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Impact of Plant Densities on Eggplant Growth and Production in Urban Horticulture Using Substrate Cultures

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ABSTRACT

The current investigation was carried out at the Central Laboratory for Agricultural Climate (CLAC), Giza, Egypt, during the two successive summer seasons of 2023 and 2024. The study aimed to investigate the effect of using three substrates mixtures sand: compost (80%:20%), sand: peat moss: perlite (50%:25%:25%), and peat moss: perlite (50%: 50%) combined with three plant-densities (6 plant /m^2, 9 plant/m^2 and 12 plant/m^2) for eggplant production (yield and quality) under urban agricultural conditions. Plant height, fresh and dry weight per plant, leaves number, branch number and total chlorophyll reading were determined at the end of each growing season. Total fruit weight/plant, fruit number/plant, average fruit weight and total yield per m2 were determined during the harvested period. N, P and K contents of eggplant were estimated beside an economic study. The obtained results indicated the possibility of using sand as a local and inexpensive substrate by mixing it with peat moss and perlite (50%:25%:25%) which allows for reducing the cost of the substrate and maintaining eggplant productivity. While, cultivating 9 plants/ m^2 led to an increase in the yield characteristics of eggplant. The highest yield per square meter and a good economic return have been recorded for substrate mixture sand: peat moss: perlite (50%:25%:25%) combined with 9 plants per square meter.

KEYWORDS: Eggplants, soilless culture, substrate culture, plant density, economic study, urban horticulture.

1. INTRODUCTION

Due to rapid human population growth, urbanization, climate changes and limited natural resources, sustainable supplies of fresh crops to urban areas have been adversely affected, which led to major disruption in their availabilities and an increase in their prices. Under Egyptian conditions, the use of substrate culture in a soilless culture technique, particularly when using the available local material such as sand, could play a role in enhancing the supply of fresh crops to urban cities (Abul Soud *et al*., 2014 and Lim and Kishnani, 2010).

Eggplants (*Solanummelongena L.*) is a beloved vegetable grown in Egypt. This vegetable is rich in nutrition and offers numerous health benefits. It is considered one of the most important crops grown during the summer season in Egypt

(Abd El-Al *et al.,* 2008). It also represents a good source of carbohydrates (6.4%), protein (1.3%), fats (0.3%) and vitamin C, Mahmoud, (2000).

Plant cultivation methods that do not use soil as a rooting medium are referred to as soilless culture technology Olympios, (2011). Furthermore, (Grillas *et al.,* 2001 and Gruda 2009) highlighted that the most intensive production methods, soilless culture systems, are based on environmentally friendly technology and can yield more even in regions with unfavorable growing conditions. Soilless culture has the potential to enhance cropping systems by maximizing the use of inputs (nutrients, herbicides, and water), controlling diseases more effectively, and increasing crop production regardless of the climatic conditions (Montagne, *et al.,* 2015). Many studies have suggested that plant growth, production and yield quality in soilless cultures are better than those in soil (Savvas *et al.*, 2013).

Substrate culture is known as the cultivation of crops in any medium except soil (FAO, 1990). Materials used as a cultivation substrate should have a high capacity for exchanging cations, appropriate aeration, suitable drainage and the ability to hold water. They should also be free of any adverse effects on plants (Javanpour-Haravi *et al*., 2004). Great total porosity, low bulk density, sufficient aeration, and high water-holding capacity are characteristics of the ideal soilless substrate that promote root penetration and boost plant nutrient availability for multi-season applications. Deepagoda *et al*., (2013). Growers who are interested in cultivation in substrates need the kind of substrates that are available, consistent, repeatable, easy to handle, low cost, and possess the right physical and chemical characteristics for the crop's growth. (Klock-Moore, 2000). Substrate culture under Egyptian conditions is a promising agriculture technique to maximize green food production under the shortage of water and soil, besides avoiding the impact of climate change and reducing pesticide use. It is important, as well, to use a local substrate (sand, gravel, depleted clay, etc...), instead of imported substrates (peat moss, perlite, rock wool, etc...), due to their (Abul-Soud *et al*., 2018). Sand is a domestic substrate with good stability in properties and low price, which allows it to be used over several years. On the other hand, the greater bulk density of the substrates and lower water holding capacity leads to suffocation of the roots (Verdonck *et al*., 1991). Maloupa *et al*., (2001) found that mixed substrates can sustain favorable physical conditions, for a longer time, than a single substrate In addition, Vaughn *et al*. (2011) noted that there is a growing interest in using mixtures of organic and inorganic materials, as a growing media, in soilless culture. Adding inorganic materials to organic materials, such as peat, increased the water-holding capacity of inorganic materials and improved aeration, which allowed for better plant growth, and therefore increased the whole yield. Therefore, by mixing the sand as a local substrate with peat moss and perlite as imported substrates, physical and chemical properties can be improved while reducing the cost of agricultural substrate.

