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Effect of Pot Substrate Volume and Nitrogen Concentration of The Nutrient Solution on Lettuce Production under Urban Conditions

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ABSTRACT

An investigation was carried out under urban conditions during two successive autumn seasons (2022 and 2023) at the Central Laboratory for Agricultural Climate (CLAC), Giza, Egypt. The objectives included the effect of five different N levels (80, 100, 120, 140 and 160 ppm) of nutrient solution combined with two pots volumes (6 and 8 L) were investigated on lettuce (cv. Robinson F1 hybrid) plant under an urban condition in a split design.

Agronomy and food security concern, increasing substrate volume from 6 to 8 L / lettuce plant led to an increase in the vegetative growth and yield parameters as well as an increasing nitrogen concentration of nutrient solution from 80 up to 140 ppm. Substrate volume 8 L presented the higher significant records of vegetative, yield and nutrient contents values plus nitrogen use efficiency (NUE), as the revealed results indicated. Similar trends were obtained by nitrogen concentration of 140 ppm of nutrient solution that gave the highest significant results.

Sustainability point of view, substrate volume 6 L/ lettuce plant combined with nitrogen concentration 80 ppm of nutrient solution achieved the environmental objective by providing the lowest NUE and natural resources while had the highest net profit on the economic scale instead of the lowest fresh weight of lettuce yield but with the same number of lettuce per area unit (12 lettuce plant / m^2).

The study encourages investigating alternatives of chemical nutrient solutions in case to maximize the economic scale of urban farming as well as match the sustainability.

KEYWORDS: lettuce (*Lactuca sativa*), urban farming, substrate culture, nutrient solution, sustainability and economic

1. INTRODUCTION

Urban farming offers food production sustainability that meets food security under climate change and environmental concerns. The huge increase in the food demand due to the expansion of urbanization and quick lifestyle changes which led to a fundamental change in the nutritional system as well as aggressive exhaustion or shortage of natural resources created the driving forces to pay more attention to sustainable urban farming. The role of urban agriculture in sustainable agriculture production and food security in urban and peri-urban areas has been investigated increasingly during the last two decades (Gockowski *et al*., 2003, Mawoisa *et al*., 2011, Grewal and Grewal 2012, Probst *et al*., 2012, Hara *et al*., 2013, Abul-Soud *et al*., 2014, Rego 2014, Abul-Soud and Mancy, 2015, Abul-Soud 2015 and Bvenura and Afolayan, 2015).

Soilless culture systems provide a successful approach for producing food under urban conditions regarding the multiple advantages (conserving water, nutrients and energy while maximizing food production), especially substrate culture via micro-scale green roof farms. The author investigated through different research the possibilities of using different soilless culture systems as an intensive food production method based on sustainable food production, that maximizes the yield production and natural resources use efficiency even in areas with adverse growing conditions (shortage of available agricultural soil, water, and power). Enhance or modifying the soilless culture management as well as the specific cultural system, to match crop demand under specific climate and environmental conditions, led to the improvement of the quality and quantity of horticultural products.

lettuce (*lactuca sativa*), is one of the most popular leafy vegetable crops that had a nutritional, healthy and economic impact on different scales of urban and commercial agriculture.

No need to mention the great impact of N fertilizer as an important input on different scales (climate change, GHG's emission, public health, economics and production) as well as optimize the nitrogen fertilizer. Pot substrate volume play a vital role as an economic impact due to its cost and production value.

As a well-known knowledge, nitrogen is an essential nutrient for plant growth, but increasing its concentration in general and in specifically nutrient solution of leafy vegetable crops in soilless culture had a significant positive impact on crop yield but also can have negative consequences on both vegetative growth and yield. This is because an excess of nitrogen can lead to imbalances in the plant's nutrient uptake and metabolism, resulting in reduced growth and yield. It is important to carefully monitor and manage nitrogen levels in the nutrient solution to ensure optimal plant growth and productivity. Accurate concentration of N in nutrient solution performed the main nutrient solution component.

Otherwise, concerning N fertilizer that has a direct and indirect relationship with climate change as one of the most greenhouse gases (GHG's) and the negative impacts of N fertilizer production and use on the environment generally.

To achieve a resilient city, mitigation and adaptation strategy procedures should be passed. Urban horticulture for the purpose of food production via rooftop gardens offers a more flexible strategy to mitigate climate change impacts and food security (Abul-Soud 2015).

To avoid the shortage of water, arable lands, and food security, soilless culture in small to micro-scale farms can be an efficient alternate strategy via applied simple substrate culture for producing vegetables

The study aimed to determine the optimum N concentration in the nutrient solution of lettuce in substrate culture, also to determine the suitable pot volume of substrate under urban conditions to guarantee the sustainable production of food. Promote sustainable urban horticulture for food production, logically driving the resilience city approach.

2. MATERIALS AND METHODS

The research was carried out in the Central Laboratory for Agriculture Climate (CLAC), Agriculture Research Centre, Dokki, Giza Governorate, Egypt, during two autumn seasons of 2022 and 2023. The research was conducted under urban conditions of Giza (open field) in a pots system of substrate culture. The objectives of this work were to study the effect of five different N levels (80, 100, 120, 140 and 160 ppm) of nutrient solution combined with two pots volumes (6 and 8 L) on lettuce (*cv.* Robinson F1 hybrid) plant under an urban condition.

2.1 Plant material:

Lettuce (Iceberg type) Robinson F1 hybrid, seeds were sown on the first days of November of both two seasons (2022 and 2023). Foam trays (84 holes) containing peat moss: vermiculite (1:1 v/v) were applied for sowing lettuce seeds. Three weeks later, lettuce transplants were transplanted into two different volumes of plastic pots (6 and 8 L), each lettuce transplant was cultivated in one pot and the pots were arranged to perform 12 plants / 1 m^2.

