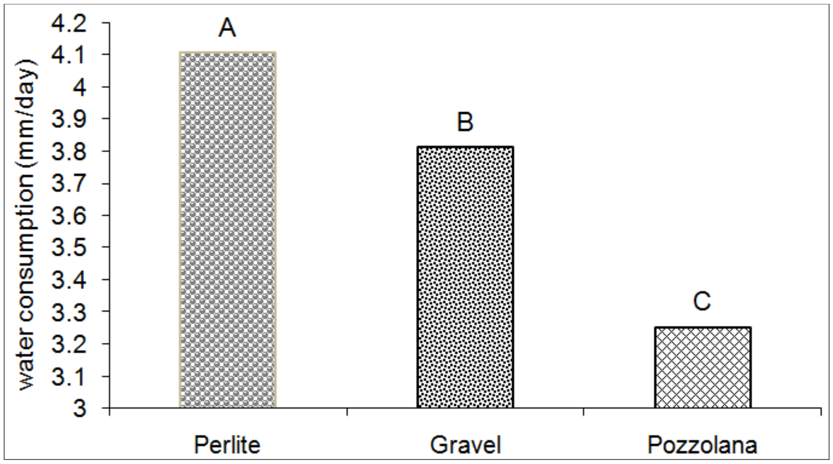

Fig. 11. Mean values of water consumption during the cropping cycle tomato under the investigated artificial substrates

The presented data show clearly that plants grown on Pozzolana consumed more water than those grown on gravel and perlite. As irrigation frequencies and volumes were equal for each variety for the three substrates, the data obtained mean that Pozzolana has a higher water holding capacity than gravel, whereas the perlite has the lowest.

In other words, drainage is greater in gravel and perlite benches. In this regard, to reduce water losses and for achieving an efficient water use in soilless culture, irrigation scheduling should be established according to the physical characteristics of the substrates. Thus, smaller volumes and higher frequencies are required for the substrates characterized by high drainage and low water holding capacity.

4. CONCLUSION

Irrigating artificial substrates with brackish water is a safe practice, provided that a sufficient leaching fraction is secured since there is no salinity build-up, contrary to the soil, where final EC in saturated paste was alarming high. moreover, Tomatoes grown in artificial substrates have a faster ripening process than those grown in the soil, with a significantly higher percentage of maturation throughout the cycle. Finally, Among the three artificial substrates compared the most effective resulted perlite, which permitted to achieve higher total yields with larger sized fruits.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Gashu D, Demment MW, Stoecker BJ. Challenges and opportunities to the African agriculture and food systems. African Journal of Food, Agriculture, Nutrition and Development. 2019;19(1): 14190-14217.
2. Jensen MH. Controlled environment agriculture in deserts, tropics and temperate regions-A World Review. In International Symposium on Design and Environmental Control of Tropical and Subtropical Greenhouses. 2001;578:19-25.
3. Savvas D. Hydroponic production of vegetables and ornamentals. H. Passam (Ed.). Embryo.;2002:299-343
4. Hamdy A, Ragab R, Scarascia-Mugnozza E. Coping with water scarcity: Water saving and increasing water productivity. Irrigation and Drainage: The Journal of the International Commission on Irrigation and Drainage. 2003;52(1):3-20.
5. Qadir M, Oster JD. Crop and irrigation management strategies for saline-sodic soils and waters aimed at environmentally sustainable agriculture. Science of the Total Environment. 2004;323(1-3):1-19.
6. Robertson LD, Labate JA. Genetic resources of tomato (*Lycopersicon esculentum* Mill.) and wild relatives. Genetic improvement of Solanaceous crops. 2007;2:25-75.
7. Anza M, Riga P, Garbisu C. Effects of variety and growth season on the

organoleptic and nutritional quality of hydroponically grown tomato. Journal of food quality, 2006;29(1):16-37.

8. Gruda N, Tanny J. Protected crops. In Horticulture: Plants for People and Places. Springer, Dordrecht. 2014;1:327-405.
9. Ilahy R, Hdider C, Lenucci MS, Tlili I, Dalessandro G. Phytochemical composition and antioxidant activity of high-lycopene tomato (*Solanum lycopersicum* L.) cultivars grown in Southern Italy. *Scientia Horticulturae*. 2011;127(3):255-261.
10. Ayers RS, Westcot DW. Water quality for agriculture. FAO Irrigation and Drainage Paper 29 Rev. 1. FAO, Rome; 1994.
11. Schwarz, M. Soilless culture management. Springer Science & Business Media. 2012;24.
12. Wenten IG, Ariono D, Purwasasmita M, Khoirudin. Integrated processes for desalination and salt production: A mini-review. In AIP Conference Proceedings. AIP Publishing. 2017;1818(1):020065.
13. Elfaki JT, Gafer MA, Sulieman MM, Ali ME. Hydrometer method against the pipette method for estimating soil particle size distribution in some soil types selected from Central Sudan. International Journal of Engineering Research and Advanced Technology. 2016;2(2):25-41.
14. Rayment GE, Lyons DJ. Soil chemical methods: Australasia. CSIRO Publishing. 2011;3.
15. Wang X, Wang J, Zhang J. Comparisons of three methods for organic and inorganic carbon in calcareous soils of north-western China. PIOS One. 2012;7(8): e44334.
16. Estefan G, Sommer R, Ryan J. Methods of soil, plant and water analysis. A manual for the West Asia and North Africa region. 2013;170-176.
17. Fonseca A, Raimundo Jr, IM. A simple method for water discrimination based on an light emitting diode (LED) photometer. Analytica Chimica Acta. 2007; 596(1):66-72.
18. Jones Jr, JB. Hydroponics: A practical guide for the soilless grower. CRC press; 2016.
19. De Anda J, Shear H. Potential of vertical hydroponic agriculture in Mexico. Sustainability. 2017;9(1):140.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/53036