Plant density is considered one of the important agricultural processes، since it influences vegetative development and productivity of crops Mojaddam, (2014). Optimizing plant density led to the production of the highest yield as a result of decreased leaf overlapping and shadowing, decreased competition between plants for nutrients and water, and increased penetration of light into the base leaves Motsenbocker, (1996), Papadopoulos & Pararajasingham, (1997), Charlo *et al*., (2007), Shirtliffe and Johnston (2002) and Santos *et al.,* (2010). Due to the high initial investment requirements, soilless cultivation methods need to choose a vegetative density that will make the optimal use of available space Martin and Christian, (2013). Furthermore, Iwuagwu *et al*., (2019) and Mehla *et al.,* (2000), reported that the spacing of the plants has a significant impact on the productivity and marketing of eggplant, as it was shown that wider spacing increases fruit yield per plant and results in larger fruits per plant. Abou Al-Azm, *et al., (*2021), investigated the effect of three inter-row plant spacing (30 cm, 45 cm and 60 cm). Their findings demonstrated that narrow spacing led to a heightening of the plant and total yield per fad. Although the large spacing resulted in more branches, leaves, and dry weight of leaves, number of fruits and yield per plant.

The study aimed to investigate the effect of different plant densities on the growth and production of white Eggplants under substrate cultures system, in order to provide sustainable supplies of fresh crops to urban areas.

2. MATERIALS AND METHODS

This research was conducted on the rooftop of the Central Laboratory for Agricultural Climate (CLAC), at Dokki - Giza - Egypt during the two summer seasons (2023 and 2024).

2.1.Plants:

Eggplant seeds (*Solanumme longena* L., *cv*. Soma F1 Hybrid) were sown on 15th January in both seasons, in polystyrene foam trays (84 holes). At the fifth true leaf stage, the eggplant seedlings were transplanted into black plastic pots (8 L volume), in different substrate treatments, on the first week of March 2023 and 2024, respectively. One seedling was planted in each pot. The pots were arranged on the cultivation tables regarding their plant density treatments.

2.2.System description:

One-meter-long, one-meter-wide, and ten centimeters deep wooden tables, with a height of 0.6 m from the roof-top floor, were used to perform a close substrate system. Each table is covered with 0.5 mm thick black polyethylene sheets and has a drainage tube on one side to collect any leaching into the main tank for close substrate culture. Each plant received the diluted nutrient solution via drip irrigation systems as part of the fertigation system, which involved a tank filled with nutrient solution.

2.3.Substrate materials:

Sand was first washed with dilute nitric acid to remove undesirable salts, then washed with running water to remove nitric acid traces. After the sand had dried it was mixed with the different substrate mixtures. The plastic pots were filled with 10L of different substrate mixtures. One seedling was planted in each pot,

2.4.Treatments:

This experiment involved 6 treatments which were the combinations between three Substrate mixtures and three plant densities as follow:

A- Substrate mixtures:

1- Sand: Compost (80%:20%) (**S:Co**)

2- Sand: Peat moss: Perlite (50%:25%:25%) (**S:Peat:Per**)

3- Peat moss: Perlite (50%:50%) (**Pet:Per**)

B- Plant density

1- plants /m^2 (two rows and three plants\row)
2- plants /m^2 (three rows and three plants\row)
3- 12 plants /m^2 (four rows and three plants\row)

2.5. Nutrient Solution

The nutrient solution utilized in this experiment is referenced in Table (1) (El Behairy, 1994).

Table 1. The Chemical Ingredients of Nutrient Solution

Chemical nutrient solution	Macronutrient (ppm)					Micronutrient (ppm)					
	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	B	Mo
	200	40	300	170	50	3.0	1.0	0.039	0.04	0.17	0.1

2.6.The measurements:

2.6.1. The characteristics of substrate mixtures, both chemical and physical

Water hold capacity percentage (W.H.C.), bulk density (B.D.), total pore space (T.P.S.), and air porosity percentage (A.P.) for substrate mixtures were calculated using Inbar *et al*., (1993) and the chemical properties i.e. pH and electrical conductivity (EC). A conductance metre calibrated with 0.01 and 0.1M KCl was used to estimate the electrical conductivity (dsm-1) of various mixtures. Table (2) provided an illustration of the substrate mixtures' physical and chemical characteristics.