2.2 System materials

Metal tables (1 x 2 x 0.6 m) were used as a base of a simple pot substrate system, each table had its nutrient solution tank (120 L) that contained a submersible pump (35 watts) for pumping the nutrient solution. The tables are covered with black plastic poly ethylene 500 microns with a drainage tube to collect the drainage of nutrient solution and back to the tank to provide a close system of substrate culture. Also, the table is located with a slope of 1 % to assist the circulation of a nutrient solution by gravity.

Two black plastic pot volumes for growing lettuce (6, and 8 L) were filled with 6, and 8 L of ideal substrate (peat moss: perlite (1:1 *v/v*)). The pots were arranged in 3 rows on every table with space 25 cm in-between the rows and 30 cm among the rows, to create a plant density 12 lettuce / m^2 (24 pots/table). Three tables were created for one experimental plot.

2.3 Nutrient solution preparation

Nutrient solution was adapted from Cooper (1979) based on Abul-Soud *et al*., (2015 and 2017). The concentrated nutrient solution base in dilution proportion 1: 100 contained N-NO_3: 80, P: 45, K: 240, Ca: 120 (Calcium nitrate is the main source of nitrogen (80 ppm) and Calcium (106 ppm) source while the rest of calcium modified up to 120 ppm by using calcium chelate), Mg: 50 and SO_4 less than 100 ppm. Ammonium nitrate (33 %) in salt form, not fertilizer form to avoid the other ingredients on the nutrient solution composition as a source of nitrogen used to modify the nitrogen levels from 80 up to 160 ppm while the rest of the micro and macronutrients were in constant concentrations in all treatments of N levels.

When the tank level reached about 20 % of its volume (safe level of water depth for submersible pump level), water was added to 90 % of the tank volume for 2 days then new nutrient solution and water were supplied to 100 % of the tank volume to guarantee the nutrient uptakes of all nutrients, especially Ca. The chemical compositions of different nutrient solutions are demonstrated in Table (1).

Table 1. Chemical composition of the different nitrogen levels of nutrient solutions.

Nitrogen levels (ppm)	Macronutrients (ppm)						
	N-NO_3	N- NH_4	P	K	Ca	Mg	SO_4
80	80	0	45	240	120	50	>100
100	90	10	45	240	120	50	>100
120	100	20	45	240	120	50	>100
140	110	30	45	240	120	50	>100
160	120	40	45	240	120	50	>100

Micronutrients (ppm)					
Fe	**Mn**	**Zn**	**Cu**	**B**	**Mo**
2	0.8	0.4	0.15	0.25	0.012

The pumping of nutrient solution was programmed to operate 4 to 6 times/day by using a digital timer (one minute) and the duration of pumping time or pumping schedule depended upon the growth stage of lettuce and season conditions. Plants were irrigated by using dripper's emitters of 2 l/hr capacity. The EC of nutrient solutions was measured by using an EC meter and modified to the required levels of different N levels (1.5 – 2.2 dsm^{-1}) depending on the growth stage and N concentration treatment. The EC of the nutrient solution decreased for all treatments to the lowest level (1.0 dsm^{-1}), 2 to 4 days before harvesting to prevent any free nitrogen in lettuce leaves. The pH of nutrient solutions of different treatments was measured in the range of 5.8 to 6.2 by using a digital pH meter. The system material and lettuce plant density were regarding (Abul-Soud *et al*., 2017)

2.4 The investigated treatments:

This experiment included 10 treatments which were the combinations between 2 pot substrate volume and 5 nitrogen levels of nutrient solution as follows:-

A- **Pot substrate volume**
   1- Pot volume 6 L
   2- Pot volume 8 L

B- **Nitrogen level of nutrient solution:**
   1. Nitrogen level 80 ppm (N 80)
   2. Nitrogen level 100 ppm (N 100)
   3. Nitrogen level 120 ppm (N 120)
   4. Nitrogen level 140 ppm (N 140)
   5. Nitrogen level 160 ppm (N 160) (Control)

A split plot design with three replicates was the experimental design used in the current investigation. The main plots and subplots were assigned to pot volumes, and nitrogen levels, respectively. Each plot consisted of 12 plants.

2.5 The study measurements

2.5.1 Vegetative growth and yield parameters

Later, 8 weeks from the transplanting date, vegetative growth and yield parameters of lettuce (Plant fresh weight (g), head fresh weight (g) (After removing the outer leaves), head volume (cm^3), Head density (g/cm^3) were measured while dry matter percentage was determined after oven-drying the samples of the head lettuce at 70 ºC for 48 hours

Total chlorophyll content was measured by Minolta chlorophyll meter SPAD -502 according to Yadava (1986).

2.5.2 Chemical analysis of lettuce plants

Mineral analysis (N, P, K and Ca) of lettuce plants were determined. Plant samples (three) of each plot were dried at 70º C in an air-forced oven for 48 h. and dried plants were digested in H_2SO_4 according to the method described by Allen (1974) and N, P and K contents were estimated in the acid digested solution. Total nitrogen was determined by the micro Kjeldahl method according to the procedure described by FAO (1980). Phosphorus content was determined using a spectrophotometer according to Watanabe and Olsen (1965). Potassium content was determined photo-metrically using a Flame photometer as described by Chapman and Pratt (1961).

2.5.3 Nitrogen use efficiency and economic assessment impact

Nitrogen use efficiency (NUE), (g/g) calculated regarding the average constant volume of concentrated nutrient solution (4 L /m^2) for all treatments and average total yield per m^2 (12 lettuce plants) during both two cultivated seasons calculated logically as follows:

NUE (g / g) = total yield (g) / total amount of N used (g)

The study avoided the nitrate content (mg/kg) and N content of lettuce plants to get the real NUE as well as the substrate volume factor that could hold more nitrogen in bigger substrate volumes compared to the smaller volumes.