Table 2. The physical and chemical properties of substrate mixtures.

Substrate mixtures	Physical properties				Chemical properties	
	B.D Kg/L	T.P.S %	W.H.C %	A.P %	pH (1:10)	EC dsm^{-1}
Sand: Compost (80%:20%)	1.67	26.0	17.8	8.2	6.7	0.4
Sand: Peat moss: Perlite (50%:25%:25%)	0.91	46.5	34.2	12.3	7.1	0.41
Peat moss: Perlite (50%:50%)	0.14	69.50	55.0	14.5	7.9	0.45

Bulk density (B.D). Total poor space (T.P.S).Water holding capacity (W.H.C).Air porosity (A.P).

2.6.2. Air temperature.

The maximum and minimum air temperature on the bare and green rooftop were daily recorded by a thermometer and hygrometer (ThermoPro Digital Hygrometer TP53) throughout the experimental period in seasons 2023 and 2024 where the values were expressed as an average weekly.

2.6.3. Vegetative growth parameter and yield:

At the end of the growing season (at harvest time), three labeled plants per replicate, for each treatment, were taken for measurement of the vegetative growth parameter. Plant height (cm) was calculated as the distance from the substrate surface to the highest point of the plant. The number of leaves, number of branches and fresh and dry weight per plant were measured. Total fruit weight/plant, fruit number/plant and average fruit weight were calculated by the summation of all the fruit pickings per plant during the season and total yield per m^2 (total fruit weight/plant x number of plant /m^2). Total chlorophyll content was determined using a chlorophyll meter (SPAD).

2.6.4. Chemical analysis:

Mineral analysis of shoots (N, P, and K) was estimated. Three plant samples at the harvest stage of each plot were dried at 70°C in an air-forced oven for constant weight. The process outlined by Allen (1974) was used to digest dried plant samples in H2SO4. The amount of N, P, and K in the acid-digested solution was estimated. Following the steps outlined by the FAO (1980), the Kjeldahl method was used to determine the total nitrogen. Page *et al*., (1982) used a spectrophotometer to determine the phosphorus content using the colorimetric method (ascorbic acid). As explained by Chapman and Pratt (1961), a Flame photometer was used to photometrically measure the potassium content.

The economic study was calculated on the basis that the system area is 6 square meters. The prices of construction costs and production costs as well as marketing prices were calculated according to the Egyptian market.

Total infrastructure costs = wooden tables+ black polyethylene sheets + drainage tube + main tank +drip irrigation systems+ pump (80 watt)

Total operation costs = seedling + irrigation + chemicals +substrate+ others.

Total investment cost = total infrastructure costs + total operation costs

Total return = total yield per $6m^2$ x marketing price per Kg

The net profit = total return – total cost.

2.7.Statistical analysis:

The data analysis was conducted through a computer program, utilizing SAS for statistical evaluation, and the significance of mean differences for all traits was assessed at the 5% level (Snedicor and Cochran 1981).

3. RESULTS AND DISCUSSION

3.1.Effect of substrates and plant densities on vegetative growth characteristics and total chlorophyll reading of eggplants during summers of 2023 and 2024.

The impact of substrate and plant density on vegetative growth characteristics and total chlorophyll reading of eggplant is presented in Table (3). Data showed that peat moss: perlite 50%:50% substrate recorded the highest results

Table 3. Effect of substrate and plant density on vegetative growth characteristics and total chlorophyll reading of eggplants at harvest time during seasons 2023 and 2024.

Substrate	2023				2024			
	Plant density / m²							
	Plant height (cm)							
	6	9	12	Mean	6	9	12	Mean
S +comp	65.9bcd	62.8 de	57.8 f	62.2 C	68.2 bc	59.8 de	55.1 e	61.0 C
S +Peat + Per	69.1 b	65.0 cde	61.8 e	65.3 B	71.5ab	69.5 bc	60.4 de	67.1 B
Peat + Per	77.6 a	68.2 bc	62.2 e	69.3 A	77.3 a	74.2 ab	63.4 cd	71.6 A
Mean	70.8 A	65.3 B	60.6 C		72.3 A	67.8 B	59.6 C	
	Number of branches/ plant							
S +comp	6.9 c	5.9 e	5.0 h	5.9 C	7.1bc	6.6 cd	6.3 d	6.7 C
S +Peat + Per	7.2 b	5.9 e	5.1 g	6.1 B	7.3 ab	6.9 bc	6.6 cd	6.9 B
Peat + Per	7.5 a	6.1 d	5.4 f	6.3 A	7.8 a	7.2 ab	6.9 bc	7.3 A
Mean	7.2 A	6.0 B	5.1 C		7.4 A	6.9 B	6.6 C	
	Number of leaves/plant							
S +comp	84.8 b	76.7 cd	71.6 d	77.7 B	87.8 bcd	84.1 cde	75.8 e	82.6 B
S +Peat + Per	91.6 a	78.5 bc	73.8 cd	81.3 A	94.0 ab	91.3 abcd	83.3 de	89.5 A
Peat + Per	92.3 a	78.6 bc	75.8 cd	82.2 A	98.4 a	92.3 abc	82.5 de	91.1 A
Mean	89.5 A	77.9 B	73.7 C		93.4 A	89.2 B	80.5 C	
	Fresh weight/plant (g)							
S +comp	152.3 b	129.9 c	112.7 d	131.6 B	160.1 ab	141.6 c	113.1 e	138.3 B
S +Peat + Per	162.6 ab	129.3 c	120.9 cd	137.6 AB	164.2 a	154.5 b	126.6 d	148.4 A
Peat + Per	164.2 a	131.6 c	123.0 cd	139.6 A	166.6 a	155.5 b	128.4 d	150.2 A
Mean	159.7 A	130.3 B	118.9 C		163.6 A	150.6 B	122.7 C	
	Dry weight/plant (g)							
S +comp	23.5 a	19.1 bc	17.4 d	20.0 B	24.4 ab	22.1 c	17.8 d	21.5 B
S +Peat + Per	24.6 a	19.3 b	18.2 cd	20.7 AB	24.2 abc	23.8 abc	19.6 d	22.5 A
Peat + Per	24.8 a	20.1 b	19.1 bcd	21.3 A	25.9 a	23.0 bc	19.2 d	22.7 A
Mean	24.3 A	19.5 B	18.2 C		24.8 A	23.0 B	18.9 C	
	Total chlorophyll reading (Spad)							
S +comp	50.0 a	46.3 bcd	43.9 d	46.8 B	48.8abc	45.8 d	42.5 e	46.2 B
S +Peat + Per	50.5 a	48.0 abc	44.8 cd	47.8 A	49.8 ab	47.6 abcd	46.1 cd	47.8 A
Peat + Per	50.5 a	48.6 ab	45.8 bcde	48.3 A	50.1 a	47.9 abcd	46.4 d	48.1 A
Mean	50.3 A	47.6 B	44.8 C		49.6 A	47.1 B	45.0 C	

Sand: Compost = (S:Co), Sand: Peat moss: Perlite = (S:Peat:Per), Peat moss: Perlite = (Pet:Per)

for all vegetative growth characteristics followed by (sand: peat moss: perlite 50%:25%:25%) substrate, with a significant difference between them in plant height and number of branches, while no significant difference in the number of leaves, fresh and dry weight of the plant and total chlorophyll content. The lowest vegetative growth characteristics and total chlorophyll contents were obtained by sand: compost substrate in both seasons.

Regarding the effect of plant density. Increasing plant density from 6 to 12 plants/ m2 led to a decrease in all vegetative growth characteristics as well as total chlorophyll reading.

Data also revealed that (peat moss: perlite 50%:50%) substrate, followed by (sand: peat moss: perlite 50%:25%:25%) substrate, combined with plant density of 6 plant/m2 recorded the highest value in all vegetative growth characteristics without significant differences between them, except for plant height and number of branches, there was a significant difference between them. On the contrary, the lowest value was estimated with the combined sand: compost substrate and plant density of 12 plants/m^2.

3.2. Effect of substrate and plant density on yield parameters of eggplants during seasons 2023 and 2024.

The effect of different substrates and plant densities on the parameters of eggplant yield are presented in Table (4). The revealed data indicated that using (peat moss: perlite 50%:50%) substrate followed by (sand: peat moss: perlite 50%:25%:25%) substrate gave the highest yield parameters average fruit weight, yield per plant and total yield / m^2, with significant differences between them and average fruit number without significance between them. On the centenary, the lowest data was obtained with (sand: compost 80%:20%) substrate in both seasons.