Economic assessment impact calculated based on 3 rotations of growing lettuce under urban conditions per 1 m^2 that included the cost of different treatment inputs such as urban substrate system (10 years), the plastic pots (2 years), substrate volume (2 years) and nutrient solution (3 rotations = 12 L per m^2 (12 lettuce plant /m^2) as an urban horticulture production unit with take in consider the total yield by head lettuce not by head weight based on average price 10 LE/head. Circulating energy costs weren't taken into account due to our focus on urban agriculture, which focuses on saving the energy used.

The economic impact as average for two growing seasons is determined logically as follows:

Fixed cost includes urban system (Metal table + Tank + plastic + irrigation and drainage stuff + pot + substrate for each treatment)

Operated cost includes the average cost of different chemical nutrient solutions and lettuce seedlings through 3 rotations/year as follows:

Nutrient solution (LE) = 4 (L) * 3 rotations * 20 (LE, the basic)

Seedlings (LE) = 1 (LE)* 12 (plants / m^2) * 3 rotations

Total cost (LE) = Fixed + operated costs

Return (LE) = 12 (lettuce head) * 3 rotations * 10 (LE)

Net return (LE) = Return – total cost

2.6 The statistical analysis:

The data statistical analysis was performed by computer using SAS (Statistical Analysis System). The differences among means for all treatments were tested at a 5 % level of significance according to the procedure described by Snedicor and Cochran (1981).

3. RESULTS

3.1 The effect of pot volume and N level of nutrient solution on vegetative growth characteristics of lettuce.

The effect of pot volume and N level of nutrient solution on vegetative and vegetative characteristics (plant fresh and dry weight (g), and plant volume (cm^3)) of lettuce plant illustrated in Table (2). Concerning the pot volume, increasing the substrate volume from 5 up to 8 L / lettuce plant led to a significant increase in plant fresh and dry weight (g), and plant volume (cm^3). The treatment of pot substrate volume 8 L gave the highest results while the lowest significant values were recorded by substrate volume 6 L / lettuce plant.

The revealed results of N levels of nutrient solution effect indicated that increasing the N level from 80 ppm up to 140 ppm led to an increase significantly the plant fresh and dry weight (g), and plant volume (cm^3) while increasing the N level up to 160 ppm had a reverse effect on the vegetative growth characteristics as Table (2) presented. N level at 140 ppm had the highest records of lettuce fresh and dry weight (g), and plant volume (cm^3) while the lowest results were given by N level 80 ppm.

Regarding the interaction effect between pot substrate volume and N level of nutrient solution on vegetative characteristics of lettuce (Table 2), data showed that pot substrate volume 8 L combined with N level 140 ppm presented the highest significant results in both cultivated seasons. The lowest values were recorded by pot substrate volume 6 L combined with N level 160 ppm.

3.2 The effect of pot volume and N level of nutrient solution on yield parameters of lettuce.

3.2.1 The physical parameters

The yield parameters that were affected by pot volume and N level of nutrient solution were presented as head fresh weight (g), (Fig. 1), head density (g/cm), (Fig. 2), total chlorophyll content (spad) and nitrate (mg/kg), (Table 5).

The obtained results of pot substrate volume on head fresh weight (g) and head density (g/cm) as demonstrated in Fig. (1 and 2) indicated that substrate volume 8 L had a positive significant effect that led to recorded higher values of head fresh weight and head density of lettuce than substrate volume 6 L.

Increasing N levels of nutrient solution from 80 up to 140 ppm led to an increase in the head fresh weight of lettuce then decreased at 160 ppm (Fig. 1). The lowest head weight value given by N level 160 ppm while 140 ppm had the highest significant result.

On the contrary, increasing N levels of nutrient solution from 80 up to 160 ppm resulted in decreasing the head density of lettuce. Increasing N levels of nutrient solution in this state had a negative significant effect on the compact of head lettuce expressed by head density.

Referring to the interaction effect on the head fresh weight of lettuce as presented in Fig. (1), the pot substrate level 8 L / plant combined

Table 2. Effect of substrate pot volume and nitrogen level on vegetative growth of lettuce plant at 8 weeks after transplanting during two autumn seasons of 2022 and 2023.

Treatment		First season			Second season		
		Fresh weight (g)	Dry weight (g)	Volume (cm^3)	Fresh weight(g)	Dry weight (g)	Volume (cm^3)
Pot volume (L)							
8		860.3 A	68.2 A	1070 A	897.8 A	76.5 A	1124 A
6		721.2 B	63.4 B	997 B	753.2 B	66.5 B	1052 B
N level (ppm)							
80		733.8 C	49.2 C	940 C	773.2 C	52.4 D	986 C
100		736.7 C	50.7 C	960 C	780.4 C	56.2 D	1009 C
120		843.0 B	74.5 B	1098 B	865.5 B	82.8 B	1178 B
140		912.0 A	82.1 A	1202 A	942.9 A	90.4 A	1266 A
160		728.2 C	72.4 B	967 C	765.6 C	75.6 C	1002 C
Interaction							
	80	739.7 d	47.8 f	955 d	775.7 d	48.0 e	982 d
	100	742.1 d	50.6 f	963 d	782.0 cd	54.9 d	1007 d
8	**120**	870.1 bc	71.7 d	1093 c	911.1 b	76.8 c	1178 bc
	140	1065.8 a	88.4 a	1261 a	1104.6 a	108.6 a	1312 a
	160	883.9 b	82.6 b	1079 c	915.8 b	94.3 b	1140 c
	80	728.0 d	50.7 f	926 d	770.7 d	56.7 d	990 d
	100	731.2 d	50.8 f	958 d	778.9 d	57.6 d	1010 d
6	**120**	816.0 c	77.4 c	1103 bc	819.9 c	88.8 b	1179 bc
	140	758.1 d	75.7 c	1143 b	781.1 cd	72.2 c	1221 b
	160	572.5 e	62.2 e	856 e	615.4 e	57.0 d	864 e