Regarding the effect of plant density. It was obvious that increasing the plant density from 6 plants / m^2 to 12 plants/m^2 led to a reduction in the average fruit weight, average fruit number and yield per plant. While plant density 9 plants/m2 gave the highest total yield per square meter followed by 6 plants/m^2 with significant differences between them. On the contrary, the lowest yield parameters were recorded by 12 plants/m^2.

Table 4. Effect of substrate and plant density on yield parameters of eggplant during seasons 2023 and 2024.

Substrate	2023				2024			
	Plant density / m^2							
	Average fruit weight (g)							
	6	9	12	Mean	6	9	12	Mean
S +comp	55.5 c	50.4 d	28.0 f	44.6 C	56.7 bc	52.9 c	32.6 e	47.4 C
S +Peat + Per	61.3 b	55.3 c	32.1 ef	49.6 B	62.2 b	58.4 bc	34.1 de	51.6 B
Peat + Per	70.2 a	60.6 b	34.4 e	55.1 A	69.8 a	62.0 b	39.5 d	57.1 A
Mean	62.3 A	55.5 B	31.5 C		62.9 A	57.8 B	35.4 C	
	Average fruit number							
S +comp	66.0 ab	56.9 cd	44.1 f	55.7 B	64.5 a	59.7 abc	45.6 d	56.6 B
S +Peat + Per	65.3 ab	60.3 bc	49.8 ef	58.5 A	65.3 a	60.3 ab	52.6 cd	59.5 AB
Peat + Per	68.9 a	59.8 bcd	53.0 de	60.5 A	66.8 a	63.1 a	56.6 bc	62.1 A
Mean	66.7 A	59 B	49.0 C		65.5 A	61.1 B	51.6 C	
	Yield (Kg/plant)							
S +comp	3.7 bc	2.9 d	1.2 f	2.6 C	3.7 bcd	3.2 d	1.5 f	2.8 C
S +Peat + Per	4.0 b	3.3c	1.6 ef	3.0 B	4.1 ab	3.5 cd	1.8 ef	3.1 B
Peat + Per	4.8 a	3.6 bc	1.8 e	3.4 A	4.7 a	3.9 bc	2.2 e	3.6 A
Mean	4.2 A	3.3 B	1.6 C		4.1 A	3.5 B	1.8 C	
	Total yield (Kg/m^2)							
S +comp	22.0 de	25.8 c	14.9 f	20.9 C	21.9 de	28.5 bc	17.8 e	22.7 C
S +Peat + Per	24.1 cd	30.1 ab	19.1 e	24.4 B	24.4 cd	31.9 ab	21.5 de	25.9 B
Peat + Per	29.0 b	32.6 a	21.8 de	27.8 A	28.0 bc	35.2 a	26.8bcd	30.0 A
Mean	25.0 B	29.5 A	18.6 C		24.8 B	31.9A	22.1 C	

The interaction effect between substrate and plant density showed that. Substrates (peat moss: perlite 50%:50%) followed by (sand: peat moss: perlite 50%:25%:25%) combined with plant density 6 plants/m^2 gave the highest average fruit weight and yield per plant with significant differences between them, also gave the highest number of fruits, but without a significant difference between them. On the other hand, the highest total yield per m^2 was obtained by (peat moss: perlite 50%:50%) followed by (sand: peat moss: perlite 50%:25%:25%) combined with 9 plants/m^2 without significant difference between them. While the lowest results in all yield parameters were recorded in (sand: compost 80%:20%) combined with 12 plants/m^2.

3.3.Effect of substrate and plant density on N, P and K contents of eggplants during seasons 2023 and 2024.

Data in Table (5) showed that, the highest values of nutrients (N, P and K) were recorded in (peat moss: perlite 50%:50%) substrate, followed by (sand: peat moss: perlite 50%:25%:25%) substrate, and the lowest values were found in sand: compost 50%:50% substrate, with significant differences between all substrates.

Data also showed that plant density of 6 plants/ m^2, followed by 9 plants/ m^2 recorded the highest nutrient contents of N, P and K (%), without any significant differences between them. While a plant density of 12 plants/ m^2 gave the lowest nutrient contents.

Data in Table (5) also showed that the highest nutrient contents of N, P and K (%) were found with (peat moss: perlite 50%:50%) substrate, followed by (sand: peat moss: perlite 50%:25%:25%) substrate, with plant densities of 6 and 9 plants/ m2. On the contrary, (sand: peat moss: perlite 50%:25%:25%) substrate, and (sand: compost 80%:20%) substrate, combined with plant density 12 plants/ m^2 gave the lowest nutrient contents.

Table 5. Effect of substrate and plant density on N, P and K content of eggplant during seasons 2023 and 2024.

Substrate	2023				2024			
	Plant density / m^2							
	N %							
	6	9	12	Mean	6	9	12	Mean
S +comp	3.02 de	3.07 cde	2.57 f	2.89 C	3.17bcd	3.14 cde	2.95 f	3.09 C
S +Peat + Per	3.29 bc	3.26 bcd	2.82 ef	3.12 B	3.37 b	3.34 bc	3.08ef	3.26 B
Peat + Per	3.66 a	3.49 ab	3.04cde	3.40 A	3.60 a	3.58 a	3.10def	3.43 A
Mean	3.32 A	3.27 A	2.81 B		3.38 A	3.36 A	3.04 B	
	P %							
S +comp	0.418 ab	0.412 ab	0.319 c	0.383C	0.407ab	0.399abc	0.317 c	0.374 B
S +Peat + Per	0.427 ab	0.430 a	0.327 c	0.394B	0.444 a	0.434 a	0.331abc	0.403 AB
Peat + Per	0.443 a	0.427 ab	0.363 bc	0.411A	0.451 a	0.440 a	0.389abc	0.427 A
Mean	0.430 A	0.423 A	0.337 B		0.434 A	0.424 A	0.346 B	
	K %							
S +comp	2.07 abc	1.98 bc	1.92 c	1.99 C	2.21 ab	2.16 ab	1.87 c	2.08 C
S +Peat + Per	2.22 ab	2.13 abc	2.06 bc	2.14 B	2.25 ab	2.19 ab	2.15 b	2.20 B
Peat + Per	2.34 a	2.22 ab	2.17 abc	2.24 A	2.41 a	2.38ab	2.21 ab	2.33 A
Mean	2.21 A	2.11 AB	2.05 B		2.29 A	2.24 A	2.08 B	

3.4.Effect of urban horticulture on rooftop temperatures.

The results in Table (6) show that the green rooftop air temperature was lower than the bare rooftop, and the reduction in maximum temperature ranged between 3 and 4°C, while the reduction in the minimum temperature ranged between 1.5 and 2.5°C. This is due to the green rooftop shading the roof and protecting the roof from extreme weather events. These findings are crucial for building a city that can mitigate while providing sustainable food production and reducing energy use.

3.5.The economic evaluation

Data in Table (7) indicated that the substrate and plant density treatments had a significant economic impact on eggplant production. The highest investment cost was recorded using (peat moss: perlite 50%:50%) substrate, combined with plant densities of 12 and

Table 6. Average weekly maximum and minimum temperatures (°C) for bare and green rooftop during the 2023 and 2024 seasons.

Month	Week	First season 2023				Second season 2024			
		Max. Temp. °C		Min. Temp. °C		Max. Temp. °C		Min. Temp. °C	
		Bar.	Gre.	Bar.	Gre.	Bar.	Gre.	Bar.	Gre.
March	1	24.6	21.9	11.4	9.9	26.2	22.8	12.1	10.4
	2	27.1	24.1	12.9	11.1	26.0	22.7	12.2	10.5
	3	27.3	23.8	13.3	11.6	25.8	22.8	12.4	10.8
	4	26.2	23.0	13.2	11.2	24.8	21.8	12.4	10.5
April	5	24.9	21.4	13.2	11.6	26.6	23.6	14.7	12.9
	6	30.1	26.8	13.8	12.0	32.1	28.7	15.0	13.1
	7	32.6	29.3	14.6	13.1	31.2	27.8	15.5	13.7
	8	33.1	29.3	17.0	15.0	32.5	29.8	16.0	13.9
May	9	35.7	32.6	19.3	17.3	34.1	31.5	18.5	16.2
	10	37.0	34.2	22.0	19.9	35.7	33.0	21.1	18.7
	11	34.2	30.2	23.2	21.0	32.9	29.1	22.8	20.6
	12	39.0	35.4	22.5	20.7	38.1	35.0	20.8	18.4
June	13	37.6	34.5	23.0	20.9	37.8	34.6	22.0	19.9
	14	34.7	31.9	21.5	19.9	36.9	33.6	22.6	20.5
	15	37.0	34.7	21.9	19.7	38.0	35.7	22.3	20.0
	16	34.2	31.2	21.2	18.9	35.2	31.7	22.1	20.2
July	17	37.5	35.2	23.8	21.6	37.6	34.0	22.9	20.8
	18	39.9	36.1	24.7	22.2	38.3	34.1	24.0	22.1
	19	37.8	34.4	24.6	22.7	37.8	34.2	23.9	21.7
	20	39.0	35.3	24.8	22.9	37.0	32.9	23.3	21.5
August	21	37.6	34.3	25.9	23.7	38.1	34.3	23.6	21.4
	22	38.5	35.1	24.9	22.8	39.0	35.7	24.4	22.4