* Similar letters indicate non-significant at 0.06 Levels.
** Capital letters indicate the significant difference of each factor ($P<0.05$)
*** Small letters indicate the significant difference in interaction ($P<0.05$)

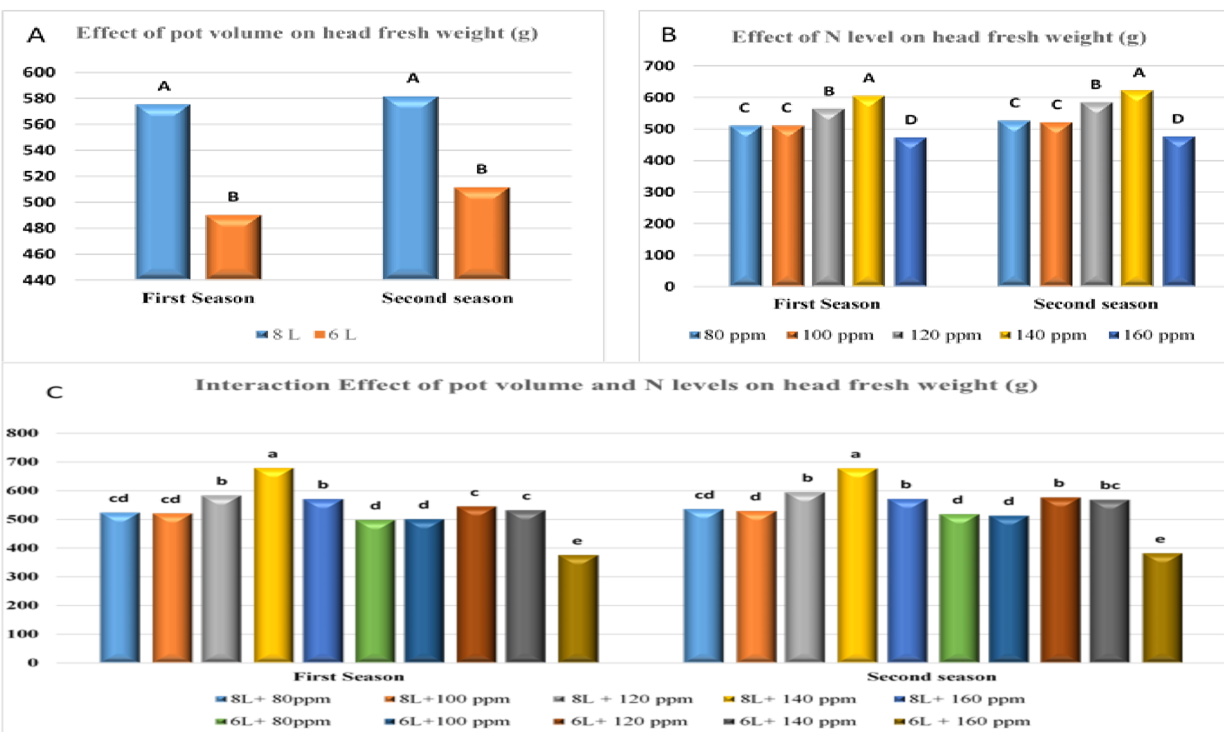

Figure 1. Effect of pot substrate volume (A), N levels of nutrient solution (B) and their interaction (C) on the head fresh weight (g) of lettuce plant at 8 weeks after transplanting during two autumn seasons of 2022 and 2023.