Bar. = Bare rooftop Temperature. Gre. = Green rooftop Temperature.

9 plants/m^2, followed by (sand: peat moss: perlite 50%:25%:25%) substrate, combined with plant density 12 plants/m^2. On the other hand, the highest negative net profit was found with sand: compost 8:2 *v: v* substrate, followed by (peat moss: perlite 50%:50%) substrate, followed by (sand: peat moss: perlite 50%:25%:25%) substrate, combined with a plant density 12 plants/m^2.

4. DISCUSSION

Regarding the effect of substrate on vegetative growth and yield of eggplant, obtained results indicated that the mixture of (peat moss and perlite 50%:50%) compared with the other substrates under study recorded the highest values of all vegetative growth and yield characteristics followed by (sand: pet moss: perlite 50%:25%:25%). While the lowest values were observed in the mixture of (sand: compost 80%:20%). These results could be explained by the effect of physical and chemical properties of substrates under study where the substrate peat moss: perlite had the highest total poor space (69.5%), water holding capacity (55%) and air-poor space (14.5%) that led to enhance the vegetative growth conditions as a result of conserving more moisture of substrate and proved better nutrient uptake for eggplant. Needless to mention that the yield of eggplant logically had been affected positively by the physical and chemical properties of substrates (as a reaction to enhance the vegetative growth, the yield of eggplant logically had affected positively). These results were in agreement with Majdi*et al*., (2012) investigated the effect of different substrates (vermiculite +sand (1:1), peat moss + perlite (1:1) and rock wool) on the production and quality of different cultivars of green pepper. It was found that, using a mixture of peat moss + perlite in

Table 7. An economic evaluation for a system substrate 6 meters for growing eggplant under different substrates and plant densities during seasons 2023 and 2024 as an average of two seasons.

Treatments		Infrastructure cost (EG)	Operation cost (EG)	Total investment cost (EG)	Total yield	Price per Kg (EG)	Total return (EG)	Net profit (EG)
S: Co	6 plants /m²	433.6	425.7	859.3	131.7	8	1053.7	194.4
	9 plants /m²	455.3	597.8	1053.1	162.8	8	1302.7	249.5
	12 plants /m²	477.1	797.0	1274.2	102.6	8	820.6	-453.5
S:Peat: Per	6 plants /m²	460.6	452.9	913.4	145.3	8	1162.7	249.3
	9 plants /m²	495.8	638.6	1134.4	185.7	8	1486.0	351.6
	12 plants /m²	531.1	797.0	1328.2	127.8	8	1022.3	-305.9
Peat: Per	6 plants /m²	490.8	561.6	1052.4	170.8	8	1366.6	314.2
	9 plants /m²	541.2	801.6	1342.8	203.5	8	1628.0	285.2
	12 plants /m²	591.6	1014.5	1606.1	146.1	8	1168.5	-437.6

(S:Co)=Sand + Compost (10:2 *v/v*), (S:Peat:Per)=Sand: Peat moss: Perlite (1:1:1*v/v/v*), (Peat:Per)= Peat moss: Perlite (1:1 *v/v*)

a ratio of 1 to 1 cause and increase in vegetative growth and yield of green pepper compared to the other substrates under study. Also, Fakhri*et al.* (1995), mentioned that the substrate must have enough readily accessible water and air for optimal plant growth. Perlite has a low readily available water content; to address this issue, it is advised to increase irrigation frequency; in this instance, adding peat moss to perlite increases water availability towards the root zone. Additionally, if the aeration and readily available water are maintained at the proper level, the roots will grow rapidly, which leads to higher absorption of water and nutrients, which gives vegetative growth and higher yields.

Moreover, referring to the plant density effect the previous results indicated that. The vegetative growth characteristics, yield properties, and (N, P, and K) contents of eggplant increased when the plant density was reduced from 12 to 6 plants/m^2, but the overall yield per m^2 decreased. On the contrary, the moderate plant density (9 plants/m^2) had the highest total yield per m^2. These results can be explained as a result of providing better ventilation among plants and reducing competition for light and space. These results matched the findings of Iwuagwu *et al*., (2019) in eggplant, Abul-Soud *et al*., (2018) in snap bean, and Makinde *et al*., 2021 in okra. Khairy (2013) demonstrated that reducing plant density reduced competition between plants for nutrients and water, light, space and other growth resources which increased the vegetative growth characteristics. Also, Ayarna *et al*., (2021) mentioned that high plant density reduced chlorophyll content in tomato plants by 9.6% because of the shade effect. Maya *et al*., (1997) reported that increasing plant density led to reduced light penetration between plants, which stimulated plants to increase endogenous auxin production and accelerate branch growth due to competition, which tended to grow more quickly to outgrow the next plant. This result was consistent with Baloch*et al*., (2012) and Abu and Odo (2017) on eggplants.

Regarding the economic view, the current research presented evidence of the possibility of enhancing the physical and chemical properties of sand as a local and inexpensive substrate, by mixing it with peat moss and perlite. This allows for reducing the cost of the substrate, while maintaining plant productivity, as well as reduces production costs, allowing the achievement of good net profit.

5. CONCLUSION

The substrate treatment of (peat moss: perlite 50%:50%) gave the highest total yield and quality parameters. But from an economic view, sand: peat moss: perlite recorded the highest profit. Increasing plant densities of eggplants up to 9 plants /m^2 with substrate mixture of (Sand: Pet moss: Perlite 50%:25%:25%) gave the highest net profit.

The economic study showed that the use of (sand: peat moss: Perlite 50%:25%:25%) substrate mixture, with plant density of 9 eggplants /m^2 achieved net profit yield and at the same time meets the environmental needs.

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الملخص العربي

تأثير كثافة النباتات على نمو وإنتاج الباذنجان في االزراعة الحضرية بإستخدام مزارع البيئات

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تم إجراء البحث في المعمل المركزي للمناخ الزراعي (CLAC) ، الجيزة، مصر، خلال موسمي الصيف الناجحين ٢٠٢٣ و ٢٠٢٤ . الهدف من الدراسة معرفة تأثير ثلاث خلطات من البيئات (رمل : كمبوست ٨٠٪ : ٢٠ % و رمل : بيتموس : بيرليت ٥٠٪ : ٢٥ % : ٢٥ % و بيتموس : بيرليت ٥٠ % : ٥٠ % مُدمجة مع ثلاث كثافات نباتية (٦ نباتات / م٢ و ٩ نباتات / م٢ و ١٢ نبات /م٢ لإنتاج نباتات الباذنجان (المحصول والجودة) تحت الظروف الزراعية الحضرية . في نهاية كل موسم نمو تم قياس (إرتفاع النبات والوزن الطازج والجاف للنبات وعدد الأوراق وعدد الفروع وقراءة الكلوروفيل). تم تقدير الوزن الإجمالي للثمار/نبات، وعدد الثمار/نبات، ومتوسط وزن الثمار، والعائد الإجمالي لكل متر مربع خلال فترة الحصاد. محتوى نباتات الباذنجان من عناصر (النيتروجين% ، الفوسفور% و البوتاسيوم %) بالإضافة إلى الدراسة الإقتصادية للتجربة البحثية. النتائج المتحصل عليها أوضحت إمكانية إستخدام الرمل كبيئة محلية رخيصت الثمن مع الخلط ببيئة البيتموس والبيرليت بنسبة ٥٠ % رمل : ٢٥ % بيتموس : ٢٥ % بيرليت مما يسمح بتقليل تكلفة بيئة الزراعة مع الحفاظ على إنتاجية الباذنجان. كما أوضحت الدراسة زراعة ٩ نباتات / م٢ أدت إلى زيادة خصائص محصول الباذنجان . تم تسجيل أعلى إنتاجية / م٢ وعائد إقتصادي جيد من خلال إستخدام البيئة الزراعية المكونة من (الرمل: البيتموس : البيرليت بنسبة ٥٠ % : ٢٥ % : ٢٥ %) مجتمعة مع ٩ نباتات /م٢.