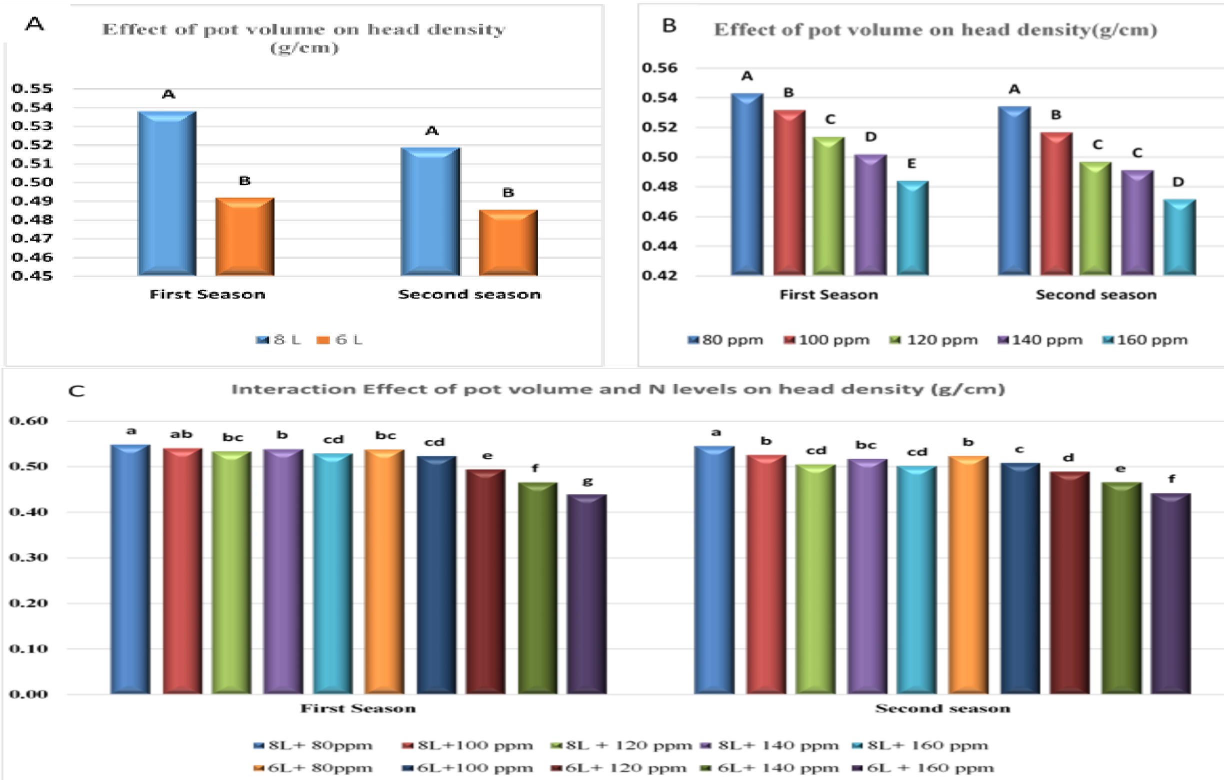

Figure 2. Effect of pot substrate volume (A), N levels of nutrient solution (B) and their interaction (C) on head density (g/cm3) of lettuce plant at 8 weeks after transplanting during two autumn seasons of 2022 and 2023.

with N level 140 ppm had the highest value while the lowest records resulted from pot substrate level 6 L / plant combined with N level 160 ppm.

On the other hand, Fig. (2) Illustrates the combined effect between substrate volume and N levels on the head density of lettuce. The results declared that to obtain the highest head density (the highest compact lettuce head), pot substrate level 8 L / plant combined with N level 80 ppm should be applied while the lowest head density given by pot substrate level 6 L / plant combined with N level 160 ppm.

3.2.1 The chemical quality parameters

Table (3) presented the effect of N level and substrate pot volume on the chemical quality parameters (Total chlorophyll content (Spad), and Nitrate content (mg/kg) of lettuce plants. Pot substrate volume 8 L had a positive impact on both total chlorophyll content, and nitrate content that appeared in recording the higher result of total chlorophyll content, and lower value of nitrate content than substrate volume 6 L / lettuce plant. The lower nitrate content of the lettuce plant has a significant positive impact, on the state's vision toward reducing the nitrate content of leafy vegetables for not just the horticulture scale but also for public health scale.

Logically, increasing the N levels of nutrient solution from 80 up to 160 ppm had logical increases in total chlorophyll content, and nitrate content of the lettuce plant as data of Table (3) demonstrated. The highest values of total chlorophyll content, and nitrate content of the lettuce plant were recorded by N level 160 ppm while N level 80 ppm had the lowest records.

Concerning the interaction between pot substrate volume and N level of nutrient solution, the obtained results of Table (3) indicated that the highest result of total chlorophyll content was given by pot volume 8 L + N level 160 ppm followed by pot volume 6 L + N level 160 ppm while the 6 L + N level 80 ppm followed by 8 L + N level 80 ppm gave the lowest records.

In the same context of an interaction effect, pot volume 6 L + N level 160 ppm followed

Table 3. Effect of pot substrate volume and N levels of nutrient solution on chemical quality parameters of lettuce plant at 8 weeks after transplanting during two autumn seasons of 2022 and 2023.

Treatment		First season		Second season	
		Chlorophyll Cont. (Spad)	Nitrate cont. (mg/kg)	Chlorophyll Cont. (Spad)	Nitrate cont. (mg/kg)
Pot volume (L)					
8		34.2 A	1108.2 B	34.6 A	1116.9 B
6		32.6 B	1144.3 A	33.1 B	1179.5 A
N level (ppm)					
80		29.9 D	925.4 E	30.3D	942.9 D
100		30.6 D	959.0 D	30.8 D	965.4 D
120		32.5 C	1070.3 C	32.5 C	1089.5 C
140		35.1 B	1255.2 B	36.8 B	1304.6 B
160		38.9 A	1421.5 A	38.9 A	1438.8 A
Interaction					
	80	30.3 de	917.0 f	31.1 ef	921.7 g
	100	30.6 de	965.3 e	31.2 ef	956.9 fg
8	**120**	33.3 c	1009.9 d	32.9 d	1039.0 e
	140	37.0 b	1247.4 b	38.1 b	1252.2 c
	160	39.8 a	1401.7 a	39.5 a	1414.9 a
	80	29.5 e	933.8 ef	29.4 g	964.1 fg
	100	30.5 de	952.8 ef	30.4 fg	973.9 e
6	**120**	31.6 d	1130.8 c	32.0 de	1140.0 d
	140	33.2 c	1263.0 b	35.4 c	1356.9 b
	160	38.0 b	1441.3 a	38.3 ab	1462.8 a

* Similar letters indicate non-significant at 0.06 Levels.
** Capital letters indicate the significant difference of each factor ($P<0.05$)
*** Small letters indicate the significant difference in interaction ($P<0.05$)

by pot volume 8 L + N level 160 ppm recorded the highest significant values of nitrate content (worst impact) of the lettuce plant. On the contrary, the lowest nitrate contents (the best impact) of lettuce plant performed by pot substrate volume 8 L + N level 80 ppm followed by pot volume 6 L + N level 80 ppm

However, these results of interaction explained strongly the effect of N levels of nutrient solution in increasing or decreasing both of total chlorophyll content, and nitrate content of the lettuce plant.

3.3 The effect of pot volume and N level of nutrient solution on nutrients composition of lettuce plants.

At the end, the effect of pot substrate volume on N, P, K and Ca (ppm) contents of lettuce plant is illustrated in Table (4). The revealed results indicated that decreasing the substrate volume from 8 to 6 L / lettuce plant led to a significant decrease in P, K and Ca contents of the lettuce plant.

The dramatic action of increasing the N level of nutrient solution on N, P, K and Ca (ppm) contents of lettuce introduced in antagonism and synergism modes. Increasing N level from 80 ppm up to 140 ppm led to an increase in N, P and Ca contents but increasing up to 160 ppm resulted in two approaches as follows:

1- Increasing the N content of lettuce plant
2- Decreasing the P and Ca contents of lettuce plant

N level 160 ppm of the nutrient solution gave the highest value of N content of lettuce plants while The highest results of P and K contents of lettuce were recorded by N levels of both 120 and 140 ppm. The N level of 80 ppm had

Table 4. Effect of pot substrate volume and N levels of nutrient solution on nutrients composition of lettuce plant at 8 weeks after transplanting during two autumn seasons of 2022 and 2023.

Treatment		First season				Second season			
		N %	P %	K %	Ca %	N %	P %	K %	Ca %
Pot volume (L)									
8		3.67 A	0.44 A	2.96 A	2.07 A	3.69 A	0.45 A	2.91 A	2.07 A
6		3.55 A	0.41 B	2.84 B	1.81 B	3.49 A	0.39 B	2.71 B	1.83 B
N level (ppm)									
80		3.32 D	0.37 C	3.52 A	1.80 C	3.20 E	0.37 C	3.32 A	1.62 D
100		3.39 D	0.38 C	3.24 B	1.87 B	3.44 D	0.38 C	3.10 B	1.80 C
120		3.51 C	0.47 A	2.78 C	2.07 A	3.54 C	0.47 A	2.78 C	2.15 A
140		3.73 B	0.48 A	2.51 D	2.05 A	3.71 B	0.46 A	2.46 D	2.21 A
160		4.11 A	0.44 B	2.45 D	1.93 B	4.07 A	0.44 B	2.39 D	1.96 B
Interaction									
	80	3.37 fg	0.39 e	3.64 a	1.94 bc	3.23 fg	0.42 c	3.40 a	1.69 f
	100	3.41 fg	0.40 e	3.28 bc	1.96 bc	3.58 de	0.43 c	3.25 a	1.84 de
8	**120**	3.56 de	0.47 bc	2.78 d	2.22 a	3.61 de	0.47 b	2.90 b	2.27 b
	140	3.81 c	0.49 a	2.57 e	2.22 a	3.78 bc	0.49 a	2.56 cd	2.44 a
	160	4.22 a	0.46 c	2.55 e	2.03 b	4.23 a	0.47 b	2.44 de	2.09 c
	80	3.27 g	0.35 f	3.41 b	1.66 e	3.17 g	0.33 d	3.24 a	1.55 g
	100	3.36 fg	0.35 f	3.21 c	1.78 d	3.30 f	0.32 d	2.95 b	1.75 ef
6	**120**	3.46 ef	0.47 b	2.79 d	1.93 c	3.47 e	0.48 ab	2.66 c	2.02 c
	140	3.65 cd	0.46 c	2.44 ef	1.87 cd	3.63 cd	0.43 c	2.37 de	1.97 cd
	160	4.00 b	0.42 d	2.36 f	1.83 d	3.91 b	0.41 c	2.33 e	1.84 de

* Similar letters indicate non-significant at 0.06 Levels.
** Capital letters indicate the significant difference of each factor ($P<0.05$)
*** Small letters indicate the significant difference in interaction ($P<0.05$)

the lowest N, P and Ca contents of lettuce plants. On the other wise, the K contents of the lettuce plant were affected strongly by increasing N level (Antagonism) from 80 to 160 ppm which led to a decrease in the K content. The highest K content of lettuce was presented by the N level of nutrient solution 80 ppm then decreased by increasing the N level up to 160 ppm the lowest value of K contents as Table (4) presented.

Regarding the interaction effect as shown in Table (4), pot volume 8 L + N level 160 ppm followed with significant difference pot volume 6 L + N level 160 ppm illustrated the highest N contents of lettuce plant while the lowest value recorded by pot volume 6 L + N level 80 ppm.

The combination treatment had the highest significant P and Ca contents of the lettuce plant while the lowest results were introduced by pot volume 6 L + N level 80 ppm. Finally, the highest K content of the lettuce plant is presented by pot volume 8 L + N level 80 ppm followed by pot volume 6 L + N level 80 ppm.

3.4 The effect of pot volume and N level of nutrient solution on nitrogen use efficiency (NUE, g/g) of lettuce plants.

One of the most important factors demonstrated in Table (5), is NUE as a result of the specific amount of nitrogen for producing kg of lettuce plant.

The gained results presented that increasing the substrate volume from 6 to 8 L / plant as well as nitrogen level from 80 up to 140 ppm led to an increase in the average total yield of lettuce / m^2 in this study.

Regarding the substrate volume effect, Pot substrate volume 8 L recorded a higher average total yield (g/m2) and nitrogen usage efficiency (NUE) than the 6 L substrate per lettuce plant.

Table 5. Effect of pot substrate size and N levels of nutrient solution on nitrogen use efficiency (g/g) of lettuce plants as an average for two growing seasons 2022 and 2023.

Treatment		Av. Total yield (g/m2)	Av. Total N (g/m2)	NUE (g/g)
pot volume (L)				
8		10549 A	48	220 A
6		8846 B	48	184 B
N level (ppm)				
80		9042 C	32	283 A
100		9103 C	40	228 B
120		10251 B	48	214 BC
140		11129 A	56	199 C
160		8963 C	64	140 D
Interaction				
	80	9092 c	32	284 a
	100	9145 c	40	229 b
8	**120**	10687 b	48	223 b
	140	13022 a	56	233 b
	160	10798 b	64	169 c
	80	8992 c	32	281 a
	100	9061 c	40	227 b
6	**120**	9815 bc	48	204 b
	140	9235 c	56	165 c
	160	7127 d	64	111 d

* Similar letters indicate non-significant at 0.06 Levels.
** Capital letters indicate the significant difference of each factor ($P<0.05$)
*** Small letters indicate the significant difference in interaction ($P<0.05$)

Increasing the N level of nutrient solution from 80 up to 140 ppm led to rising average total yield significantly then decreased at 160 ppm. Conversely, NUE values decreased with increasing N level of the nutrient solution from 80 up to 160 ppm.

The highest significant average total yield was performed by substrate volume 8 L + N level 140 ppm (13022 g / m2) while substrate volume 6 L + N level 160 ppm recorded the lowest average total yield of lettuce / m2 (7127 g/m2).

Needless to mention, increasing the N levels from 80 (32 g / m2) up to 160 ppm (64 g / m2) of the nutrient solution of lettuce plants under urban conditions would decrease the practical use of nitrogen as Table (5) cleared.

The highest NUE result was given by substrate size 8 L+N level of 80 ppm followed by substrate size 6 L+N level of 80 ppm without significant difference between them. While the lowest NUE value was recorded with the substrate size 6 L + N at a level of 160 ppm.

3.5 The economic impact of pot volume and N level of nutrient of lettuce plants.

The results shown in Table (6), which reviews the economic impact of the pot volume and N concentration treatments, were interesting and in contrast to the trend of lettuce production and its various measurements.

Mathematically, the total cost increased due to increasing the cost of substrate volume as well as increasing the N concentration of the nutrient solution. Nutrient solution cost performed as the major cost about 70 % of the total cost while other factors like system, substrate volume, pots, and seedlings created 30 % of the total cost of substrate culture in urban farming.

Table (6) demonstrates the economic impact of pot substrate volume and N levels of nutrient solution of lettuce plants. The highest total cost value was recorded by pot volume8 L + N level 160 ppm followed by pot volume8 L + N level 140 ppm while pot volume 6 L + N level 80

Table 6. The economic impact of pot substrate volume and nitrogen levels of nutrient solution of lettuce plant as an average for two growing seasons 2022 and 2023.

Pot. volume	N level (ppm)	Fixed cost (LE)/m^2	Operated cost (LE)/m^2	Total cost (LE)/m^2	yield (Head)	Price (LE/head)	Return (LE)/m^2	Net return (LE)/m^2
8 L	80	88.3	276	364.3	36	10	360	-4.3
	100	88.3	288	376.3	36	10	360	-16.3
	120	88.3	300	388.3	36	10	360	-28.3
	140	88.3	312	400.3	36	10	360	-40.3
	160	88.3	324	412.3	36	10	360	-52.3
6 L	80	69.3	276	345.3	36	10	360	14.7
	100	69.3	288	357.3	36	10	360	2.7
	120	69.3	300	369.3	36	10	360	-9.3
	140	69.3	312	381.3	36	10	360	-21.3
	160	69.3	324	393.3	36	10	360	-33.3

Fixed cost includes (Metal table + Tank + plastic + irrigation and drainage stuff + pot + substrate
Operated cost includes (chemical nutrient solutions + lettuce seedlings) through 3 rotations/year

ppm had the lowest total cost result followed by pot volume 6 L + N level 100 ppm.

The net return of different treatments was quite the opposite of the lettuce yield parameters where pot volume8 L + N level 160 ppm followed by pot volume8 L + N level 140 ppm presented the lowest net return results of lettuce production under urban condition farming.

The highest net return (profit) of lettuce in urban farming is introduced by the lowest yield treatment of pot volume and N level of nutrient solution. Pot volume 6 L + N level 80 ppm followed by pot volume 6 L + N level 100 ppm gave the highest profit results compared to the rest treatments.

4. DISCUSSION

For achieving resilience urban, urban farming could play a vital role in food production but optimizing the production inputs created the key for economic and public health scales. Micro-scale farms (urban farms) in the near future should provide food production and address the impact of climate change on urban conditions and agricultural production. Optimizing the used of substrate and N fertilizer in producing vegetable crops via substrate culture had a relation with mitigation and adaptation of climate change strategies that increase the use efficiency of natural resources.

The standard pot substrate volume differed regarding the plant type and implemented management method in substrate culture. In urban farming, pot substrate volume acquires great importance while forwarding for more sustainability and food production. Optimizing the substrate volume gives an impression of expanding urban farming and its sustainability.

Increasing the pot substrate volume means objectively increasing the root zone volume which will provide better conditions for root growth and more access to nutrients and water that result in enhancing the vegetative growth and yield characteristics as well as increase the nutrient uptake. Increasing the pot substrate volume from 5 to 8 L per lettuce plant led to a significant increase in plant fresh and dry weight (g), plant volume (cm3), head fresh weight (g) and head density (g/cm), total chlorophyll content (spad), N, P, K and Ca (ppm) contents while reducing the nitrate content of lettuce plants. These results agreed with those of Cardoso *et al.*, (2015), Sayed *et al.*, (2017), and Islam *et al.*, (2021). Instead of the mentioned significant positive effects of the pot substrate volume, the economic impact didn’t meet the same positive effect.

Likewise, increasing the concentration of nitrogen in the nutrient solution of lettuce hadn’t in all cases a positive impact on vegetative growth and yield but also can have negative consequences regarding to increasing rate, the balance among the nutrients and the growth stage and type of the plant. The optimum N level in the nutrient solution of lettuce is not decided solely based on the characteristics of vegetative growth and yield parameters, but on factors that seem more important, especially in urban farms, in terms of the percentage of nitrates and the efficiency of nitrogen use, in addition to the economic trend. In summary, increasing the N concentration in the nutrient solution can positively impact lettuce yield. However, the effect may vary depending on factors such as lettuce cultivar, environmental conditions, and nutrient composition. Optimal N concentrations for lettuce growth and yield range from 100 to 150 mg/L as Desire and Daniel (2019) investigated.

Needless to explain manipulating the pot volume and nitrogen concentration in the nutrient solution provided significant impacts on lettuce growth and yield as well as nutrient uptake.

Concerning NUE, the distinctive results that are expected in this case are the lowest values that express the highest efficiency in using nitrogen in lettuce production. The lower the value, the higher the efficiency of using nitrogen fertilizer.

As a consequence, increasing the N concentration of nutrient solution had different effects on P, K and Ca uptake that Table (4) presented. Logically, increasing the N concentration from 80 up to 140 ppm led to an increase in the N content of lettuce plant as well as P and Ca but decreased K content of lettuce plant. These results could be explained regarding the encouraging effect of increasing N that caused improvement in the vegetative growth and enhanced P and Ca uptake while increasing N-NH_4 through increasing total N concentration of nutrient solution had an inhibition effect on K uptake. These results also agreed with different studies focusing on the interaction among the nutrients such as antagonisms (competition for the same nutrient transport pathways) among the cations, suggesting that with cation-cation interactions, similar uptake mechanisms and competition between two cations might explain these effects and a lower yield. Synergism occurs when the combination of two nutrients has a significantly higher yield than expected René *et al*., (2017).

Providing adequate crop nutrition offered better vegetative growth and yield as a result of enhancing the nutritional and healthy states of plants.

Shilpha *et al*., (2023) reported that Ammonium, while beneficial to plants at lower concentrations, can be toxic to plants at higher concentrations due to proton extrusion linked to ammonium uptake. An excess of ammonium can also lead to calcium deficiency and negatively impact plant development. Ammonium's effect on plant nutrients can result in both antagonistic and synergistic outcomes, affecting nutrient use efficiency and overall plant development.

However, the economic aspect comes into play because using greater substrate volume or higher N concentration of nutrient solution can increase production costs. Additionally, more substrate or N concentration may have a positive impact on the lettuce yield but not on the economic scale. In this respect, Sayed *et al*. (2017) stated that determining the suitable pot volume for maximizing yield and economic production, especially under urban conditions is essential for more resilience.

Growers need to weigh the benefits of increased growth and yield against the associated costs. They must consider factors such as the cost of the substrate, system material, water usage, nutrient solution, and other resources required. It's essential to optimize the substrate volume and N concentration to achieve a balance between enhanced growth and cost-effectiveness in lettuce cultivation, but the most essential is to minimize the nutrient solution cost that performed 66 to 70 % of the total cost. Otherwise, minimizing the use of substrate based on peat moss and chemical nutrient solution had great potential on the environmental scale as well as the economic scale. The use of chemical nutrient solution alternatives decreases cultivation expenses and offers economic profit of urban farming as explained by Abul-Soud (2015 b), Abul-Soud *et al*., (2017), and Sayed et al. (2017).

5. CONCLUSION

The targets of sustainable urban production extend logically to match the food security demands, fight hunger and meet the strategies of mitigating and adaptation of climate change impacts. Concerning the sustainable goals and economic assessment of urban farming, substrate volume 6 L/ lettuce plant combined with nitrogen concentration 80 ppm of nutrient solution achieved what was required.

The economic assessment encourages investigation of unconventional alternatives to the nutrient solution due to the high cost of its use, which reinforces other studies on the use of compost or vermicompost-tea as a nutrient solution.

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الملخص العربي

تأثير حجم بيئة الأصيص وتركيز النيتروجين في المحلول المغذي على إنتاج الخس تحت الظروف الحضرية

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تم إجراء الدراسة تحت الظروف الحضرية خلال موسمين خريفي متتالين (٢٠٢٢ ، ٢٠٢٣) في المعمل المركزي للمناخ الزراعي (CLAC) ، الجيزة ، مصر. وكانت أهداف الدراسة كالتالي تأثير خمسة مستويات مختلفة من النيتروجين (٨٠ ، ١٠٠ ، ١٢٠ ، ، ١٤٠ ، ١٦٠) جزء في المليون من المحلول المغذي مع حجمين من الأصص (٦ ، ٨ لتر) على نبات الخس (نوع روبنسون F1 هجين) تحت الظروف الحضرية في تصميم قطعة منشقة. من وجهة الزراعة والأمن الغذائي أوضحت النتائج زيادة حجم البيئة من ٦ إلى ٨ لتر / نبات الخس أدت إلى زيادة النمو الخضري وقياسات المحصول وكذلك زيادة تركيز النيتروجين من ٨٠ إلى ١٤٠ جزء في المليون. حجم البيئة ٨ لتر أعطت أعلى تسجيلات معنوية للقياسات الخضرية والمحصول وقيم العناصر في النبات بالإضافة إلى زيادة كفاءة إستخدام النيتروجين (NUF) ، نفس النتائج أعطيت عند إستخدام تركيز النيتروجين ١٤٠ جزء في المليون في المحلول المغذي. من وجهة نظر الإستدامة حجم البيئة ٦ لتر / نبات الخس مع تركيز النيتروجين ٨٠ جزء في المليون في المحلول المغذي يحقق الهدف البيئي وذلك من خلال إستخدام أقل كمية من النيتروجين وبيئة الزراعة مع تحقيق أعلى صافي ربح على المستوى الإقتصادي وذلك بنفس عدد الخس لكل وحدة مساحة (١٢ نبات خس / م٢) . تحث الدراسة على إيجاد بدائل للمحاليل المغذية الكيميائية لتحقيق أقصى قدر من النطاق الإقتصادي للزراعة الحضرية وكذلك تطبيق الإستدامة.